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Handbook

Towards Clean Heating Zones in Europe

A Handbook for practitioners and policymakers

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Glossary

AAQD	Ambient Air Quality Directive: EU directive setting limit and target values for ambient air pollutant concentrations to protect human health and the environment.
As	Arsenic: Toxic trace element regulated as an air pollutant due to its carcinogenic properties.
B(a)P	Benzo(a)pyrene: Polycyclic aromatic hydrocarbon formed by incomplete combustion, used as a marker for carcinogenic air pollution from sources such as residential heating.
C₆H₆	Benzene: Volatile organic air pollutant linked to combustion and fuel evaporation, classified as a human carcinogen.
CHZ	Clean Heating Zone (CHZ): Geographically defined area where decisionmakers implement a policy mix of regulatory, financial, infrastructural and engagement measures to reduce heating-related air pollution and greenhouse gas emissions, while fostering the uptake of cleaner and progressively lower-carbon heating alternatives.
CO	Carbon Monoxide: Colourless, odourless gas produced by incomplete combustion, harmful to human health at elevated concentrations.
CO₂	Carbon Dioxide: A greenhouse gas emitted primarily through combustion.
DHC	District Heating and Cooling: Centralised systems that distribute heat or cooling from a shared source to multiple buildings.

EEA	European Environment Agency: EU agency providing independent information on the environment to support policy development and public information.
EED	Energy Efficiency Directive: EU directive establishing a common framework of measures to promote energy efficiency across Member States.
EFD	Ecodesign Framework Directive: EU directive setting minimum energy efficiency and environmental performance requirements for energy-related products.
EPBD	Energy Performance of Buildings Directive: EU directive establishing requirements for the energy performance of buildings, including certification and renovation standards.
ETS2	Emissions Trading System 2: Separate EU carbon market, distinct from the existing EU ETS (ETS1), that puts a price on CO ₂ emissions from the combustion of fuels in buildings, road transport and small industry. Its entry into force has been postponed from 2027 to 2028.
EU	European Union.
EU-27	The 27 Member States of the European Union.
IPCC	Intergovernmental Panel on Climate Change: The United Nations body responsible for assessing the science related to climate change, providing policymakers with regular scientific assessments and reports.
LEZ	Low Emission Zone: defined area in which a vehicle access regulation is applied, restricting entry for more polluting vehicles based on emissions standards, in order to reduce transport-related air pollution and traffic congestion in cities.
MLG	Multilevel Governance.

NCRES	Non-Combustion Renewable Energy Sources: renewable energy sources that do not rely on combustion to generate power and do not involve air quality degradation (e.g. wind, solar and hydropower).
NH₃	Ammonia: Gaseous pollutant primarily emitted from livestock activities, contributing to the formation of secondary particulate matter.
NO₂	Nitrogen Dioxide: Reddish-brown gas produced mainly by combustion processes, particularly road transport, associated with respiratory health effects.
NO_x	Nitrogen Oxides: A collective term for nitrogen oxide (NO) and nitrogen dioxide (NO ₂).
NMVOCs	Non-Methane Volatile Organic Compounds: A group of organic chemicals, excluding methane, that contribute to ground-level ozone formation.
Pb	Lead: A toxic heavy metal regulated as an air pollutant due to its harmful effects on human health, particularly neurological development.
PM₁₀	Particulate matter with particles with aerodynamic diameters between 2.5 and 10 microns, capable of penetrating the upper respiratory tract.
PM_{2.5}	Fine particulate matter with a diameter of 2.5 microns or less, able to penetrate deep into the lungs and bloodstream.
O₃	Ozone: A secondary air pollutant formed by chemical reactions between NO _x and volatile organic compounds in sunlight, harmful to health at ground level.
PV	Photovoltaic.

SO₂	Sulphur Dioxide: Gas primarily emitted from the burning of sulphur-containing fossil fuels, contributing to acid rain and respiratory issues.
RED III	Renewable Energy Directive III: EU directive setting binding targets and rules for the promotion of renewable energy sources.
RES	Renewable Energy Sources.
REPowerEU	An EU plan launched in 2022 to end dependence on Russian fossil fuels by saving energy, diversifying supply and accelerating renewables, including the deployment of heat pumps.
T2D	Type 2 Diabetes: Chronic metabolic condition that causes the level of glucose in blood to become higher than normal.
WHO	World Health Organisation.

Executive Summary

Across Europe, domestic-heating-led air pollution poses a serious health threat. Air pollution in Europe contributes to an estimated 182,000 premature deaths in 2023 from exposure to fine particulate matter (PM_{2.5}) above WHO guideline levels. Residential heating is an important contributor to this pollution. While significant progress has been made in reducing emissions from certain sectors, including industry and transport, residential heating from fossil fuels, waste and solid biomass is an open issue severely affecting air quality, public health and climate objectives.

This handbook introduces for the first time the concept of Clean Heating Zones (CHZs) as a practical approach for practitioners with the objective of improving air quality and the transition to clean heating. Inspired by the experiences gathered from low-emission and clean-heating measures implemented across European municipalities, CHZs are a combination of regulatory measures, financial support, infrastructural investments, promoting active stakeholder engagement, and social safeguards to reduce emissions from residential heating while ensuring their social acceptability.

Developed as part of the “Beyond the Smoke” project, the handbook builds on the insights gathered through four case studies examining local measures implemented at the city level to improve air quality through sustainable heating. The case studies focus on policies adopted in Sofia, Kraków, Utrecht and Madrid, which were selected for their distinctive features: one of the first LEZ for heating in Europe (Sofia); a total ban on solid fuels for heating that was promoted by a grassroots movement and, through strong cooperation with local authorities, contributed to changes in Polish law (Kraków); the first complete ban on wood-burning in the Netherlands (Utrecht), scheduled to enter into force in 2030; and an ambitious sustainability strategy addressing both climate change and air pollution (Madrid). Despite their differences, all the case studies show that effective clean heating strategies are tailored to local contexts, governance structures, housing characteristics, energy systems, and social needs. Therefore, common lessons emerge on the importance of long-term planning, citizen engagement, financing, and targeted support for vulnerable households, which have been identified as key steps for the design of CHZs.

This handbook is intended for local authorities, practitioners, wider-scale policymakers and stakeholders with vested interests in air quality, energy, climate and social policies. The insights collected aim to provide practical guidance on how to design, implement and monitor CHZs, suggesting the introduction of key elements, the steps needed at each stage of design and implementation and how to integrate key elements such as engaging affected communities, securing funding, managing challenges and evaluating outcomes.

A central message of this handbook is that clean heating cannot be reached through technical solutions alone. The success of the measure(s) will depend on public trust, addressing affordability concerns correctly and ensuring that costs and benefits are distributed fairly. Policies failing to account for social aspects risk public resistance, while measures integrating social justice considerations have higher chances of bringing concrete, long-lasting health and environmental benefits.

As European cities aim to meet increasingly ambitious air quality and climate goals, CHZs offer an adaptable and replicable approach to reducing emissions from domestic heating and simultaneously offer health, comfort and quality of life improvements. Through evidence, practical experience and actionable recommendations, the handbook's objective is to support decision-makers in producing equitable and effective measures for cleaner heating systems and healthier communities.

Highlights:

- Domestic heating is a significant source of pollution and greenhouse gas emissions across Europe;
- Clean Heating Zones can provide a holistic approach to address air quality, climate goals, energy security and social objectives at the same time;
- To successfully implement a Clean Heating Zone, a mix of regulatory instruments, incentives, infrastructural investments and stakeholder engagement is required;
- Social justice and affordability must be included in the policy design from the beginning;
- Examples from European cities show that an ambitious clean heating transition is feasible and beneficial, if adequately tailored to local context;
- Local authorities are key players in driving the transition, but the success will ultimately depend on cooperation across all levels of governance and with affected communities.

1. Introduction

1.1 Air quality and the heating sector

Air pollution poses a serious environmental health threat in the European Union (EU), responsible for an estimated 240,000 premature deaths each year from fine particulate matter (PM_{2.5}) alone, alongside other illnesses affecting the lungs and the heart (European Commission, 2026a). Beyond its human toll, air pollution degrades ecosystems through excess nitrogen deposition, acid rain, and ground-level ozone, while imposing substantial economic costs, estimated at between €231 and €853 billion annually (European Commission, 2026a). With more than 70% of Europeans living in urban areas, the majority of the EU's population is exposed to harmful concentrations of PM_{2.5} and nitrogen oxides (NO_x), the pollutants most strongly linked to adverse health outcomes (EEA, 2023). Although European cities have seen visible improvements in air quality over the past decade, pollutant concentrations in many cities still exceed official EU limit values and, more significantly, the stricter health-based guidelines recommended by the World Health Organisation (WHO) (WHO, 2023). This indicates that further targeted emission reductions are still needed to achieve genuinely safe air quality in European cities (Nahorski, Holnicki, & Kałuszek, 2024).

To address this complex challenge and achieve its zero-pollution vision for 2050, the EU has developed a comprehensive clean air policy framework built on three pillars: ambient air quality standards that all Member States must meet; measures to reduce emissions from key polluting sources; and emissions standards targeting those sources directly (European Commission, 2026a). This framework is complemented by binding national reduction commitments for the main air pollutants, EU-wide monitoring and cooperation tools, and a clear target of reducing premature deaths attributable to PM_{2.5} by at least 55% by 2030. Together, these pillars form the backbone of the EU's response to air pollution, providing the regulatory foundation within which sector-specific measures are designed and implemented (Billerbeck, et al., 2022).

Among the sectors contributing to the pronounced deterioration of air quality in Europe, **heat-related activities, including the residential heating sub-sector, are** a notable source of pollution, contributing, in 2022, to nearly 73% of PM_{2.5}, 60% of carbon monoxide (CO), 48.6% of sulphur dioxide (SO₂), and smaller percentages of NO_x and non-methane volatile organic compound (NMVOC) emissions (Banja, et al., 2024). The release of these harmful pollutants is largely driven by the combination of solid-fuel combustion and inefficient heating systems, such as the choice of fuel, fuel quality, and the sulphur, ash, and moisture content of the fuel, as well as the type and age of appliances. Economic factors such as market dynamics and financial incentives also influence these choices (Banja, et al., 2024). Within the EU specifically, coal and wood combustion for

residential heating and cooking are identified as the main contributors to the health-related social costs of outdoor air pollution (Banja, et al., 2024). This underscores the urgent need for an acceleration of the energy transition through the deployment of non-combustion renewable energy sources (NCRES) systems in the heating sector.

Recognising the scale of this problem, within its broader regulatory framework to address air quality concerns, the EU has developed a targeted body of legislation aimed specifically at reducing emissions from the heating sector, with concrete directives focused on enhancing energy efficiency and promoting the use of renewable energy sources (RES). On the demand side, the Ecodesign Framework Directive (2009/125/EC) (EFD) sets minimum efficiency and environmental-performance requirements for heating appliances, phasing the least efficient and most polluting units out of the market. The Energy Performance of Buildings Directive (EPBD), recast as Directive (EU) 2024/1275, reinforces this by requiring member states to set minimum energy performance standards for buildings, including provisions to phase out stand-alone fossil-fuel boiler installations by 2040 and to prohibit subsidies for them from 2025. On the supply side, the Renewable Energy Directive ((EU) 2018/2001) (RED) sets binding targets, including specific sub-targets for heating and cooling. Underpinning both dimensions, the Energy Efficiency Directive (EED) sets binding EU-wide targets for reducing energy consumption and requires member states to prioritise efficiency in policymaking, including measures to tackle energy poverty (European Commission, 2026b).

The heating sector lies in the **nexus between climate and air quality**. On one hand, as a significant contributor to atmospheric emissions, it damages air quality and drives climate change, placing it at the heart of the energy transition in terms of mitigation. On the other hand, heating systems are also key for climate adaptation, as they are an important tool for adapting to the new realities of a changing climate (Staffell, Pfenninger, & Johnson, 2023). Heating infrastructure must therefore become both more resilient and less polluting. Although current policies aim to address the heating sector's emissions, they remain insufficient to meet the air quality challenges Europe faces (Nahorski, Holnicki, & Kałuszek, 2024). **The social dimension** of this problem is equally critical. As this report outlines, many of the structural barriers and implementation gaps that current policies fail to overcome are rooted in issues of social acceptability and local participation. At the same time, beyond air quality results, policies must also aim to be socially responsible, uphold the principles of a just transition, and ensure that their social impacts address, rather than exacerbate, existing socioeconomic inequalities or the exclusion of vulnerable groups (Kazmierczak, 2019).

Addressing these complex, interlinked challenges effectively requires looking beyond the EU and national levels to adopt a more local perspective. **Municipalities** play a crucial role in the effective implementation of air quality policies, incorporating EU and national requirements while remaining attentive to local needs and circumstances (Monstadt,

Pilo, & van Gils, 2025). Similarly, robust socioeconomic analysis at the local level is crucial for designing policies that are both just and efficient, particularly for addressing energy poverty and ensuring the inclusion of vulnerable groups. This involves studying grassroots initiatives and local civil society structures, identifying social inequalities, and accounting for sociodemographic variables (Blanchet, 2015). EU policy has, in fact, created a clear mandate and **opportunity for cities to act** on heating-related emissions. For instance, the EED requires municipalities with a population over 45,000 to prepare heating and cooling plans for their cities, while local authorities are also responsible for updating their Air Quality Plans on the specific issue of clean air (European Commission, 2026b). This combination of contextual knowledge, socioeconomic insight, and implementation responsibility positions municipalities as key actors in policymaking around the heating sector's air quality and social challenges.

1.2 Scope and methodology

This handbook presents practical lessons for policymakers on designing and implementing policies to improve urban air quality by targeting the heating sector, with a special focus on its local and social dimensions. It draws on several pieces of evidence from research conducted for a project funded by the Clean Air Fund. The policy approach analysed in this handbook is inspired by the Low Emission Zones (LEZs) for vehicles already in force in many European cities. Building on this precedent, the concept of Clean Heating Zones (CHZs) emerges, referring to an area where a policy package and framework are applied to reduce heating emissions.

The insights gathered in this handbook stem mainly from three sources. First, a compendium of residential heating measures, ranging from outright bans to partial restrictions and regulatory incentives, covering cities across EU Member States, the UK, and Norway. This compendium is the result of a comprehensive literature review, mapping, and analysis of heating policies and measures across Europe, including an overview of emission reduction measures for heating, an exploration of the EU, national, and local legislative landscape with a focus on barriers to residential energy measures, and a discussion of the environmental and social impacts of LEZs in heating (e.g., air quality, health, financial viability, resource use, and business opportunities). Information was drawn from municipal websites and original policy texts, as well as academic literature and media outlets to gather complementary insights.

Second, the development of four European city case studies, selected to provide a deeper dive into how air pollution from the heating sector is addressed at the local level, highlighting success factors, challenges, and replicable practices. The case studies were developed through an additional review of city-relevant literature and qualitative, semi-structured stakeholder interviews, and focus on policies adopted in Sofia, Kraków, Utrecht, and Madrid, which were selected for their distinctive features. These four case studies also reflect geographical diversity across Europe and, as a result, different

climatic conditions, winter heating needs, and energy sources for residential heating. Finally, a dedicated online roundtable brought together stakeholders, including cities not directly covered by the case studies, from which valuable insights and lessons were drawn.

1.2.1 Structure

Following this methodology, the results are presented as follows. Chapter 2 identifies and explains the specific issues and challenges of urban air pollution caused by heating emissions, including the roots of the problem, the structural barriers to policymaking, and existing gaps in policy implementation. Chapter 3 sets out the framework that needs to be established to enable local policies to be effectively designed and implemented, covering the legal, institutional, technical, financial, and social landscape required for solutions to succeed. Chapter 4 provides a step-by-step guide on how to design and implement clean heating policies in a way that is socially acceptable, locally accurate, and effective. Chapter 5 draws out the lessons learned from the project's research on what works in practice, including success factors, replicable practices, transferability lessons, and differentiating factors. Finally, Chapter 6 sets out specific recommendations for policymakers at the local, national, and EU levels.

2. Understanding the challenges

2.1 Why residential heating matters

2.1.1 Current emissions and trends

As mentioned in the Introduction, air pollution from residential heating primarily results from solid-fuel combustion and inefficient heating systems. The main pollutants emitted from this sector are PM₁₀ and PM_{2.5}, which may contain toxic chemicals such as benzo(a)pyrene (B(a)P) and CO, particularly present when burning coal and wood. Residential heating also emits other pollutants such as NO_x, NMVOCs, and SO₂, but in smaller proportions than other sectors and heat-related subsectors, including transport, non-energy-related sectors, and heat industries (Banja, et al., 2024).

Overall, in the EU-27, emissions from the residential sector have decreased over the years, driven by improvements in energy-efficient heating systems and a declining share of fossil fuels in the energy mix. Table 1 shows part of this reduction by highlighting the relative change in air pollutant emissions per type of fuel from the residential sector between 2005 and 2022. While emissions of nearly all pollutants by fuel type declined, the relative change in PM_{2.5} from biomass only decreased by 1%, and NO_x and SO₂ from biomass drastically increased. This pattern can be explained by the transition from coal- and oil-based heating systems to biomass since the 2000s.

	Biomass		Coal		Gas		Oil	
NO _x		32.74		-19.10		-23.40		-48.00
SO ₂		22.40		-26.10		-21.00		-80.10
PM _{2.5}		-1.00		-19.60		-23.30		-41.40
NMVOC		-22.20		-22.80		-21.20		-37.90
NH ₃		-15.60		-30.90		-19.20		-36.20
CO		-3.20		-18.80		-20.80		-34.80

Table 1. Relative change in residential sector air pollutant emissions in the EU-27, by fuel, 2005-2022 (%). Source: (Banja, L. et al. 2024); EDGAR version 8.1, 2024.

In the latest [Air Quality Status in Europe 2026](#), the European Environment Agency (EEA) highlights that even though air quality continues to improve in Europe, about **20% of monitoring stations¹ for air pollution are still above the current EU air quality standards for several pollutants**, particularly for PM₁₀ and B(a)P, which are mainly emitted from residential heating (EEA, 2026a). In addition, the concentration of most pollutants remains above the WHO air quality guideline levels². Figure 1³ presents the percentage of monitoring stations across Europe, with pollutant concentrations respecting the EU standards and WHO guideline levels, in 2024. For PM_{2.5}, only 7.5% of monitoring stations were aligned with WHO guidelines.

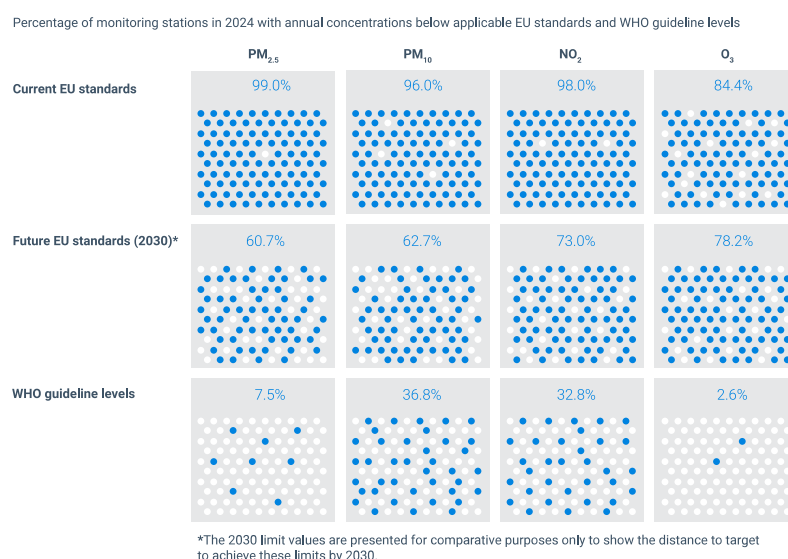


Figure 1: Percentage of monitoring stations in 2024 with annual concentrations below applicable EU standards and WHO guideline levels. Source [EEA, 2026](#).

2.1.2 Health and social impacts

Air pollution remains the greatest environmental health risk for Europeans in 2026, according to the EEA (EEA, 2026a). **Poor air quality notably increases the risk of respiratory and cardiovascular diseases** (EEA, 2019). This reinforces an already well-established body of literature and evidence, as, for instance, the 2013 International Agency for Research on Cancer report, which classified PM as carcinogenic to humans (WHO, 2013). As a result, the diseases generated or exacerbated by air pollution can lead

¹ There are [different types of national fixed monitoring stations](#): traffic stations, industry stations and background stations (EEA, 2024). The latter captures pollution levels which are representative of the average exposure of the general population or vegetation. However, some [EU countries](#) still lack monitoring stations or good data quality, creating an issue in identifying the true level of pollution and distinguishing the source (Jovanovic Andersen, et al., 2025). National monitoring networks can also be supplemented by local monitoring stations to better understand the emissions, but it is different for each city.

² The EU legislative framework and the WHO guideline will be explored in 2.2

³ This EEA's figure does not differentiate between pollutant sources. Therefore, the percentage of monitoring stations represented does not disaggregate air pollution for different sectors. Although it distinguishes different pollutants, which are commonly associated with specific sectors.

to many premature deaths. In 2023, the number of premature deaths attributable to PM_{2.5} exposure in the EU was about 182,000 (EEA, 2025c). In addition to that, particulate matter also generates other less-known health impacts. For instance, by reviewing epidemiological studies on air quality and type 2 diabetes (T2D), Yang et al. (2020), demonstrated the adverse association between exposure to PM_{2.5} and PM₁₀ and the increased risk of T2D. More recently, studies have shown that long-term exposure to air pollution, particularly PM_{2.5} and nitrogen dioxide (NO₂), was associated with an increased prevalence or risk of newly diagnosed depression, with depression symptoms being exacerbated by high levels of pollution (EEA, 2025b).

Health impacts from residential heating air pollution also create economic and social effects on society. The health-related social costs of outdoor air pollution due to residential heating and cooking in the EU and the UK were estimated by Delft University to account for 29 billion euros (0.2% of GDP) in 2018 (Kortekand, de Vries, van Berkel, & de Bruyn, 2022). This includes medical care, productivity losses and years of life lost using WHO (2013) guidelines. In addition, while almost all European urban citizens are exposed to PM_{2.5} at higher concentrations than those recommended by the WHO levels, air pollution disproportionately affects certain groups. **Children, the elderly, and those already suffering from chronic diseases are more vulnerable to air pollution compared to the rest of the population.** Additionally, several factors (including occupational risks, limited access to healthcare, and the inability to relocate to another less polluted area, which are directly influenced by economic resources, the level of awareness and the social and cultural circumstances of individuals) create disparities among the population.

2.1.3 Disparities across Europe

Although air pollution from residential heating in Europe has decreased over the past 20 years, disparities between countries, and among and within cities remain significant. According to the EEA Air quality status in Europe 2026 report, high concentrations of PM₁₀ are mainly in Eastern Europe, as well as in Italy and southern Spain, while Western and Northern Europe benefit from better air quality (Figure 2) (EEA, 2026a). These disparities look similar for PM_{2.5} (Figure 3) and can be partly related⁴ to the types of residential heating systems used, as Eastern Europe tends to utilise solid-fuel heating systems – coal in Poland, wood in Bulgaria, etc. These differences across Europe imply disproportionate health, economic and social impacts, while the EU legislative framework for air quality applies the same to all Member States⁵.

⁴ Air pollution concentrations are also influenced by meteorology, topography, transport, industry and transboundary pollution.

⁵ See Section 2.2 – Why current approaches don't work? The policy gap

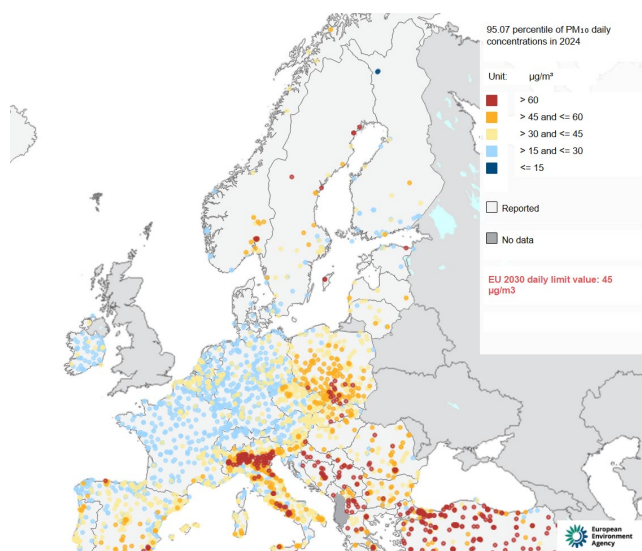


Figure 2: PM₁₀ concentrations in 2024 relative to the 2030 EU daily limit value. Source: [EEA, 2026](#).

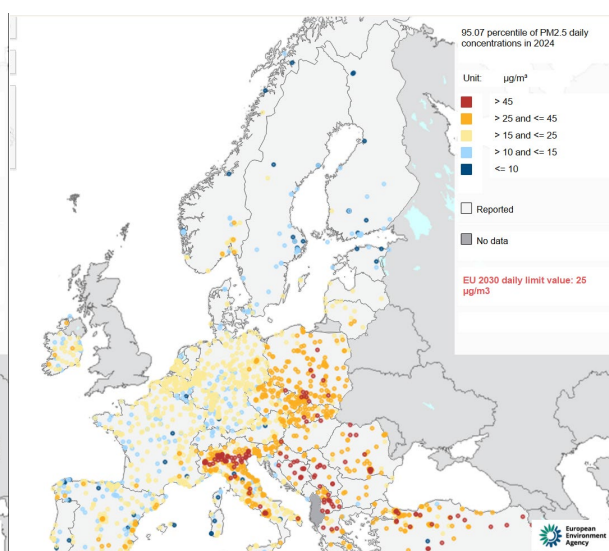


Figure 3: PM_{2.5} concentrations in 2024 relative to the 2030 EU daily limit value. Source: [EEA, 2026](#).

Additionally, inside a country and within a city, large inequalities of vulnerability and exposure to air pollution from residential heating occur between households (see Chapter 5 for further details).

2.2 Why current approaches don't work: the policy gap

Despite significant progress in reducing emissions from residential heating, current policy approaches have not delivered consistent improvements in air quality across Europe. A major reason is that the governance framework for residential heating is fragmented across multiple levels (EU, national, regional and local), while responsibilities, ambitions and enforcement capacities differ substantially between jurisdictions. This creates a policy gap between European objectives and local implementation.

2.2.1 Legislative framework

The regulation of residential heating sits within a complex multi-level framework. At the EU level, the revised Ambient Air Quality Directive (AAQD), which was formally adopted in late 2024, is at the core of this framework. The revised AAQD sets out stricter EU limit values for 2030 for major pollutants, strengthens monitoring and modelling requirements (Recital 11 & 12), and requires Member States to develop Air Quality Roadmaps and Air Quality Plans where exceedances occur (Recital 13). The Directive also reinforces public access to information and seeks to improve the effectiveness of implementation by strengthening reporting and enforcement provisions (Recital 46).

Pollutant	AAQD (2008/50/EC)	Revised EU AAQD (2024/2881/EC)	WHO Air Quality Guidelines (2021)
PM _{2.5}	25 µg/m ³ (annual)	10 µg/m ³ (annual)	5 µg/m ³ (annual)
PM ₁₀	40 µg/m ³ (annual)	20 µg/m ³ (annual)	15 µg/m ³ (annual)
NO ₂	40 µg/m ³ (annual)	20 µg/m ³ (annual)	10 µg/m ³ (annual)
SO ₂	125 µg/m ³ (24-hour mean)	20 µg/m ³ (annual)	40 µg/m ³ (24-hour mean)
Benzene (C ₆ H ₆)	5 µg/m ³ (annual)	3.4 µg/m ³ (annual)	/
Lead (Pb)	0.5 µg/m ³ (annual)	0.5 µg/m ³ (annual)	/
Benzo(a)pyrene (BaP)	1 ng/m ³ (annual)	1 ng/m ³ (annual)	/
Arsenic (As)	6 ng/m ³ (annual)	6 ng/m ³ (annual)	/
Carbon monoxide (CO)	10 mg/m ³ (maximum daily 8-hour mean)	4 mg/m ³ (24-hour mean)	4 mg/m ³ (24-hour mean)
Ozone (O ₃)	120 µg/m ³ (maximum daily 8-hour mean)	100 µg/m ³ (maximum 8-hour mean)	100 µg/m ³ (maximum 8-hour mean)

Table 2 Comparison of ambient air quality annual/daily limit values under the original AAQD (2008/50/EC), the revised AAQD (EU) 2024/2881 (applicable from 2030) ([annex 2](#)), and the [WHO Global Air Quality Guidelines \(2021\)](#). Note: Values are based on different averaging periods (annual mean, 24-hour mean, or maximum daily 8-hour mean) and should therefore not always be interpreted as directly comparable.

Complementing the AAQD, the [National Emission Reduction Commitments \(NEC\) Directive](#) sets legally binding national emission reduction targets for key air pollutants, including particulate matter PM_{2.5}, NO_x, SO₂, non-methane volatile organic compounds (NMVOCs) and NH₃.

However, the choice of heating technologies, subsidy schemes such as for heat pumps (EHPA, 2023), building regulations and enforcement mechanisms remain largely under national and sub-national control. EU legislation defines targets and minimum requirements, but Member States decide how these are translated into national laws, and municipalities often determine whether and how restrictions on solid-fuel heating are applied (Billerbeck, et al., 2022). Consequently, households and local authorities face rules that vary considerably across Europe. For instance, the municipality of Utrecht has decided to implement a full indoor wood-burning ban, whilst other municipalities in the

Netherlands refer to an air quality tool to determine whether residents are allowed to burn wood or not.

2.2.2 Key barriers

Many structural barriers limit the effectiveness of current approaches to reducing air pollution from residential heating, making the transition particularly challenging. Some of these barriers were identified during the drafting of the compendium and the four case studies, as part of the project⁶.

- *Enforcement challenges*

A major limitation of existing policies is the difficulty of monitoring and enforcing emissions from individual residential heating sources, with residential heating relying on millions of individual appliances with highly variable operating conditions, fuel quality and maintenance practices. Emissions can either be generated directly within individual residential buildings through heating and cooling systems using fuels such as oil, gas or biomass, or indirectly from centralised energy sources supplying multiple buildings or neighbourhoods, such as DHC networks or solar photovoltaic (PV) electricity generation (Schoenefeld, Hilden, & Siiskonen, 2025). For instance, in the UK, monitoring household-level emissions is often technically complex and economically unfeasible for local authorities (UK Parliament, 2022). As a result, regulations on solid fuel combustion can be difficult to enforce in practice, particularly in areas where local administrative capacities are limited.

Even when restrictions on wood or coal burning exist, such as in Utrecht and Madrid, authorities often lack the resources, monitoring tools or political support required to ensure compliance. This creates a **gap between regulatory objectives and actual emission reductions**. Effective enforcement is not only a question of capacity, but also of legal competences, which can vary across Europe. Municipalities often face significant limitations in monitoring compliance, as they generally cannot enter private property without permission. In the Netherlands and other countries, local authorities often rely on voluntary tools, such as the *Stookwijzer*⁷, as well as reports submitted by residents. While these tools can contribute to identifying violations, their effectiveness depends on citizen awareness and engagement, meaning that they are typically used by

⁶ Chiocchetti, I., Tang, A., & Antonelli, C. (2026). *Improving air quality with residential heating policies. A compendium of local approaches across Europe*. Institute for European Environmental Policy; Tang, A. M., & Antonelli, C. (2026). *Low Emission Zone in the Heating Sector: Sofia case study*. Institute for European Environmental Policy; Tang, A. M., & Chiocchetti, I. (2026). *Anti-Smog resolution banning solid fuels for heating: Kraków case study*; Holle, G., & Chiocchetti, I. (2026). *Banning indoor wood burning: Utrecht case study*. Institute for European Environmental Policy; Chiocchetti, I., Holle, G., & Ruiz González, L. (2026). *Ban on coal-fired boilers: Madrid case study*. Institute for European Environmental Policy.

⁷ The Stookwijzer is a Dutch air-quality advisory colour-coded tool that provides daily guidance on when it is not advised to use wood stoves or fireplaces based on air pollution levels and weather conditions. It is not a mandatory tool, but municipalities can choose to adopt it as part of their local air quality policies.

a portion of the population. The case of Antwerp illustrates a different approach: the ban on wood-burning devices is enshrined in the Municipal Police Code, granting the enforcement authorities a formal role in monitoring compliance and efficiency (Chiocchetti, Tang, & Antonelli, 2026).

- *Social resistance and behavioural barriers*

Residential heating is closely connected to **household preferences and cultural habits**, making policy interventions particularly sensitive. In many European regions, wood and coal heating have historically been part of local traditions and are perceived as reliable, affordable or more independent energy sources, especially in countries such as Finland (Kilpeläinen, Pelsmakers, Castano-Rosa, & Miettinen, 2025) (Savolahti, et al., 2019). Chapter 5.2.3 reports more details about social aspects to factor in a policy framework.

- *Energy poverty and affordability constraints*

Transitioning away from inefficient heating systems requires **significant upfront investments**, which can represent a major barrier for many households. In 2023, 18.5% of households did not have adequate insulation or heating systems to keep their homes warm (Ozdemir & Koukoulakis, 2025). Thus, replacing old heating systems with cleaner technologies or improving insulation often involves costs that vulnerable households cannot afford without financial assistance. Furthermore, renewable and more efficient technologies such as heat pumps and energy management systems often depend on substantial upfront capital investment (Kraaijevanger, Verma, Doorn, & Goncalves, 2023). However, subsidy schemes are often designed as reimbursements rather than anticipated payments, placing the initial financial burden on the consumer.

- *Political and governance challenges*

Residential heating policies are also shaped by political priorities, which can change over time and lead to inconsistent implementation. While EU legislation has established long-term air quality objectives, decisions on local measures such as restrictions on solid-fuel heating, low-emission zones or financial support schemes are influenced by the political leadership of the region or country. As a result, measures introduced by one administration may be weakened or reversed by its successor. Even for well-established measures, such as the Anti-Smog Resolution in the Polish region of Małopolska, some fear that opposing factions might attempt to prevent the introduction of additional measures or scope extension, with the risk of ultimately weakening the objectives of policies that have been in place for a long time (Tang & Chiocchetti, 2026). Long-term emission reductions require stable governance frameworks that provide certainty for citizens, businesses and public authorities while maintaining public support for the transition to cleaner heating systems.

- *Evolving geopolitical circumstances*

In addition to political changes resulting from shifts in local electoral outcomes, energy crises and other major events may force policymakers to revise their priorities and introduce temporary suspensions of certain measures (Mišík & Nosko, 2023). Events such as the COVID-19 pandemic or the war in Ukraine shape public support and economic contexts through their direct effects on energy prices, thereby shifting the social and political acceptance of energy policies (Steffen & Patt, 2022). For example, at the time the ban on coal-fired boilers was introduced in Kraków, its adoption was facilitated by strong cooperation among local authorities and citizens, and the broader geopolitical and economic context was more favourable compared to just a few years later. The strong public support for the ban and its widespread social acceptance may have been less pronounced during periods marked by the COVID-19 pandemic or energy crises (Interviewee 1, Kraków case study, 2026).

- *Risk of misalignments in climate and air quality objectives*

Measures aimed at phasing out polluting heating technologies may sometimes cause unintended adverse effects. In some cases, households may be encouraged to switch to alternative fuels that are perceived as more affordable, sustainable and readily available, without necessarily reducing overall environmental impacts. As a result, progress towards one policy objective may undermine improvements for another. For example, the replacement of coal-based heating with biomass combustion can reduce GHG emissions but would increase emissions of particulate matter and other pollutants. As a result, climate objectives may be advanced, but local air quality would be impacted.

Similarly, restrictions on coal- and wood-burning systems have, in certain contexts, encouraged the uptake of natural gas as a cleaner, affordable and readily available alternative. However, natural gas is itself being phased out as part of the EU's transition away from fossil fuels towards an energy system increasingly based on RES.

In this regard, it is important to note that not all RES are equally clean from an air-quality perspective (Ricardo, 2025). While RES are naturally restored, some technologies, such as biofuels (especially solid biomass), rely on combustion processes that release pollutants, contributing to local air quality problems.

2.2.3 Implementation gaps

In addition to structural barriers hindering policy effectiveness, current programs face crucial implementation gaps. These can depend on flaws in design or deployment that undermine the policies' capacity to achieve tangible impact and overcome structural barriers, but which can be corrected by refining existing approaches.

- i. Insufficient adaptation to local context*

While current policy approaches are tailored to their implementation areas, they often fail to capture all context-specific aspects necessary for a genuinely multidimensional strategy. This oversight creates an implementation gap, as policies cannot accurately reflect local problems, stakeholders, or solutions (Swarnakar & Singh, 2022). Preliminary studies are necessary during the design phase, assessing the environmental, technical, health, socioeconomic, and cultural dimensions. Technical infrastructure, such as district heating or electrification capacity, varies significantly by area and directly influences policy needs (European Commission, 2023). Similarly, robust socioeconomic analysis is crucial for designing just and efficient policies that address energy poverty and are inclusive of vulnerable groups, including the study of grassroots initiatives and local civil society structures, the identification of social inequalities and the consideration of sociodemographic variables (Kazmierczak, 2019; Blanchet, 2015). Cultural factors also play a decisive role in determining whether a policy will be accepted or rejected by residents, or effective locally (Perlaviciute, Steg, & Sovacool, 2021). Crucially, policies fail to incorporate a cross-cutting approach involving all these dimensions. For instance, Bucharest's heating distribution measures relied solely on air quality data, ignoring broader contextual factors (Chiocchetti, Tang, & Antonelli, 2026). Likewise, Utrecht's ban on burning indoor wood was paired with a subsidy scheme that was abandoned due to poor cost-effectiveness, revealing a mismatch between the design data and local reality (Holle & Chiocchetti, 2026).

ii. Gap in stakeholder engagement

Despite strong evidence supporting participatory approaches in climate policy, many measures **lack truly representative stakeholder engagement during design and implementation** (Cattino & Reckien, 2021; Haustein & Lorson, 2021; Kiss, et al., 2022; Freschi, Menegatto, & Zamperini, 2024). This creates a gap in inclusive participation, compromising the process of informing policies with local knowledge, which enhances not only fairness, but also relevance, effectiveness, and acceptance (Swarnakar & Singh, 2022). This gap may derive from different sets of circumstances. Participation is frequently limited to early stages, such as public consultations during drafting, without sustained feedback loops during or after implementation. The case of Amsterdam's Wood Burning Policy Framework's participatory process, which only occurred during the drafting of the measures, illustrates this common gap (Chiocchetti, Tang, & Antonelli, 2026). The case of Sofia's Heating LEZ constitutes a different example, in which non-expert stakeholders were only included once the policy had been drafted (Tang & Antonelli, 2026). Limited stakeholder involvement during earlier stages may have fuelled civil society opposition to the measure, which was subsequently challenged in court.

iii. Lack of effective communication

Effective communication is crucial for ensuring that policies are both socially acceptable and operationally successful. In the energy transition, policymakers frequently overlook certain social perceptions that emphasise the importance of

communication and shape the way in which information should be presented. Firstly, new technologies might be unfamiliar to the broad public, or there might be misinformation around them, which can shape public attitudes and erode trust (Ricci, Bellaby, & Flynn, 2008). For instance, clean energy is often associated with negative notions such as intermittent supply or high costs (Perlaviciute, Steg, & Sovacool, 2021). In addition, new policies are frequently linked to an overestimation of burdens and underestimation of benefits by the public (Volken, Xexakis, & Trutnevyte, 2018).

Furthermore, a lack of transparent dialogue can make citizens feel excluded, perceiving policies as top-down expert mandates rather than collaborative efforts, similarly leading to an erosion of trust (Magnani, 2021). Consequently, many policies fail to include mechanisms that proactively address these uncertainties and knowledge gaps. Finally, communication and stakeholder engagement can be understood as a synergy, where poor communication not only deteriorates public acceptance but also acts as an obstacle to inclusive participation. Therefore, improving communication strategies is vital for simultaneously bridging gaps in both public understanding and stakeholder involvement.

iv. Absence of robust monitoring frameworks

Monitoring mechanisms are critical for evaluating air quality policy outcomes and guiding necessary adjustments (OPS, 2026). Beyond securing access to accurate, territorially specific data, it is essential to establish robust common frameworks that standardise how this data is interpreted. A study supporting European Commission policies highlights significant implementation gaps across Member States regarding the Ambient Air Quality Directive (AAQD). Key issues include a lack of guidance on applying low-cost sensors and complementary methods (such as satellite data), uncertainty about sensor performance in real-world networks, and the absence of harmonised definitions for estimating population exposure (Conlan, et al., 2022). Without these standards, there is a risk of significant policy inaccuracy, and monitoring data failing to effectively inform corrective actions.

v. Limited local capacity & multi-level governance integration

Local governments often lack the financial and technical capacity that other governance levels rely on, emphasising a gap that limits the extent to which energy transition policies can be implemented, particularly those involving infrastructure upgrades or extensive subsidy schemes (Swarnakar & Singh, 2022). This issue of limited capacity highlights a broader **gap in multilevel governance** (MLG) integration. Local authorities possess essential context-specific knowledge, which allows them to identify actors, dynamics and practical information more accurately. They are also key in facilitating the participation of these local actors in MLG structures (Cheung, Davies, & Trück, 2019). However, they depend on national and regional bodies for the funding, training, and regulatory competencies needed to design and enforce effective policies (Cochrane,

2020). Consequently, poor integration of current MLG frameworks creates gaps in local governance capacity, posing important obstacles to accurate, socially acceptable and inclusive policymaking. This visibly manifests as a divide between well-resourced municipal governments and underfunded counterparts (Choi, 2021).

Insufficient local capacity and inadequate MLG coordination are therefore two gaps that intersect. Bridging these gaps requires enhanced resource flows and stronger collaboration across governance levels to unlock the full potential of local expertise backed by higher-level support. An exemplary case is the city of Kraków. During the grassroots demonstrations calling for a ban on coal-fired boilers, the municipality did not have the legal competence to act on environmental issues. Driven by strong civic mobilisation, the municipality successfully advocated for changes to the national law, ultimately securing the powers needed by local authorities to introduce such measures (Tang & Chiocchetti, 2026).

3. Enabling solutions

3.1 Clean Heating Zones as a framework for combined local action

Across Europe, cities are increasingly stepping up to reduce emissions from residential heating. As already mentioned, a wide range of measures have been implemented by European municipalities⁸. Restrictions and bans on coal and wood burning, incentive schemes to install clean heating technologies, investments in district heating networks, and communication and awareness campaigns are just a few examples of them. While this set of measures shows heterogeneity in its characteristic typologies, there is one common approach: a mix of policy instruments within a specific geographic area with the objective of improving air quality and the transition to clean heating.

This handbook refers to such an approach as a **Clean Heating Zone (CHZ)**, defined as a geographically distinct area where decision-makers implement a policy mix of regulatory, financial, and engagement measures to reduce heating emissions while ensuring cleaner alternatives. While a ban on coal or a clean subsidy programme is a single measure, a CHZ combines several methods and instruments to reduce air pollution and potentially address barriers and gaps households can experience when switching to cleaner alternatives.

The measures that compose the policy mixes of CHZs aim at reducing both air pollution and GHG emissions. For example, biofuels, particularly solid biomass, despite being classified as renewable energy sources, can significantly harm air quality. Indeed, while their net climate impacts vary considerably depending on feedstock, sourcing and accounting assumptions, they emit significant quantities of toxic air pollutants, most notably PMs. However, the technologies deployed within a CHZ may differ depending on local circumstances, infrastructure availability, affordability, and the stage of the transition. In some contexts, for instance, the use of transitional solutions such as modern gas-based heating systems or district-heating connections has delivered in the past significant air-quality improvements compared with coal. Nevertheless, the long-term objective of a CHZ is to promote heating solutions delivering both air quality improvements and climate neutrality. Among these, non-combustion renewable energy sources (NCRES), which by definition do not rely on combustion to generate power (e.g. heat pumps, solar thermal, and non-combustion district heating technologies), should be the preferred long-term clean alternatives because of their limited impacts on air quality (Ricardo, 2025).

⁸ Examples are collected in the Compendium mentioned in Chapters 1 and 2.

The concept of CHZ is inspired by the logic of a Low Emission Zone (LEZ), which is mainly

Textbox 1: Cleaner vs clean alternatives

This handbook distinguishes between *cleaner* and *clean* heating alternatives. Cleaner alternatives are technologies that significantly reduce air pollutant emissions compared with existing systems and may play an important role as transition technology in specific contexts. Clean alternatives are solutions supporting both air quality and climate neutrality. While some municipalities have relied on natural gas or transitional technologies to phase out coal and wood combustion, the long-term planning established by the EU climate policy framework favours NCREs, electrification, and highly efficient heating systems.

used in the transport sector. Like a LEZ in the transport sector, a CHZ combines different instruments, but it recognises that the heating system has clear technical, economic and social challenges, which require a broad and systemic approach.

Thus, a CHZ does not necessarily translate into a specific and formal designation of a regulatory zone. Rather, it can be used as a practical policy framework for local authorities, municipalities and practitioners who aim at coordinating different ad hoc measures in specific neighbourhoods, in broader districts or even entire cities.

3.1.1 Core characteristics

Building on the measures reviewed and selected in IEEP's "Improving air quality with residential heating policies. A

compendium of local approaches across Europe", several key characteristics can be identified as part of a CHZ (Chiocchetti, Tang, & Antonelli, 2026).

- A CHZ usually targets emissions caused by residential heating, and it operates in a geographically defined area (neighbourhood, district(s), whole city). As it moves from a singular intervention to a systemic approach, a CHZ can combine different policy instruments, which can include bans on coal, Smoke Control Areas or decarbonisation of buildings, to mention a few.
 - i. A CHZ, overall, has the objective of improving both air quality and providing positive public health effects. This, however, can be combined with additional objectives, be they emission reduction for climate neutrality and/or accelerating the energy transition.
 - ii. A CHZ also supports the uptake of cleaner heating technologies, such as heat pumps, new boilers, and electric heating devices, which can support both climate neutrality and air quality improvements through the energy transition. A key characteristic that arises is also the social engagement and acceptability of the policy, which includes or should include measures to protect vulnerable households and increase the affordability of the measures.

- iii. Mostly, a CHZ is adapted to local circumstances: a well-designed CHZ is tailored to local needs and conditions; it is based on infrastructure availability and on pre-existing housing conditions, which are a key factor in enabling a switch to cleaner heating systems.

3.1.2 What can be learned from Low Emission Zones?

The success of Low Emission Zones in the transport sector can encourage policymakers to apply a similar concept to the residential heating sector. Many municipalities have already taken steps toward the introduction of measures that share several characteristics with LEZs.

The Heating Low Emission Zone in Sofia, Bulgaria, for instance, is the most relatable example to a LEZ in the transport sector in Europe, so far. The measure prohibits the burning of solid fuels in areas where a district heating system or a gas distribution network is available (Metropolitan Municipal Council, 2022). The LEZ is scheduled to be expanded to the entire municipality from 1 January 2029. To support households affected by the obligation to phase out low-efficiency heating systems at no cost, the Municipality has introduced financial support, such as the Life Programme and the Operational Programme Environment 202120279 (Sofia Municipality, 2024). As of December 2025, over 15,000 solid-fuel heating systems have been replaced in 11,127 households, resulting in 219 tons of PM avoided annually.

Other cities introducing clean heating initiatives have similarities with LEZs design. Malmö, for instance, prohibits, in certain areas covered by a detailed plan and in densely populated areas, small-scale burning of solid fuel for heating and hot water production in a boiler that is not environmentally approved or equipped with an accumulator tank, or recreational burning with solid fuel (Chiocchetti, Tang, & Antonelli, 2026). It also provides recommendations on how and when to burn wood to limit pollution. Similarly to a LEZ communication campaign, the local government disseminates information on public websites to encourage awareness of cleaner wood-burning practices and to disseminate knowledge of specified local zoning regulations. **Riga** has established different heating zones with varying requirements depending on pollution levels, population density and access to district heating (Chiocchetti, Tang, & Antonelli, 2026). Examples from these and other cities across Europe show that, using a tailored, place-based approach, municipalities can effectively address heating-related pollution.

Notwithstanding, there are caveats when comparing a heating zone with transport LEZs. First, unlike vehicle owners, households cannot change their heating system as easily as vehicle owners when new requirements arise. Heating appliances, in fact, are in use for a long time, and their replacement can be quite costly. Often, new installations of heating systems, especially cleaner alternatives, may depend on the availability of district heating networks, current electricity infrastructure, building renovations and retrofitting.

In addition to potentially high upfront costs, national and local regulations can impact domestic heating and households' habits, potentially creating social and political sensitivity. Thereby, successful clean heating measures can rarely rely on restrictions alone. On the contrary, a CHZ is composed of different regulatory measures with financial support, investments in specific infrastructures, public engagement activities, and targeted subsidies. The examples provided in the Compendium show how, even in contexts with different geographical, political and socioeconomic circumstances, policy packages are likely to be more effective than isolated interventions (See [Section 5.2 Differentiated pathways across Europe](#)).

3.2 Building blocks for Clean Heating Zones

Affordable, clean heating is increasingly recognised as a need by European municipalities, and various measures resemble or are inspired by the logic of LEZ – through spatial targeting, gradual phase-in or conditional application. The experience gathered across European cities highlights that there are specific measures which are particularly relevant for a CHZ fostering a clean heating transition.

3.2.1 Regulatory instruments

Regulation establishes the direction of travel for a CHZ. Legislation can effectively provide certainty to citizens about phasing out polluting activities, with a long-term planning approach.

Across Europe, many municipalities have adopted different regulatory measures to improve air quality in the cities. In Kraków, for example, a **ban on the use of solid fuels**, such as coal, wood, and other biomass, for heating and non-heating purposes was adopted by the Lesser Regional Assembly and financial support was provided by the municipality through different programmes (Tang & Chiocchetti, 2026). Still in Poland, Warsaw applied in 2023 a **Ban on the use of hard coal and solid fuels produced by coal** in household heating appliances, with exemptions for only particular appliances.

In the case of the UK, the country's primary policy addressing air pollution is the implementation of **"Smoke Control Areas"**, introduced under the Clean Air Act of 1956 (national law). Since then, many cities have adhered to these rules, such as Bristol, Manchester or London, for instance (Chiocchetti, Tang, & Antonelli, 2026).

3.2.2 Financial incentives

Upfront costs against the long-term benefits of the switch to clean heating appliances are a crucial point to address when implementing a CHZ. Thereby, financial support is a key instrument to support households facing costs when replacing older or polluting heating devices with cleaner ones. Many instruments and subsidies have been put in place by municipalities so far. This is the case with specific grants for old boiler replacements, targeted subsidies for heat pump installations, renovation and

retrofitting grants, low-interest loans, and ad hoc support schemes for vulnerable households.

As a matter of fact, many cities have associated regulatory measures and restrictions with financial assistance for citizens. Using the previous examples, both Kraków and Warsaw have proceeded accordingly, offering **grants** to replace polluting heating systems. Hamburg has also adopted a similar approach, offering **funding programmes** to citizens shifting to heat pumps and similar low-carbon heating solutions.

The examples provided through the case studies and the Compendium have clearly shown that financial support plays a crucial role in heating system transformation, as the measures in CHZ affect low-income, most vulnerable households experiencing or at risk of energy poverty.

3.2.3 Investing in infrastructure

Switching to clean energy for residential heating requires the necessary infrastructures put in place to make cleaner alternatives available and accessible.

Therefore, several cities have invested in enabling solutions, such as, for instance, district heating networks. Other solutions include geothermal energy, retrofitting of older buildings, and structural investment in electricity grids and NCRES.

As an example of infrastructure investments for clean energy, in 2025 Aarhus provided the most extensive **geothermal project** in the EU. The city is supplied with heat from a district heating grid that covers almost the entire city, with geothermal reservoirs acting as its own storage facilities. In the future, Aarhus geothermal plant will become part of a diverse energy mix, including air-to-water and seawater heat pumps, as well as waste-to-energy with Carbon Capture and Storage. Ghent, instead, focuses on investments for heat pumps and **small-scale, low-temperature district heating networks** as solutions to phase out fossil-fuelled heating systems, while also excluding biomass burning for air quality reasons. Helsinki started the construction of a **heat plant** in 2023 to produce **carbon-neutral district cooling and heating**. Using waste energy from purified wastewater, the heat plant will reduce carbon dioxide emissions as it replaces heat production based on fossil fuels in the winter and produces district cooling in the summer. As the demand for district cooling in Helsinki is on the rise, the new plant enables local, carbon-neutral cooling production (Chiocchetti, Tang, & Antonelli, 2026).

Overall, investing in infrastructure has proven to be crucial as it lays down the enabling technical conditions for feasible and just regulatory measures.

3.2.4 Behavioural and communication channels

A milestone to design and successfully implementing a CHZ is its social acceptability. Public understanding is thus critical to ensure the success of a comprehensive policy package for clean heating policies at the local level.

Ad hoc stakeholder engagement and tailored information campaigns are the most powerful tools in communicating the health, environmental and economic benefits of a CHZ, laying out the effects of air pollution on human health, and informing citizens of all available solutions and alternatives, including how to access financial support.

Many examples across Europe show the importance of adopting policy measures with awareness-raising activities and consultation processes. In its Wood Burning Policy Framework, Amsterdam has included, as one of the main measures, an **awareness campaign** about the risks of wood smoke via flyers, social media, and local campaigns in affected areas. Also, a **consultation process** provided citizens with an adequate space to report nuisances. In Utrecht, an ad hoc campaign was designed to raise awareness of wood burning's effects and foster its reduction, **to prepare citizens well in advance** for the ban on burning indoor wood from 2030.

As such. Communication is not a mere add-on tool in a policy mix for CHZ. Rather, it is a key component of successful policy implementation.

3.3 Enabling a successful Clean Heating Zone

The success of CHZs depends not only on the selected measures, but also on the broader conditions through which they are implemented.



Figure 4: *Enabling conditions for a successful CHZ*

- 1. Legal and governance conditions:** Municipalities need legal authority to regulate emissions and implement policies. Responsibilities must be clearly allocated across different levels of government. Being a cross-sectoral topic, a joint approach across air quality, climate, energy transition and housing policy departments is needed to implement a CHZ.
- 2. Technical conditions:** municipalities and practitioners should consider the availability of cleaner heating solutions **before** planning and introducing specific restrictions. Grid capacity, district heating availability, workforce capacity, buildings suitability are all factors that can have an impact on the success of a policy.
- 3. Financial conditions:** as already mentioned, funding is a crucial success factor. Thereby local authorities should be able to identify stable resources, not only for incentives or short-term planning, but also for long-term investments, monitoring and support plans.
- 4. Social Conditions:** clean heating transformation can have different distributional impacts on households, depending on income levels, housing conditions, ownership of the building, and accessibility to cleaner alternatives. If a policymaker aims at designing a socially just framework, they will therefore need to include targeted support for vulnerable groups, as well as mechanisms able to prevent energy poverty from increasing in the city.
- 5. Institutional conditions:** Municipalities need adequate administrative capacity to design, implement and monitor a policy framework for air quality improvement. Having access to reliable data, ensuring adequate enforcement mechanisms and providing effective stakeholder engagement is therefore crucial.

4. Implementation guidance

4.1 How to design Clean Heating Zones?

As a matter of fact, the cities examined have implemented a wide range of regulatory measures, incentives, infrastructure investments and stakeholder engagement processes which are highly dependent on local contingencies.

Even so, there is a minimum common denominator in these diverse local experiences; all the initiatives have been phased in thanks to a structured, gradual approach which takes into consideration the social acceptability of the measures, potential social impacts and fairness implications, and their technical feasibility.

Considering the experiences shared by the four municipalities and enriched with the highlights of other cities collected in the Compendium, this chapter presents a short guide to design and implement a CHZ, shedding light on the main enabling conditions and the barriers to anticipate and address.

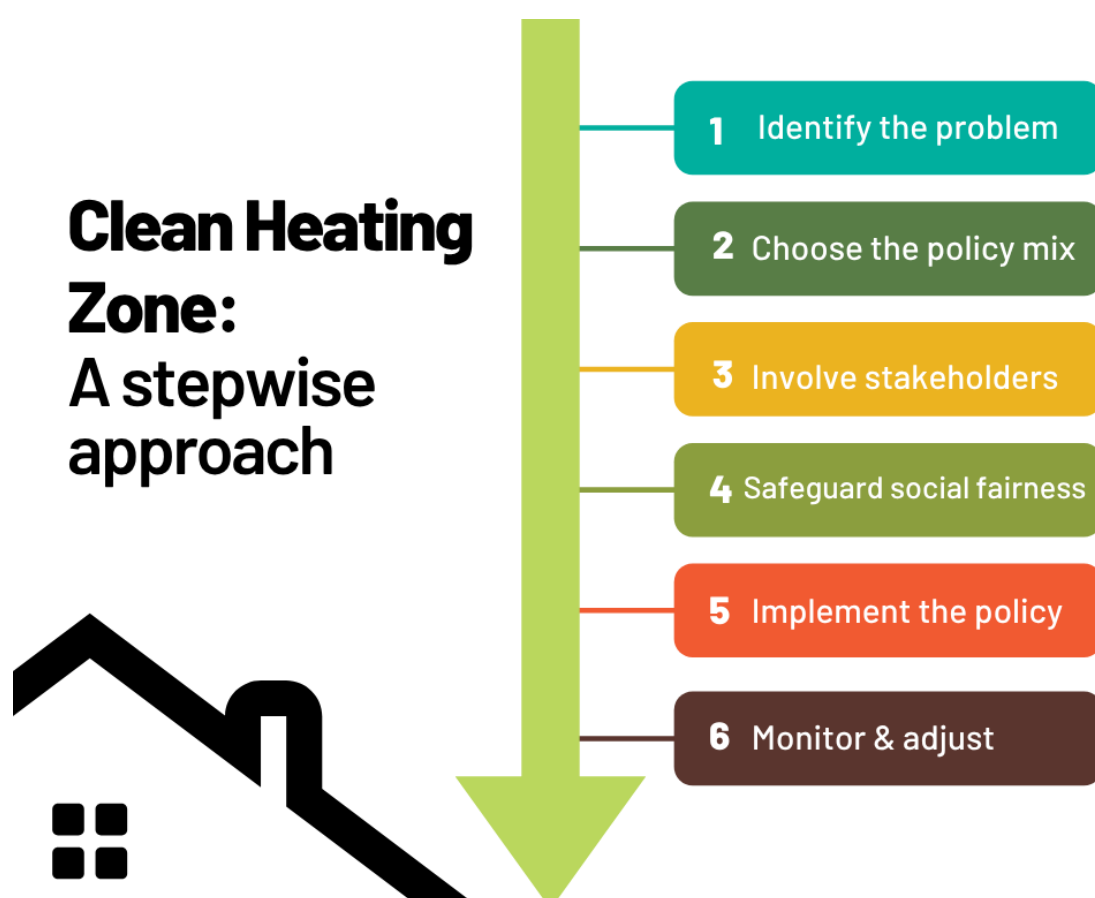


Figure 5: Designing a Clean Heating Zone: A stepwise approach

Step 1: Identify the problem

A common starting point for a CHZ in any municipality should be detecting and recognising what the real challenge is and then providing a detailed, comprehensive picture of the problem. Therefore, local authorities should first assess the sources of air pollution in the city, while also considering how it is distributed across the municipal territory and which households and neighbourhoods are most vulnerable to the harmful effects.

Potential key questions to start the identification process are depicted in Figure 6.

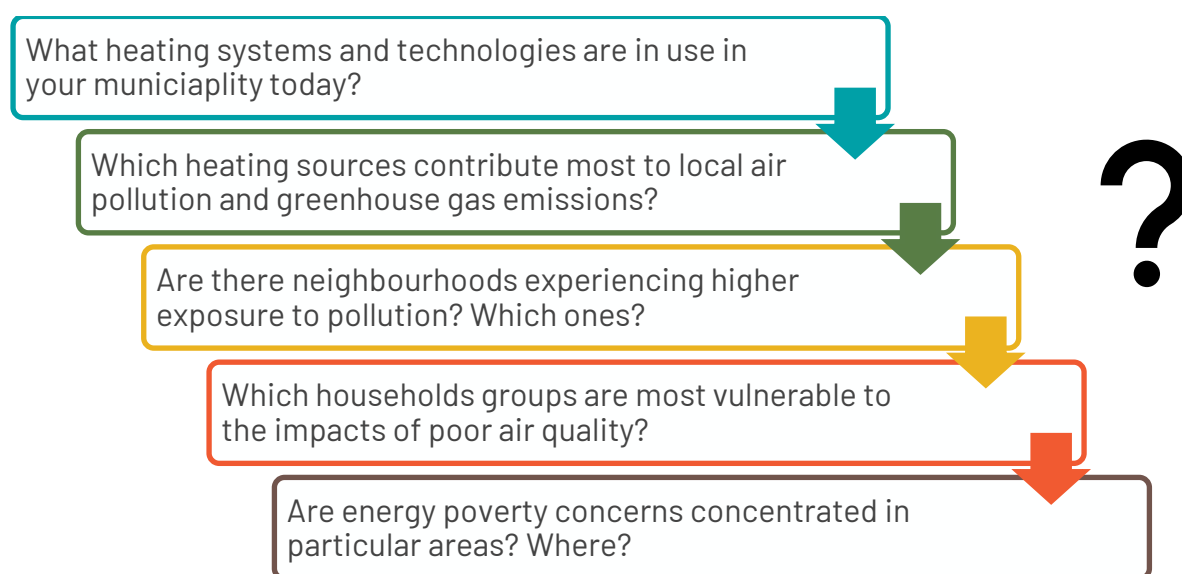


Figure 6: Questions to start the identification process

If the local authorities are able to provide a solid and meticulous initial evaluation, this will be crucial to 1. correctly and efficiently identify which intervention areas should be priorities and 2. avoid generic, one-size-fits-all solutions to very different local contexts.

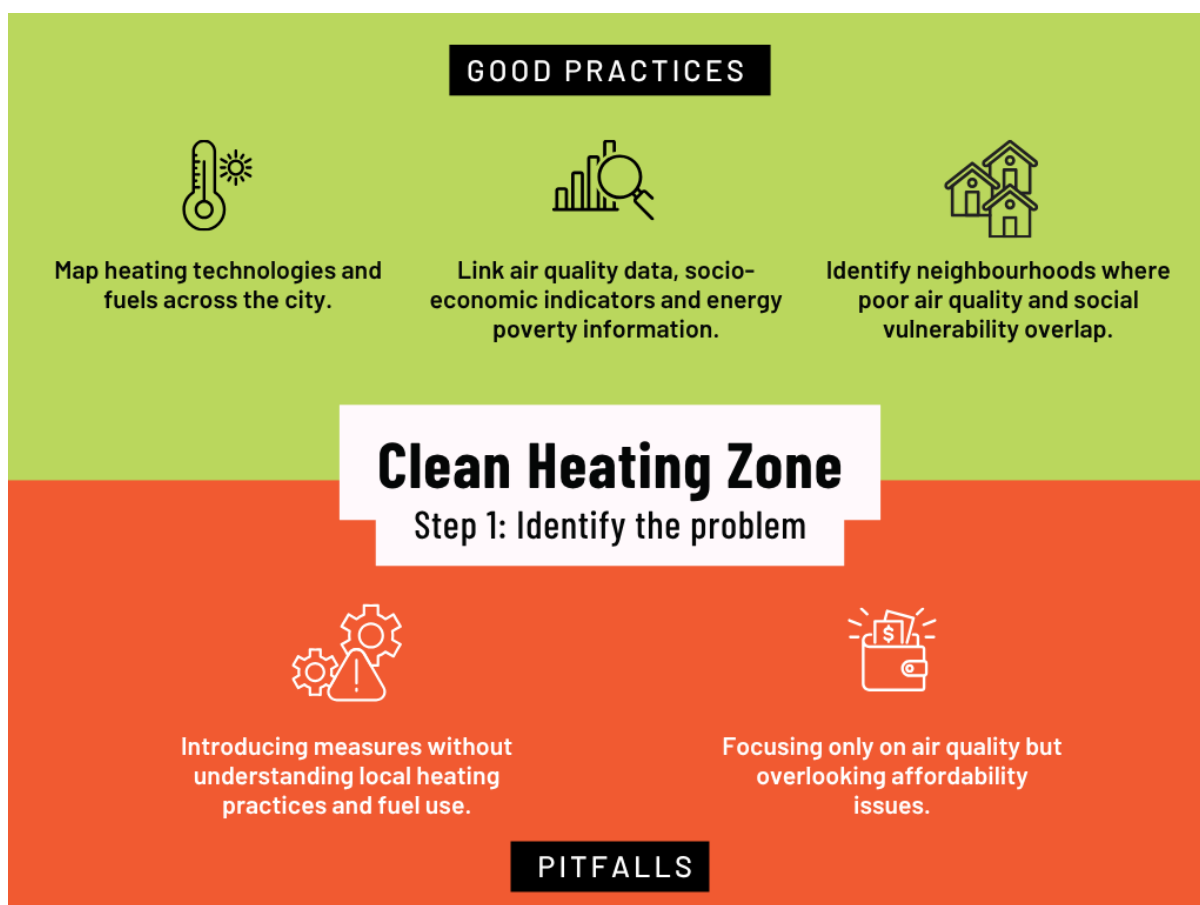


Figure 7: Common practices and pitfalls

Step 2: Choose the right policy mix

As made clear in the previous Chapter, an efficient CHZ does not rely on a single measure or policy instrument. Rather, the Sofia, Madrid, Utrecht, and Krakow case studies have demonstrated, through different avenues, suggest that combining complementary measures can be an effective approach to tackle air pollution at the local level. Table 3 indicates the main macro areas for typology examined in previous comparative analyses, highlighting their rationales and providing a few examples of their implementation across Europe.

Typology of measure	Rationale	Example
Regulatory	Regulation can provide clear expectations for citizens and gives a long-term oriented approach to air quality initiatives	▪ Bans on specific polluting fuels ▪ Phase-out processes for older devices ▪ Setting emission standards ▪ Restrictions on in-house wood burning ▪ Increase in fuel quality standards
Financial	Financial support and planning are key to reducing technical barriers to adopting air quality measures. Plus, financing improves fairness and reduces social resistance.	▪ Subsidies for heat pumps ▪ Retrofitting incentives ▪ Low-interest loans ▪ Social bonus for vulnerable households ▪ Replacement subsidies
Infrastructural	Investments in infrastructure enable citizens to meet the necessary technical conditions to switch to clean heating appliances.	▪ Expanding district heating systems ▪ Improvement of renewable networks ▪ Upgrade of electricity grids ▪ Building retrofitting planning
Communication	Effective communication and awareness-raising activities are social tools improving public understanding of the process and eventually its social acceptance.	▪ Public awareness campaigns ▪ Open days and citizens information events ▪ One-stop shops for advice ▪ Ad-hoc support for vulnerable affected communities

Table 3: Example of measures and rationale for a CHZ policy mix

Step 3: Involve the relevant stakeholders

Given their technical, social, economic and environmental implications, heating policies create effects on a wide range of stakeholders at the local level. This means that a third, crucial step in designing the right policy mix for a CHZ is identifying and engaging the relevant stakeholders with a case-by-case approach, in order to improve the social acceptability of the policy and at the same time identify potential issues in advance that might arise during the implementation phase.

Stakeholders should therefore be involved before the policy decisions occur and keep their engagement throughout the entire design and implementation process.

As good practice, it is thereby important to engage the relevant stakeholders during the policy design, and not after that. Attention should be given to explaining to them the rationale of the policy measures, their role, the expected benefits and any support available. Consultation, for instance, is a powerful tool to identify risks connected to implementation and any potential barriers.

Communication should be constant throughout the whole process, and the policymakers and practitioners should refrain from contacting only the stakeholders who are already favourable to the policy and should rather involve as many citizens as possible to get the majority on board with the measure.

A summary, non-exhaustive scheme of key stakeholders to involve is identified in Figure 8 below.

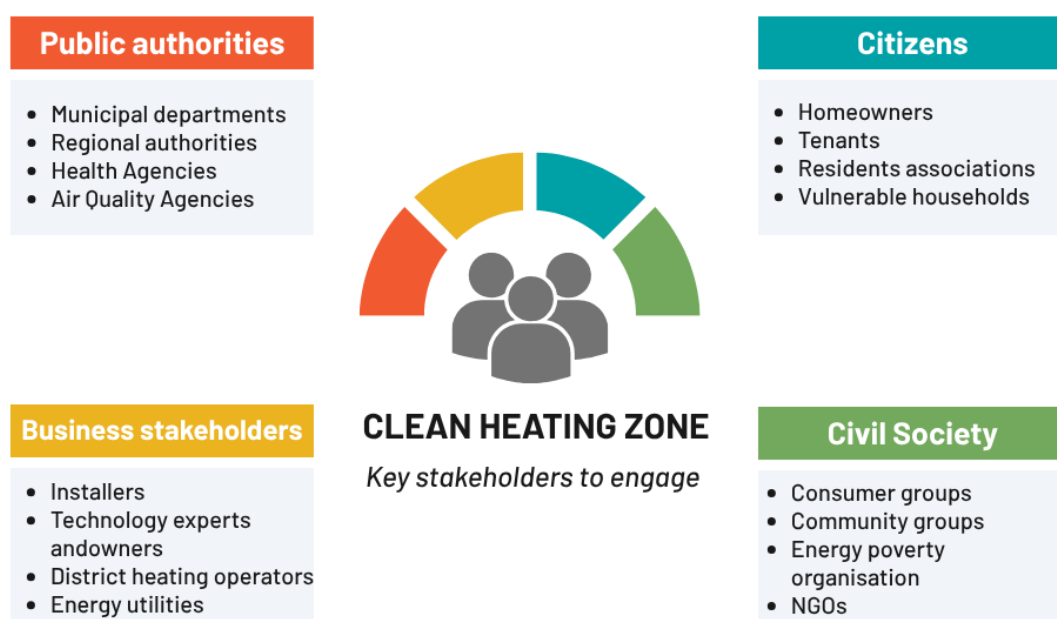


Figure 8: Key stakeholders to engage in a CHZ

Step 4: Safeguard social justice

No successful transition towards clean heating happens without being a just transition. Potential distributional impacts to keep in mind to ensure social justice are numerous. Unequal access to clean technology, mainly due to financial capabilities, can be the first harmful distributional effect. In addition, high upfront costs versus long-term benefits are equally burdensome, if not unaffordable, to vulnerable households, low-income

families, and, in general, citizens most exposed to energy poverty. The increasing energy expenditure connected to the transition, taken together with geopolitical and global circumstances, might exacerbate inequalities among citizens. Municipalities have also reported different impacts across neighbourhoods, where air quality and economic capacity can affect them differently.

Nevertheless, several mitigation measures can be put in place to phase down harmful impacts for social fairness. Municipalities could take into consideration targeted financial measures for citizens most exposed to the transition and most vulnerable to its risks. Higher subsidy rates should be considered for vulnerable households, while flexible compliance periods can also help. Additional measures for complementary energy efficiency programmes can be valuable options, while potential and temporary exemptions can be considered as a last resort when no other alternative is available.

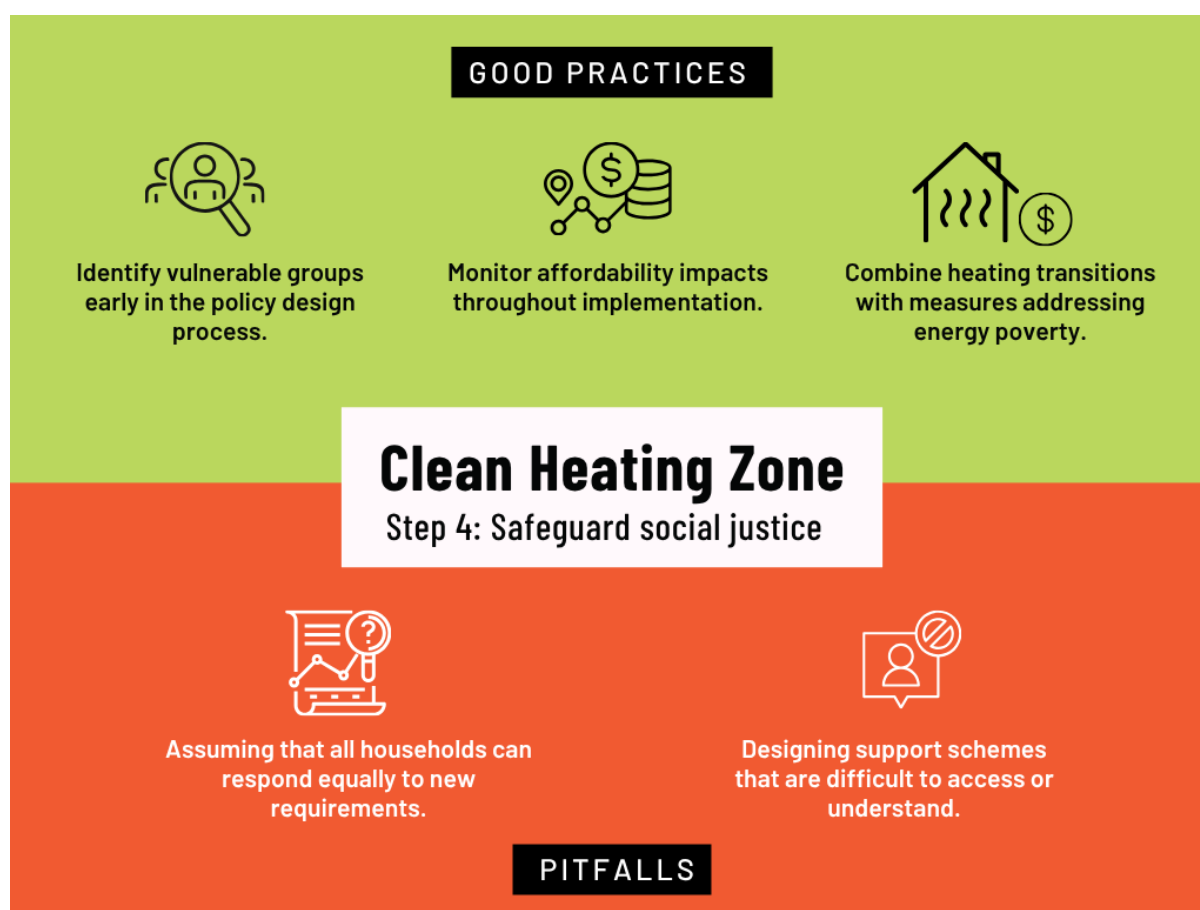


Figure 9: Common practices and pitfalls

Step 5: Implement the policy

To implement the policy framework for a CHZ, local authorities should follow a structured and predictable pathway, thereby providing households, businesses, and CSOs with confidence and sufficient preparation time.

This can be structured in four main phases, as explained in Figure 10.

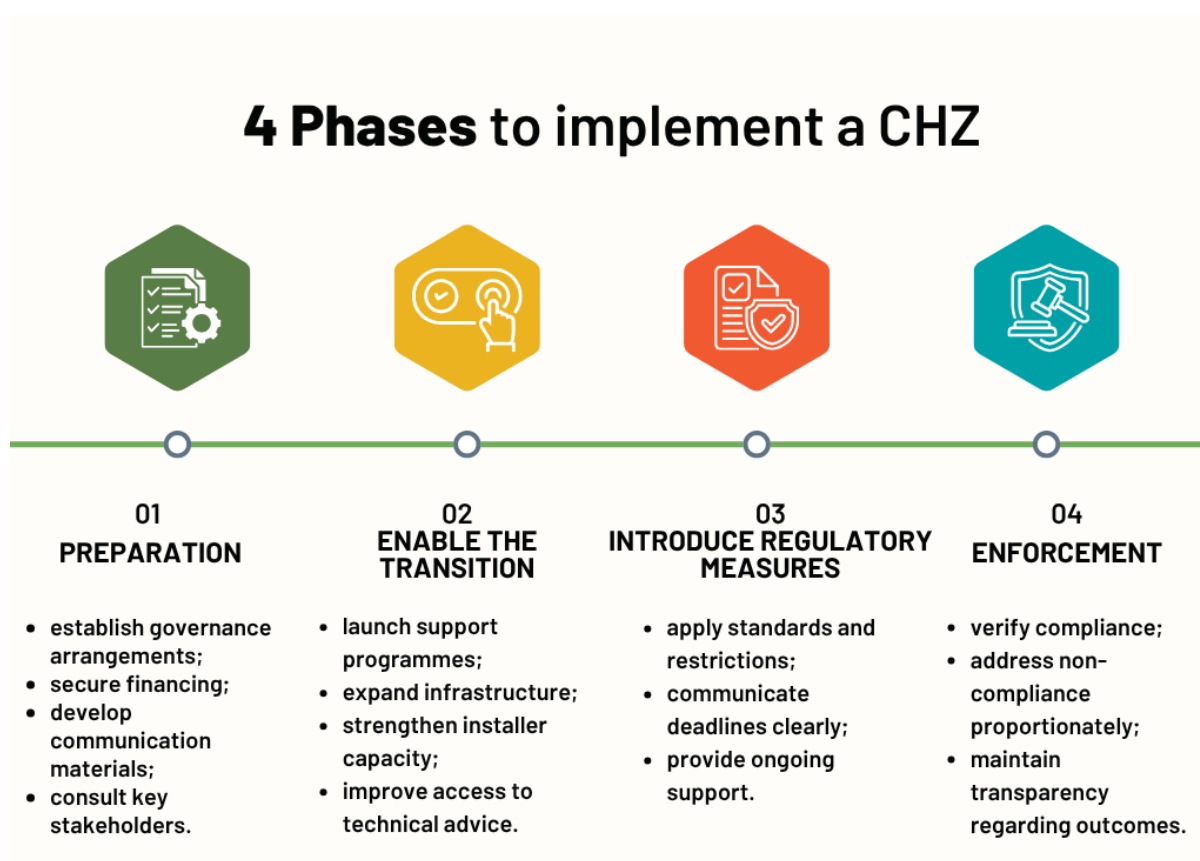


Figure 10: Four phases to implement a CHZ

Bearing this in mind, it is of utmost importance to set realistic deadlines, publish a clear implementation timeline and provide early support before the introduction of the restrictions, where available. Citizens should be aware of where and how to obtain sufficient information and support, with clear support mechanisms available.

Step 6: Monitor and adjust

A distinguishing characteristic of a CHZ is its flexibility. The measure itself is designed to be an adaptive policy framework over time, which is quite far from a single, fixed intervention. When municipalities provide adequate monitoring processes, there is a real chance for local authorities to evaluate the progress. Assess whether any collateral consequences arise and adjust measures when necessary.

Outcomes must be monitored regularly, with results of such assessments being published transparently. It is key, when affordability issues emerge, to adjust support measures promptly.

Several potential indicators can be used, according to data availability in each city. The Figure below summarises some examples.

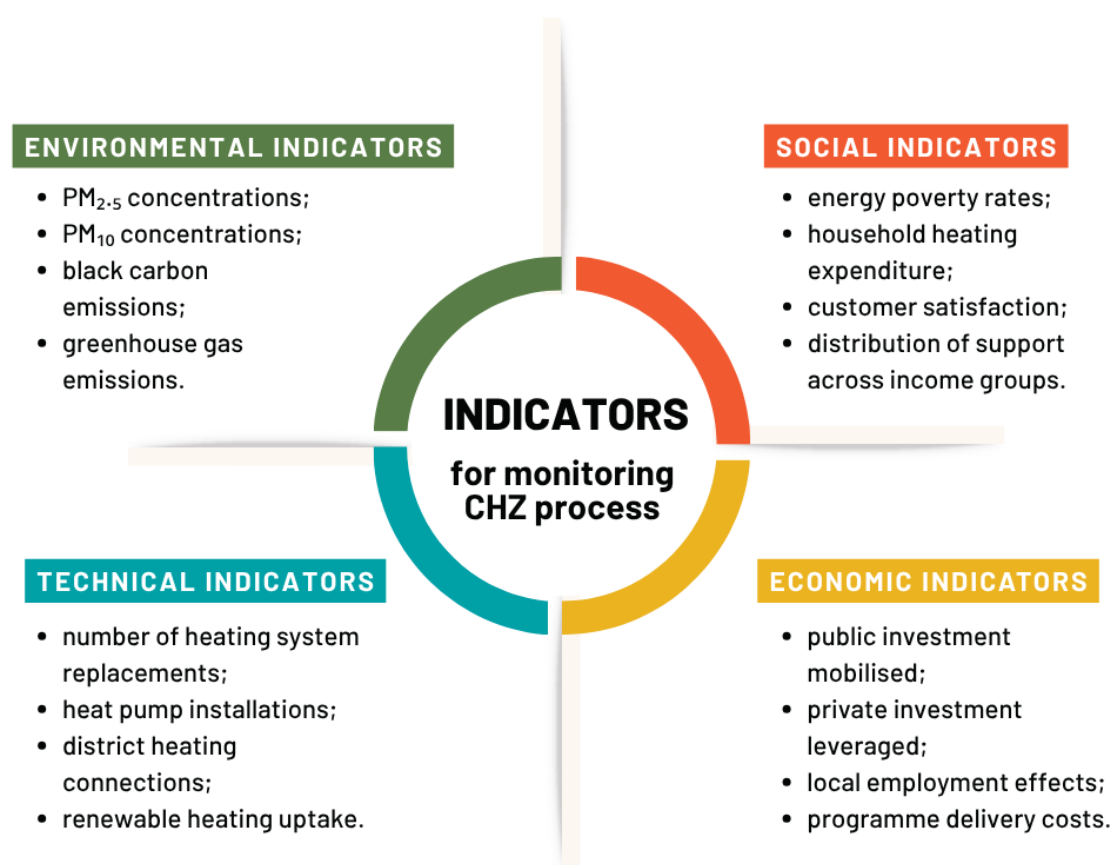


Figure 11: Set of indicators for monitoring process

4.2 Addressing the impacts

When setting up and implementing a Clean Heating Zone, several environmental, health, social and economic impacts can arise from it, both intended and unintended ones. Municipalities should be aware of such impacts and deeply understand them, thereby maximising their benefits while reducing any unintended consequences.

4.2.1 Environmental impacts

There are several environmental benefits that can be counted after the implementation of a CHZ in a city. First, Air quality would improve. When cities replace the most polluting heating systems with cleaner solutions, this can substantially reduce local air pollution and its associated emissions (Joint Research Centre, 2025). Another important benefit for the environment is the reduction in greenhouse gas emissions. Since heating in

buildings causes around 10% of global CO₂ emissions, replacing heating systems running on fossil fuels with technologies such as heat pumps can significantly bring down the volume of emissions (International Energy Agency, 2022). It is worth noting that restrictions on coal and wood-burning systems have, in certain contexts, encouraged the uptake of natural gas as a cleaner, affordable and readily available alternative. However, natural gas is also being phased out as part of the EU's transition away from fossil fuels. Driven by the EU climate-neutrality objectives and the efforts to decrease energy dependency through the REPowerEU, the implementation of the EPBD will progressively phase out fossil-fuel boilers in new buildings. Other EU policies, including RED III and ETS2, aim to accelerate the decarbonisation of the heating sector and increase the deployment of RES. Therefore, moving forward, it is important to shift from "cleaner" alternatives (natural gas) to clean alternatives (NCRES), as defined by Ricardo (2025). Installing heat pumps and providing financial support for their deployment is key to generating a lower dependence on fossil fuels for heating. In the current and near-future circumstances, reducing the reliance and thus the exposure to fossil fuel availability and price volatility becomes a strategic advantage for energy security.

There is also an important caveat which needs to be flagged about the resource requirements associated with new technologies. Clean energy systems need a substantial amount of minerals and critical raw materials. These have lately been in the spotlight of global and EU policy discussions, since the increasing need for energy technologies requires significant attention to supply chains, recycling, resource efficiency and circularity solutions (Gielen, 2021). While many policies tackling Critical Raw Materials are mainly addressed at the EU and national level, municipalities will gradually need to abide by them through local implementation, and circular solutions linked to tool production and disposal are thereby increasingly needed.

4.2.2 Health impacts

It is a well-known fact that heating-related air pollution is associated with stroke, respiratory infections, lung cancer, heart disease, among others (WHO, 2015). Implementing a successful CHZ, therefore, significantly supports emission reductions from residential heating, which in turn directly reduces population exposure to PM_{2.5} and other pollutants, and it improves both indoor and outdoor air quality others (WHO, 2015).

The WHO and IPCC highlight that cleaner energy access generates important public health benefits through improved air quality and reduced exposure to harmful pollutants, lowering cardiovascular risks and rates of respiratory conditions, therefore improving health, wellbeing and overall quality of life. While health benefits may appear gradually after the implementation, they can begin as soon as the exposure level decreases.

4.2.3 Social impacts

Several social impacts can be associated with the implementation of a CHZ. First, a shift to cleaner and more efficient energy systems improves comfort, as modern heating technologies and building retrofits improve thermal conditions, indoor environmental quality and energy performance. As mentioned before, reduced exposure to air pollution also has a social impact; it improves health outcomes and wellbeing.

There are potential social risks to be considered for effective implementation. Increased energy costs from the switch to clean technologies, paired with pre-existing energy price volatility conditions, can unevenly burden the most vulnerable households. This is connected to the unequal distribution of benefits and costs. In fact, the transition may cause upfront costs which can in turn disproportionately affect low-income citizens, if strong economic support is not foreseen.

4.2.4 Economic impacts

A CHZ implementation brings both benefits to foresee and costs to plan when designing it. Moreover, it is important to discern the effects on households, on the market and on the municipality itself.

Households will likely be in an advantageous position due to lower operating costs for clean technologies and greater energy efficiency. Heat pumps, in fact, are more energy efficient than gas boilers, thus reducing households' energy bills and bringing more favourable economic conditions. However, there are costs which households might likely bear and are thus important to consider. The installation of clean heating solutions usually involves upfront costs, which may be higher, depending on the investment. Heat system replacement or building retrofits and renovations may require such high upfront costs, which not every household would be able to afford. Policy networks are then required to overcome these economic barriers.

There are also opportunities and challenges for **businesses** to factor in. On the one hand, the implementation of a CHZ brings important market opportunities, such as an increased demand for local installations and, with a wider uptake of the policy, also a sensible growth in clean heating technologies associated with manufacturing and subsequent employment opportunities. On the other hand, the deployment of new clean technology might bring some important challenges to be aware of in advance.

A sudden spike in clean technology requests can create temporary installer shortages and readjustments of supply chains that could face short-term bottlenecks. A rapid scale-up of clean technology might also be hindered by workforce shortages, which would take sufficient time for reskilling and an adjusted job market.

Lastly, the economic impacts for the **municipalities** should also be considered. Improved public health and reduced environmental damage, with associated reduction costs, can offset an important share of the transition costs for a CHZ. An important local

benefit to count on is the progress towards climate targets as well. Overall, the switch to clean technologies and its related benefits for the firms and households will bring considerable local development for the municipality implementing a CHZ. There are costs that the municipality must necessarily consider during the early planning of a CHZ design. The design of local incentive schemes and the investment needed in new infrastructure will require upfront costs from the administration. Moreover, Administrative and enforcement costs for local clean heating programmes have been consistently recognised across EU municipal programmes and energy transition strategies. Therefore, careful planning and cost analysis are needed from the early stages of a CHZ design.

5. What works in practice

5.1 Lessons from four cities

5.1.1 Context

As mentioned above, IEEP has produced four case studies examining local measures implemented at the city level to improve air quality through sustainable heating. The case studies focus on policies adopted in Sofia, Kraków, Utrecht and Madrid, which were selected for their distinctive features: the first LEZ for heating in Europe (**Sofia**); a total ban on solid fuels for heating that was promoted by a grassroots movement and, through strong cooperation with local authorities, contributed to changes in Polish law (**Kraków**); the first complete ban on wood-burning in the Netherlands (**Utrecht**); and an ambitious sustainability strategy addressing both climate change and air pollution (**Madrid**).⁹

These four case studies also reflect geographical diversity across Europe. Sofia is in Eastern Europe, Kraków in Central Europe, Utrecht in North-Western Europe, and Madrid in South-Western Europe. As a result, the cities experience different climatic conditions, heating needs in winter, and energy sources for residential heating.

The four cities are generally large, densely populated and relatively affluent within their national contexts, with two being the national capitals. However, significant economic disparities exist between them. Another important difference consists of the degree of authority granted to local governments by national and regional legislative frameworks, allowing for the examination of different governance models.

⁹ The four case studies are available here: Tang, A. M., & Antonelli, C. (2026). *Low Emission Zone in the Heating Sector: Sofia case study*. Institute for European Environmental Policy; Tang, A. M., & Chiocchetti, I. (2026). *Anti-Smog resolution banning solid fuels for heating: Kraków case study*; Holle, G., & Chiocchetti, I. (2026). *Banning indoor wood burning: Utrecht case study*. Institute for European Environmental Policy; Chiocchetti, I., Holle, G., & Ruiz González, L. (2026). *Ban on coal-fired boilers: Madrid case study*. Institute for European Environmental Policy.

The case studies placed particular emphasis on socioeconomic and procedural dimensions. They explored whether and to what extent local stakeholders were involved in the design and implementation of the measures, what actions policymakers took to mitigate potential social impacts arising from the transition, and how the measures were perceived by the public, including the level of social acceptance. For measures that have been in place for several years, it was also possible to assess their effectiveness and their impact on air quality, public health, and vulnerable households.

Table 4 summarises the main highlights of the four case studies analysed.

Bulgaria	Sofia Low-Emission-Zone in the heating sector (2025)	Kraków Ban on solid fuels for heating (2019)	Poland
	The LEZ for heating in Sofia entails a progressive ban on the use of coal, coal briquettes and wood for domestic heating. The measure has been in force since 2025 in certain areas of the city, and, from 2029, will apply to the entire municipal area. One of the main sources of air pollution is residential heating using solid-fuel appliances, which are primarily used by low-income groups experiencing energy poverty and living in pollution hotspots. Solid fuels supply approximately 32,000 households and contribute to 80% of winter PM exceedances. Air pollution has been reported to cost €2.6 billion per year in health damages and up to 13.4% GDP loss from productivity/absenteeism.	The Anti-Smog Resolution, a regional regulation, prohibits the use of solid fuels (coal, wood, and other biomass) for both heating and non-heating purposes in the city of Kraków. The measure resulted from a successful bottom-up initiative driven by citizen pressure and supported by the scientific community and the media, who called on the authorities to address the city's severe air pollution problem. Before the ban, Kraków experienced high concentrations of NO ₂ and PM _{2.5} , including black carbon, that substantially exceeded WHO guideline levels. This occurred particularly in the winter season and had serious public health implications, especially for children, negatively affecting their health and daily lives.	
The Netherlands	Utrecht Ban on wood-burning indoor (2030)	Madrid Ban on coal-fired boilers (2022)	Spain
	Utrecht is the first Dutch city to introduce a total ban on indoor wood burning in all wood-burning appliances, covering both residential and commercial buildings. This pioneering measure forms part of the city's efforts to comply with WHO air quality limits and to address pollution sources within its direct sphere of influence, considering that around 80% of local air pollution originates outside the municipality. While outdoor wood-burning is the leading source of air pollution-related health issues and is already prohibited, residential wood-burning accounts for 25% of total PM _{2.5} emissions in Utrecht, slightly above the national average of 23%.	Madrid's Air Quality and Climate Change Ordinance includes a ban on coal-fired boilers and aims to phase out oil-based boilers, while requiring a "nearly zero" electricity consumption for new buildings. The regulation is part of Madrid 360, a comprehensive sustainability strategy that combines ambitious climate and air quality targets. The city's pollution, namely NO ₂ , NO _x and PM _{2.5} , mainly derives from road traffic (including commuting flows from nearby towns) and residential heating in winter. In summer, however, air quality is deteriorated by extreme wildfires. Although only around 500 coal-fired boilers remained in operation in 2017, this ban is considered a key component of a broader strategy.	

Table 4: Policy approaches adopted in each city

5.1.2 Addressing social concerns during design and implementation

Stakeholder consultation and other participatory approaches play a crucial role in this context. While these practices allow engagement and raise awareness of forthcoming laws, they also enable citizens to express their concerns, provide feedback, and feel involved in the decision-making process. Policymakers should also work with technical experts and the scientific community, who are essential to identify the most effective evidence-based policy objectives.

Sofia – Low Emission Zone for heating (2025)
Sofia's municipality engaged with several actors for the design of the LEZ: air quality experts contributed to its shape, public health authorities and technical experts were occasionally consulted, while civil society participated to some extent with rather some proactive outreach. NGOs played a prominent role in informing citizens about the upcoming law, while disseminating their own studies, but had limited space in the design process. A public consultation was also launched, but only a few responses were collected. Nevertheless, the LEZ did not create major backlash, suggesting overall citizen support for air quality measures. Both EU and national funds were mobilised to support the transition. They started to be distributed before the LEZ started, with applications ending in 2029.
Kraków – Ban on solid fuels for heating (2019)
Kraków's case is almost unique because of the great community mobilisation which turned into a genuine social movement, the Kraków Alarm Smog (KAS). KAS played a key role in shaping the ban and building a positive narrative around the transition, contributing to citizens' social acceptance. The municipality organised a public hearing, which received almost unanimous feedback for the introduction of a complete ban on fossil fuel heating. Given the high number of devices, social impacts were a priority, which were addressed with dedicated financial schemes from different programmes and sources, allocated <i>before</i> the replacement of the boilers. This was key to avoiding any unintended socioeconomic impacts and ensuring public support.
Utrecht – Ban on wood-burning indoor (2030)
The municipality took early actions to raise awareness among the population, with communication efforts beginning nearly 10 years before 2030. Online surveys, street conversations with residents, and targeted meetings with relevant stakeholders took place over the years. Although most wood-burning furnaces are used for recreational purposes, generally by wealthy citizens, the municipality has considered exceptions for the few households that use wood-burning as the first source of heating and cooking, limiting socio-economic impacts. Financial schemes were also available for the replacement from 2021 to 2025; however, these were provided after the works were completed. Continuous informative campaigns are recommended for greater social acceptance up until its entry into force.
Madrid – Ban on coal-fired boilers (2022)
According to the standard procedure, the municipality held an online public consultation open to organisations and individuals and held targeted meetings with specific stakeholders on urban sustainability issues. Public sessions were organised to inform citizens and make them aware of the implications and the funds available for replacement. In addition, contact was

kept throughout implementation for the following two years. The ban has attracted relatively limited public controversy but was initially poorly received by the citizens directly affected. However, later, some households expressed satisfaction with improved comfort given by the new devices. The support scheme, distributed in the form of reimbursement after the installations, contributed to limiting the socioeconomic impacts.

Table 5: Successful approaches to social aspects from the four case studies

5.1.3 Results and success factors

The four case studies highlight the potential for measures tackling heating-related pollution to have a significant positive impact on overall urban air quality. While some cities have already demonstrated measurable improvements, the impacts of more recently adopted measures have yet to be fully assessed. Nevertheless, the findings reinforce the importance of decarbonising buildings, transitioning to clean heating systems and improving energy efficiency in making cities more sustainable and liveable for their residents.

In **Kraków**, coal-based heating was the primary source of air pollution for decades. Multiple studies have confirmed substantial reductions in PM_{2.5} and PM₁₀ and other pollutants following the implementation of the Anti-Smog resolution. In addition, the number of days exceeding the daily PM₁₀ limit decreased from 132 in 2012 to 31 in 2023. Improvements in air quality have also generated significant public health benefits, including lower rates of childhood asthma and pre-term births (Pac et al, 2024), as well as premature mortality (Maciejewska & Adamkiewicz, 2026) associated with poor air quality. A key enabling factor for Kraków's success was the strong cooperation between civil society organisations, local authorities and the scientific community. In particular, the local administration was responsive to citizens' concerns and to the alarming evidence presented by researchers and medical professionals regarding the high incidence of severe respiratory diseases, especially among children.

Textbox 2:

Highlights from the Kraków case study

- **23-39%:** Reduction estimates in the annual average of PM₁₀.
- **From 132 (2012) to 31 (2023),** annual number of days exceeding PM₁₀ limit values.
- **Close cooperation** among stakeholders was key.

In other cases, it is more difficult to isolate the impacts of specific measures, especially when they form part of broader strategies encompassing multiple actions. In **Madrid**, the ban on coal-fired boilers was introduced alongside a (renewed) LEZ for cars, with road transport emissions being historically a major source of air pollution. As a result, it is

challenging to attribute reductions in pollutant concentrations specifically to the boiler ban. It is also important to note that the measure affected a relatively small number of installations: approximately 500 coal-fired boilers were recorded in 2017. Consequently, the ban is likely to play a comparatively minor role in reducing overall pollution levels, especially if compared with pollution from road traffic. Nevertheless, the objective of eliminating all coal-fired heating systems was successfully achieved by 2022.

For some of the case studies (in particular for Sofia and Utrecht), it is still too early to assess the full impact of the measures. However, it is possible to identify some expected outcomes and the conditions that are likely to support their achievement. In **Sofia**, given the recent introduction of the LEZ, ongoing studies are based on projected scenarios rather than observed results (Dimitrova, 2025) (Sofia Municipality, 2024) (Sofia Municipality, 2021). Nonetheless, the measure is expected to significantly improve air pollution, and in turn enhance public health and wellbeing. Poor air quality has caused serious health problems, which have led to increased absenteeism at work and lower productivity, which underscores the close correlation between public health and economic prosperity. Similar cautious assessments are required for **Utrecht**, where the policy has not yet entered into force. Some positive effects on air quality are anticipated, including reductions in respiratory diseases among children, lower mortality rates among adults, and preventing the worsening of pre-existing health conditions.

Textbox 3. Focus: financing the transition for clean air in the EU

It is now clear that funding is key to the successful implementation of heating measures, contributing to climate and air quality objectives as well as their social acceptability. At the same time, promoting clean air has the potential to increase **economic growth in the EU by €50 billion to €60 billion annually Invalid source specified**. However, air pollution is estimated to cause annual losses of €600 billion, equivalent to 4% of the EU annual GDP, through productivity losses, reduced workplace performance, and ecosystem degradation.

Across the case studies analysed, support schemes for heating device replacement proved essential for mitigating affordability challenges and the socio-economic impacts on residents, particularly vulnerable households. A particularly successful approach was the combination of EU, national and local financing mechanisms.

Kraków was able to seize funding opportunities effectively, while making strategic use of local resources and prioritising investment to address the urgent problem of air pollution. The city successfully secured support through national funding programmes and benefited significantly from EU funding. In particular, the **EU Cohesion Policy funds** contributed to the Low Emission Reduction Programme (PONE), which subsidised replacement costs. The **LIFE Programme** of the Małopolskie Region financed the hiring of eco-advisers, while the Clean Air Programme supported boiler replacement and thermos-modernisation, through resources from the **Next Generation EU facility** and the **Modernisation Fund**, as part of the EU Emission Trading System. Similarly, Sofia utilised the LIFE Programme for the replacement of devices and the Operational Programme Environment (OPE) 2021-2027, which is co-financed by the EU **Cohesion Fund** and the Bulgarian national budget.

For both countries, EU funding has been crucial. The **current Multiannual Financial Framework (MFF) allocates approximately €185 billion (9.7%) to clean air objectives**, with most expenditure delivered through shared management instruments, such as Cohesion funds, European Regional Development Funds (ERDF), and Interreg. Additional sources of [EU support for clean air](#) include Horizon Europe, the Connecting Europe Facility, InvestEU, the Just Transition Mechanism and the Common Agricultural Policy. Despite these significant investments and improvements, the [EEA](#) has identified a €40.7 billion financial gap to achieve the EU's Zero Pollution targets by 2030, highlighting the importance of the new funding framework.

Within the proposed **MFF 2028-2034**, the [Health and Environment Alliance](#) has identified greater uncertainty regarding future clean air funding allocation. While the **National-Regional Partnership Plans (NRPP)** regulation includes air quality objectives eligible for funding, it does not provide a dedicated budget and explicit pathways for ending fossil fuel subsidies. In addition, although the **European Competitiveness Fund**, a central pillar of the next MFF worth €400 billion, includes pollution prevention, control, and remediation among its objectives, its primary focus remains decarbonisation, which could reduce resources to tackle other sources of pollution.

From 2028, **ETS2 revenues** will play a role in tackling air pollution, as they are expected to support investments in clean heating and transport solutions, while the Social Climate Fund will help mitigate the impacts of the expanded Emission Trading System covering emissions from buildings and road transport.

As the EU moves towards its climate, energy and zero pollution objectives, maintaining and strengthening dedicated funding streams will be essential to ensure that local authorities can deliver a fair and effective transition to cleaner heating.

5.1.4 Transferability lessons

Across the four case studies, although many of the challenges and barriers reflect those identified in Chapter 3, it is more difficult to identify common solutions that could be applied universally. Each city has its own characteristics and needs; thus, tailored strategies for transitioning from and phasing away specific systems are needed. However, several transferable lessons emerge from the case studies. While these lessons cannot be simply replicated, they may prove effective in other contexts if carefully adapted to local circumstances.

A strong social dimension is essential for a successful energy transition. Ensuring that no one is left behind requires targeted outreach, tailored support measures, and meaningful opportunities for dialogue and participation. Flexibility in policy design, including exemptions or transitional arrangements in certain situations, can also help address specific circumstances and avoid sanctions, which would raise discontent and resistance.

The case studies also demonstrate the value of **gradual implementation**. When the objective is particularly ambitious, as it affects many households, long-term planning is fundamental. It gives people and businesses sufficient time to adapt, while allowing municipalities to monitor progress and refine measures where necessary.

Finally, **adequate funding** is crucial to facilitate implementation. Where sufficient funding is available, comprehensive support measures should be introduced before implementation. In contrast, with limited budgets, municipalities may achieve better results by focusing initially on smaller, targeted actions, tackling the most pressing priorities and gradually scaling up efforts over time.

The next chapter establishes how certain intrinsic characteristics of the territory or socio-cultural factors require different approaches and pathways, showing the limits of a one-size-fits-all approach.

5.2 Differentiated pathways across Europe

5.2.1 Urban vs. rural

Although this handbook and previous works focus primarily on urban pollution and cities' actions, it is important to highlight the realities of rural areas.

Urban and rural areas differ in population density, available infrastructure and resources, and heating behaviours, and thus require a targeted approach to decarbonising residential buildings. Rural areas are less densely populated, the territory is larger, and houses are more spacious than in urban areas.

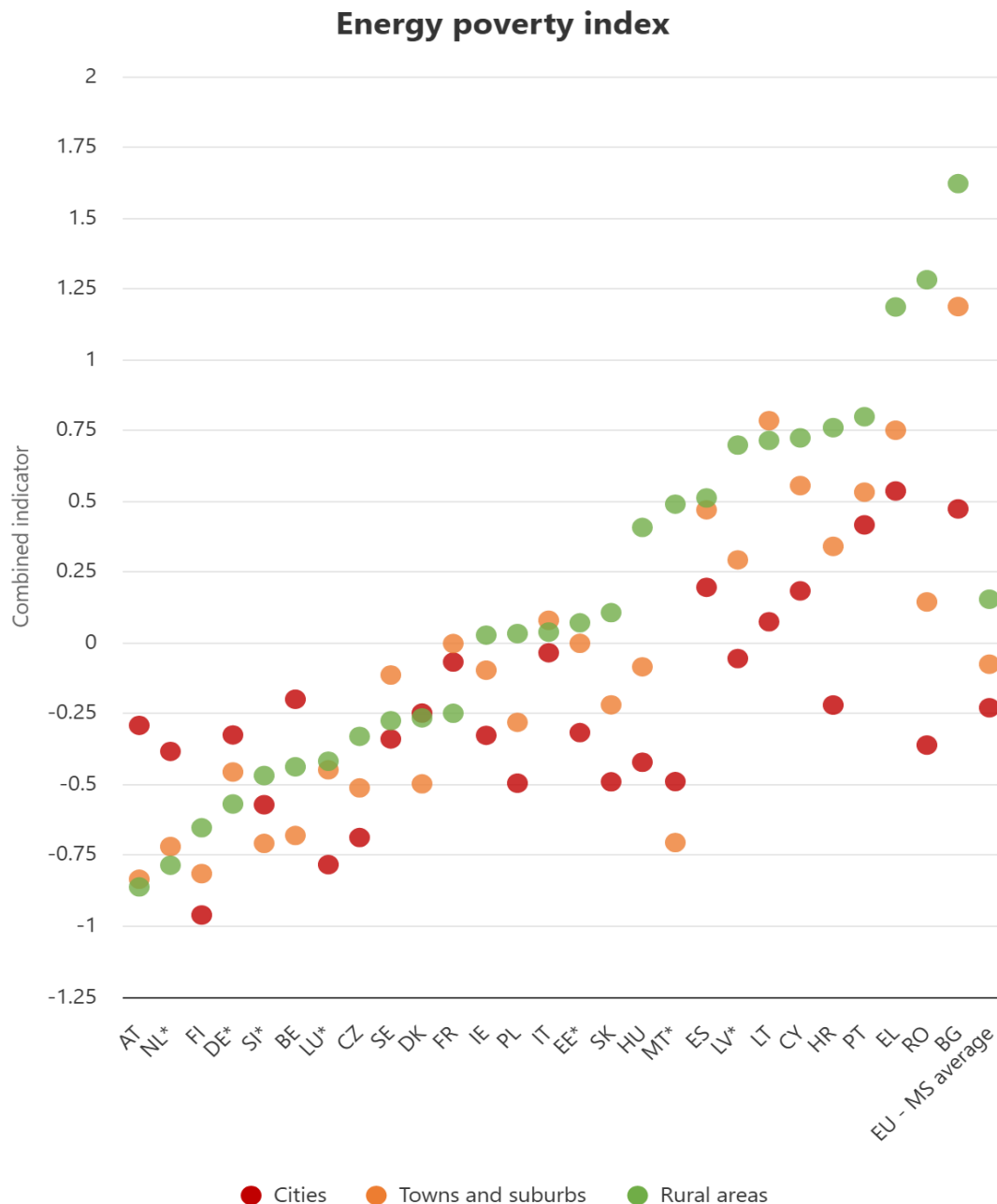
While, on the one hand, rural areas generally experience lower levels of traffic- and industry-related air pollution than urban areas, on the other hand, air quality in such

contexts can be particularly affected by residential heating, especially due to solid fuel combustion such as wood and coal, which can produce substantial PM pollution, particularly during winter months. Rural areas can present higher levels of ground-level ozone (O₃) than in cities, which is equally harmful for the respiratory system and is also regulated by the AAQ directive (EEA, 2026b). Buildings and houses in rural areas, particularly in Central-Eastern Europe, are commonly heated with wood, coal and other fossil fuels. These areas also often lack access to district heating and may face greater challenges in connecting to the electricity grid due to limited grid capacity, for example, when seeking to join energy communities (Sebi & Vernay, 2020).

As a result, inhabitants of rural areas generally have fewer heating options available and tend to rely on traditional and cheaper options, such as wood and lignite (Campos, Csontos, Harmat, Csüllög, & Munkácsy, 2020) which are also more polluting. This has broader implications for surrounding areas, particularly when wind patterns and the landscape features cause smoke and pollutants to drift towards urban centres. In the case of Kraków, for example, a significant share of air pollution originates from the small villages around the city, where restrictions on coal-fired devices are less stringent. Because Kraków lies in a valley, pollutants tend to accumulate there and, under unfavourable atmospheric conditions, such as limited rainfall and weak wind, are particularly difficult to disperse.

Rural areas are also more affected by energy poverty than cities, towns and suburbs, due to lower income levels, combined with buildings that are typically older, bigger and less energy efficient (Perpiña Castillo, et al., 2024). As shown in the graph below, this is particularly true for Bulgaria, Romania and Greece.¹⁰

¹⁰ See Annex 1 for data from all EU Member States



(*) Missing data in 2 or more indicators

Figure 12: Energy poverty index across EU Member States. Source: JRC (2024), European rural areas face higher levels of energy poverty.

However, rural areas are reported to be ahead of cities in terms of energy-efficient renovations, with 29% of residents having undertaken energy efficiency improvements in their homes, against 25% and 23% of households in towns and cities (Perpiña Castillo, et al., 2024). Moreover, rural areas have significant potential to drive the transition to NCRES through solar photovoltaics (PV), onshore wind and hydropower. This is due to the greater availability of land and the high rate of home ownership, which facilitates renovation works compared with rented properties (Perpiña Castillo, et al., 2024). Rural areas also offer considerable, yet underexploited, potential for energy communities,

thanks to the abundant natural resources and large-scale infrastructures (Shi, Liang, & Pezzuolo, 2024). Regarding infrastructural costs, both cities and rural areas face distinct challenges. While rural areas require longer cable networks to connect buildings and renewable energy installations to the grid, cities bear higher excavation and installation costs (Reiser, Klerks, & Hermelink, 2022), due to their dense built environment.

In conclusion, both urban and rural areas face challenges and opportunities in decarbonising heating systems and improving air quality. While cities often have more developed infrastructure and access to shared and cost-efficient solutions such as district heating, rural areas have significant potential for the deployment of non-combustion renewable energy technologies. The electrification of heating through the combined use of PV systems and heat pumps could substantially reduce emissions in rural areas, especially in colder climates. Studies have shown that this combination can immediately halve GHG emissions from residential buildings, with reductions reaching as much as 90% as the targets for renewables continue to grow (Padovani, Sommerfeldt, Longobardi, & Pearce, 2021).

To realise this potential, local and national authorities should make strategic investments in infrastructure and implement policies that target heating system replacement, building retrofits and energy efficiency improvements, differentiating between urban and rural areas. Awareness-raising initiatives and dedicated financial incentives for available alternatives can also help replace traditional and more polluting heating devices.

5.2.2 Climate and geographic variations

Designing context-specific, effective heating policies requires that the diverse climatic and geographic landscapes of the European territory are accounted for. These factors shape regional energy needs and dictate viable pathways for adopting clean heating solutions. Europe is generally divided into four climatic types (Mediterranean, Oceanic, Continental, and Central), with significant local topographically related variation (Berensten, Windley, & Poulsen, 2026).

Climate determines the quantity, intensity, and variability of heating and cooling energy needs across Europe. In cold climates, such as those in Finland or Denmark, heating demand is high and steady for over half the year, requiring significant energy inputs to maintain habitable temperatures. Conversely, in warm climates like Greece or Italy, heating demand is lower and less intense, while cooling demand is more predictable and stable; the gap between minimum and average cooling demand is narrower than in cooler regions, where demand is more volatile due to sporadic heatwaves driving sharp peaks (Jakubcionis & Carlsson, 2017). Beyond these baseline climatic conditions, it is crucial to account for the accelerating impacts of climate change, ranging from increased extreme weather events to slow, permanent shifts in regional climates. These trends emphasise the need for a policy approach focused on resilient heating systems

that ensure independent, secure, and reliable supply during extreme cold, while also maintaining infrastructure resistant to extreme heat, droughts, and floods (Staffell, Pfenninger, & Johnson, 2023). Furthermore, policies must adapt to the newly emerging climatic realities across European regions, acknowledging that rising average temperatures are fundamentally altering long-term energy demand patterns (D'Agostino, Congedo, Albanese, Rubino, & Baglivo, 2024).

Natural resource wealth or proximity to resource-rich areas is another factor closely linked to geographic location that is often overlooked in energy transition policy. While frequently treated as an exogenous structural variable, this factor profoundly shapes national energy traditions and dependencies (Ahmadov & van der Borg, 2019). These established patterns influence national energy mixes, public opinion on specific energy sources, price dynamics, and the social acceptance of environmental policy decisions (Strunz, Gawel, & Lehmann, 2016; Marques, Fuinhas, & Pires Manso, 2010). For instance, Poland's long-standing reliance on coal, which is rooted in the country's abundant domestic reserves, has resulted in extensive infrastructure, deep economic ties of the mining sector to the resource, and strong cultural attachments in mining regions (Zywiolek, et al., 2025). In addition, Ahmadov & van der Borg (2019) highlight how the Netherlands, which discovered significant natural gas fields in the 1960s, was still lagging behind Belgium in the energy transition by 2019, despite similar socioeconomic characteristics. Even though the Netherlands has since then overtaken Belgium by a wide margin, this disparity was attributed to the weight of the natural gas sector as a source of revenue for the Dutch national budget and the lobbying power of fossil fuel corporations, and the current trend reflects the Netherlands' ability to acknowledge and address its specific situation (Ahmadov & van der Borg, 2019; EEA, 2026c).

These examples illustrate the diverse European landscapes and underscore the critical role of local or **nearby resource availability** in shaping appropriate policy approaches. Rybak et al. (2026) analyse EU progress toward clean energy, demonstrating that energy transformations across Europe are spatial and structural in nature. The authors argue that policy must be tailored to each country's specific profile, where natural resource availability is a defining characteristic. For nations historically reliant on fossil fuels, increased financial support, removal of systemic barriers, and careful management of the restructuring of former mining regions are recommended, while countries lacking these resources should focus more on technological advancements in renewable energy storage and grids (Rybak, Wilk, & Joostberens, 2026).

Beyond the climatic and geographic factors that determine heating needs and energy baselines, **topographic and meteorological conditions** significantly influence air pollution exposure and associated health impacts across Europe. When energy policies take into consideration these aspects, priority and emergency status are more accurately assigned to the areas where they are most needed (Keyte, Reynolds, Sims, Cooke, & Vichev, 2024). Furthermore, setting specific health improvement objectives in

response to localised air quality degradation allows for their effectiveness in reducing both pollution levels and targeted health impacts (Bouscasse, et al., 2022). These decisions must be data-informed based on spatial environmental and air quality conditions, as well as population exposure, as emphasised in Sustainable Development Goal 11 (United Nations, n.d.).

Research indicates a general gradient where northern and central European cities face fewer air quality challenges, with issues intensifying toward the southeast and, to a lesser extent, the Mediterranean region (Krzyżewska, 2025). Southern and Western cities contend with significant particulate matter (PM) and ozone challenges, often exacerbated by Saharan dust events and stagnant summer atmospheric conditions characterised by high temperatures and intense solar radiation (Krzyżewska, 2025). Topography plays a critical role in pollutant accumulation. For instance, Madrid is partially enclosed by mountain ranges that restrict air circulation, causing pollutants to stagnate over the city (Harris, 2025). As mentioned above, Kraków's location in the Vistula River valley, surrounded by hills, limits ventilation and traps emissions. Climatic factors attributed to climate change further exacerbate air pollution.

Most notably, increased heat intensity and frequency contribute to air stagnation, keeping harmful particles closer to the ground, while higher temperatures accelerate chemical reactions in the atmosphere, multiplying secondary pollutant formation (Burston, 2026). In terms of exposure, it is important to consider the population density of urban areas. For example, while Paris may exhibit lower frequencies of regulatory exceedances compared to other cities, its high population density results in a significantly greater population exposure burden (Krzyżewska, 2025).

Finally, climatic and geographic factors determine an area's potential for clean energy production, thereby shaping the most suitable transition pathway based on physical characteristics. A 2023 report by Braundgardt et al. for the European Commission's Directorate-General for Energy examined the suitability of alternative clean heating and cooling technologies across Europe, highlighting how geographic and climate differences drive these choices. Key determinants include solar irradiation, which favours PV systems and heat pumps as replacements for fossil-fuel-based heating. Similarly, regions with high wind volumes and strength (both onshore and offshore) are well-suited for wind-based electricity generation. Hydropower potential, dependent on steep terrain, abundant water resources, and significant elevation drops, offers favourable prospects for electrifying heat supply, as is the case in Sweden and Norway (Braundgardt, et al., 2023). Additionally, geothermal potential, which is influenced by factors such as altitude, heat flow, sediment thickness, and seismic activity, is ideal for replacing fossil fuels with ground-source thermal energy connected to district heating networks, as illustrated by the case of Aarhus, Denmark (Lorenzen, 2025; Richter, 2020). Beyond infrastructure suitability, Wang et al. (2018) demonstrate that regional warmth or coldness also dictates the supply and demand profile for RES within local markets.

This underscores the necessity of integrating these spatial and climatic variables into policymaking to ensure that energy transitions are both technically feasible and economically viable for each specific context.

5.2.3 Cultural factors

Changing heating habits is particularly challenging, as heating behaviours are often driven by cultural factors and are closely connected to social and emotional human needs (Sahlberg, Karlsson, Sjöblom, & Ström, 2022). In their analysis of public resistance to the 2017 ban on wood stoves in Sweden, Sahlberg et al. (2022) found that people are more likely to accept measures that are not perceived as conflicting with needs such as emotional comfort, a sense of tradition, social connections, or feelings of security and self-reliance. Wood-burning is also frequently perceived as a sustainable heating system, being a natural element. Moreover, in the Swedish case, many protesters who were interviewed preferred to continue using old functional devices, rather than replacing them with new technologies.

At the same time, when introducing clean heating policies, highlighting environmental and health benefits alone is not always sufficient to drive behavioural change. Concerns about replacing a long-established habit with unfamiliar technology and economic considerations are common among households. A public survey conducted across five European countries (Germany, Italy, Spain, Sweden and the UK) on heat decarbonisation identified several shared challenges (Sovacool, Demski, & Noel, 2021). First, respondents reported high levels of satisfaction with their existing heating systems, many of which were fossil fuel-based, making them less inclined to switch to cleaner alternatives. Low levels of familiarity with and knowledge of alternative heating technologies further reduced willingness to change them. While respondents generally recognised the importance of environmental aspects and expressed support for low-carbon solutions such as district heating, natural gas remained the most preferred source for the high level of comfort it provides (Sovacool, Demski, & Noel, 2021).

Satisfaction with heating systems is strongly influenced by local contexts and technology types. These findings highlight the importance of considering household needs and preferences when designing clean heating policies. Gradual and flexible approaches may help facilitate the transition by allowing households sufficient time and support to make informed choices. Continuous dialogue, clear and accessible information on available options, and reassurance regarding comfort and performance can help build confidence in alternative heating systems. Economic incentives and targeted support measures are also necessary to address financial concerns and facilitate uptake.

FACTORS	CHARACTERISTICS	EXAMPLE: <u>KRAKÓW</u>
Climatic conditions	• Climate zone • Exposure to climate change	Central European climate.
Geographic factors	• Morphology • Natural resource availability nearby • Abundance of water resources • Air pollution exposure	Located in a valley enclosed by mountains and high pollution exposure, availability of coal reserves nearby.
Renewable resource potential	• Wind volume & strength • Solar irradiation levels • Geothermal potential	Meaningful physical solar resource potential, limited wind, unproven geothermal.
Urban form	• Level of urbanisation	Urban area.
Socioeconomic and cultural factors	• Perception of thermal and emotional comfort • National fuel tradition • Trust in RES • Energy poverty rates	Cultural attachment to coal and relatively high energy poverty rates.
Infrastructural factors	• Presence of district heating (DHC) infrastructure • Progress in RES transition	Lagging behind in RES transition infrastructure deployment, presence of DHC.

Figure 13: Factors and characteristics relevant to heating policy design.

Figure 13 presents the main categories of factors that determine area-specific characteristics relevant to the design of heating policies. As each spatial unit embodies a unique combination of these variables, local contexts require distinct pathways through which policies can be designed, implemented, and evaluated. The list of characteristics presented is non-exhaustive but is intended to provide an illustrative example for the city of Kraków (see column 3).

6. Key recommendations

Tackling air pollution remains an urgent challenge for the EU, with residential heating being a major source of harmful emissions and associated environmental, health, and economic impacts. While improving building energy efficiency, modernising heating systems, and promoting electrification are critical actions to reduce these impacts, their successful implementation depends on coordinated action across local, national and EU levels. Such efforts must create the appropriate incentives for businesses and citizens alike, while ensuring that vulnerable households are protected from the risk of energy poverty. It should also be recognised that not all RES heating technologies are equally beneficial from an air quality perspective. Policymakers should therefore promote the uptake of non-combustion renewable energy sources (NCRES) solutions, which do not rely on combustion processes. Such technologies can contribute to simultaneously achieving climate and air-quality objectives. A few recommendations in this final Chapter can support policymakers to accelerate the transition to cleaner heating, achieve EU climate and air quality goals, and ensure that the benefits of the transition are shared equitably.

6.1 Local level

- Collect and integrate data on air pollution levels, housing conditions, heating systems and household socio-economic circumstances to better identify transition needs and target support effectively.
- Provide adequate financial, technical and administrative support for households adopting clean heating solutions, with ad hoc and, if possible, upfront assistance for vulnerable and hard-to-reach groups.
- Ensure citizen participation, including civil society organisations, businesses, and independent experts (doctors explaining the health benefits, energy experts showcasing the financial value of heat pumps, environmental researchers informing on the added values for citizens, and so on), from the early stages of policy design and maintain an open feedback mechanism throughout implementation.
- Adopt integrated approaches that address air quality, energy efficiency, building renovation, public health and social inclusion simultaneously rather than through separate policy silos.
- Promote the benefits of clean heating through clear communication on health, environmental, comfort, and economic gains, while ensuring support measures are accessible and well understood (through info-days, one-stop-shops, media channels with local administration, etc.).

6.2 National level

- Ensure national strategies recognise the interconnected benefits of building decarbonisation, air quality improvement, public health, and energy poverty reduction, directly improving productivity and the overall economy.
- Facilitate meaningful participation of regional and local authorities in the design of national plans, including the Air Quality Plans, policy frameworks, and the transposition of EU legislation to reflect all territories' realities and implementation challenges.
- Prioritise clean heating and building renovation policies that leverage private investment alongside public funding and encourage collaboration across sectors.
- Design funding schemes that reduce upfront costs and administrative burdens for low-income and vulnerable households.
- Strengthened coordination across different levels of governance to ensure efficient implementation of policies.

6.3 EU level

- Maintain a strong commitment to the Zero Pollution target by ensuring sufficient funding within the MFF 2028-2034 to support air quality improvements.
- Keep just transition policies and mechanisms going and accompany vulnerable households and regions throughout the transition.
- Ensure consistency between EU climate, energy, air quality and social objectives, while providing adequate financial and technical support for national, regional and local authorities responsible for implementation.
- Strengthen mechanisms for local and regional participation in EU policymaking to better incorporate territorial needs and a place-based transition.
- Establish a more comprehensible and standardised framework for monitoring mechanisms and interpretations and assessing policy impacts.

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Annex

Annex 1 Socio-demographic data in the four selected cities

	Sofia	Kraków	Utrecht	Madrid
Area coverage	472 km ²	327 km ²	93.77 km ²	605.7 km ²
Population density	2,600 habitants/km ²	2,500 habitants/km ²	4,033 habitants/km ²	5,713 inhabitants/km ²
GDP per capita	EUR 31,600	EUR 34,188	EUR 75,651	EUR 52,386
GDP per capita of the country	EUR 14,700	EUR 21,491	EUR 62,381	EUR 30,812
City's average annual wage	EUR 19,801	EUR 29,856	EUR 75,651	EUR 34,410.01
Country's average annual wage	EUR 14,257	EUR 23,077	EUR 62,381	EUR 29,540.26
EU average annual wage	EUR 39,800			

Annex 2 Inability to keep home adequately warm

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	2,7	3,2	2,7	3,2	2,6	2,7	2,4	1,6	1,8	1,5	1,7	2,7	3,9	4	4
Belgium	7,1	6,6	5,8	5,4	5,2	4,8	5,8	5,2	3,9	4,2	3,5	5	6	4,8	4,2
Bulgaria	46,3	46,5	44,9	40,5	39,2	39,2	36,5	33,7	30,1	27,5	23,7	22,5	20,7	19	16,1
Croatia	9,8	10,2	9,9	9,7	9,9	9,3	7,4	7,7	6,6	5,7	5,7	7	6,2	4,6	4,2
Cyprus	26,6	30,7	30,5	27,5	28,3	24,3	22,9	21,9	20,6	21	19,2	19	17,1	14,6	11,3
Czechia	6,4	6,7	6,2	6,1	5	3,8	3,1	2,7	2,8	2,2	2,2	2,9	6,1	4,9	4,1
Denmark	2,3	2,5	3,8	2,9	3,6	2,7	2,7	3	2,8	3	2,8	5,1	6,9	4,4	4,5
Estonia	3	4,2	2,9	1,7	2	2,7	2,9	2,3	2,5	2,7	2	3,4	4,1	3,6	3,1
Finland	1,8	1,5	1,2	1,5	1,7	1,7	2	1,7	1,8	1,8	1,3	1,4	2,6	2,7	2,6
France	6	6	6,6	5,9	5,5	5	4,9	5	6,2	6,7	6	10,7	12,1	11,8	11,5
Germany	5,2	4,7	5,3	4,9	4,1	3,7	3,3	2,7	2,5	7	3,3	6,7	8,2	6,3	5,7
Greece	18,6	26,1	29,5	32,9	29,2	29,1	25,7	22,7	17,9	17,1	17,5	18,7	19,2	19	18,1
Hungary	12,2	15	14,6	11,6	9,6	9,2	6,8	6,1	5,4	4,1	5,4	4,6	7,1	6	5,8
Ireland	6,8	8,4	10	8,9	9	5,9	4,4	4,4	5,1	3,6	3,4	6,8	7,2	4,9	4,5

Italy	17,8	21,3	18,8	18	17	16,1	15,2	14,1	11,1	8,3	8,1	8,8	9,5	8,6	8,6
Latvia	22,5	19,9	21,1	16,8	14,5	10,6	9,7	7,5	8	6	4,9	7,1	6,6	4,9	4,3
Lithuania	36,2	34,1	29,2	26,5	31,1	29,3	28,9	27,9	26,7	23,1	22,5	17,5	20	18	16,7
Luxembourg	0,9	0,6	1,6	0,6	0,9	1,7	1,9	2,1	2,4	3,6	2,5	2,1	2,1	3,6	3,5
Malta	17,6	22,1	23,9	22,3	14,1	6,6	6,3	7,6	7,8	7,2	7,8	7,6	6,8	7,8	7,6
Netherlands	1,6	2,2	2,9	2,6	2,9	2,6	2,4	2,2	3	2,4	2,4	5,3	7,1	7,1	6,6
Poland	13,6	13,2	11,4	9	7,5	7,1	6	5,1	4,2	3,2	3,2	4,9	4,7	3,3	3,2
Portugal	26,8	27	27,9	28,3	23,8	22,5	20,4	19,4	18,9	17,5	16,4	17,5	20,8	15,7	15,6
Romania	15,6	15	14,7	12,9	13,1	13,8	11,3	9,6	9,3	10	10,1	15,2	12,5	10,8	11,9
Slovakia	4,3	5,5	5,4	6,1	5,8	5,1	4,3	4,8	7,8	5,7	5,8	7,1	8,1	8,3	8,1
Slovenia	5,4	6,1	4,9	5,6	5,6	4,8	3,9	3,3	2,3	2,8	1,7	2,6	3,6	3,3	3,6
Spain	6,5	9,1	8	11,1	10,6	10,1	8	9,1	7,5	10,9	14,2	17,1	20,8	17,5	15,9
EU27	10,3	11,2	10,8	10,4	9,6	9	8,1	7,6	6,9	7,5	6,9	9,3	10,6	9,2	8,8

Table 6. Percentage of population unable to keep home adequately warm. Data source: [Eurostat, 2026](#)

Table 6 shows a time series between 2011 and 2025 of the percentage of the population unable to keep their home adequately warm, by EU country. This is based on the question "Can your household afford to keep its home adequately warm?", which makes the concept of adequate warmth a subjective one, varying by country, region, household, and even individual basis (e.g. two roommates experiencing the same temperature might perceive different levels of thermal comfort based on different social habits and personal standards) (Energy Poverty Advisory Hub, 2026).

As shown in Table 6, 8.8% of the EU population was unable to keep their home adequately warm in 2025 (around 40 million people). That year, the countries with the highest shares were Greece (18.1%), Lithuania (16.7%), and Bulgaria (16.1%), while those with the lowest were Finland (2.6%), Estonia (3.1%), and Poland (3.2%). Throughout the period, a persistent group of countries has typically recorded low values (ranging from 0.6% to 6.9%), including Austria, Czechia, Denmark, Estonia, Finland, Luxembourg, and Slovenia; while another group has typically recorded high values (ranging from 9.3% to 46.5%), including Bulgaria, Cyprus, Greece, Lithuania, Portugal, and Romania. Counterintuitively, colder Northern and Central European countries tend to show lower rates than Mediterranean and Eastern ones. This can be attributed to better insulation and heating infrastructure, higher income levels, and different perceptions of "adequate warmth" (Kosowski, 2025). Other countries show intermediate rates or more pronounced shifts over time. Latvia, for instance, moved from 22.5% in 2011 to 4.3% in 2025, and Poland from 13.6% to 3.2%. Conversely, Spain shows a significant long-term increase, from 6.5% to 15.9%, countering the general EU downward trend. This pattern is echoed by France (from 6.0% to 11.5%), the Netherlands (from 1.6% to 6.6%), and Slovakia (from 4.3% to 8.1%). Despite these divergent trajectories, the period as a whole shows stronger convergence across countries by 2025 than at the 2011 starting point: in 2025, all countries fall within a range of 2.6% to 18.1%, compared with a much wider range of 0.9% to 46.3% in 2011. This suggests that EU countries have been becoming more similar in this respect, although the remaining spread is still substantial.

A final point worth highlighting is a break in the trend in 2022. Up to that year, most countries (along with the EU average) had been on a downward trajectory; in 2022, most countries saw an increase in the share of the population unable to keep their home warm, again mirrored by the EU average. The downward trend generally resumed in 2023, suggesting that this break can be attributed to the 2022 energy crisis.

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