# Cooling inequalities in a warming Europe: implications for health, wellbeing, and resilience

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**SUMMARY**
Rising summer temperatures and more frequent heatwaves are increasing difficulties in maintaining adequate indoor thermal comfort across Europe during warm periods, particularly for vulnerable households. This paper examines cooling inequalities in eight European countries using data from a multinational survey conducted in 2025 (N ≈ 14,000) and longitudinal data from EU-SILC (2007–2012). Descriptive and regression analyses assess the prevalence and drivers of cooling discomfort and its association with self-reported health and wellbeing.
Cooling discomfort is widespread, with particularly high levels in northern Europe: over half of households in Estonia and nearly one-third in Finland reported being unable to keep their homes cool. Poor building energy performance emerged as the strongest predictor, with households in the lowest efficiency categories over four times more likely to experience cooling discomfort. Financial strain and unemployment further increased vulnerability. Despite a rise in air conditioning ownership since 2007, cooling discomfort has not declined proportionally. Cooling discomfort is also associated with poorer health and wellbeing, highlighting cooling inadequacy as a growing public health concern and supporting a systemic cooling poverty perspective.

**KEYWORDS**
Air conditioning, Cooling inequalities, Climate adaptation, Thermal comfort, Health and wellbeing

## 1 INTRODUCTION

Climate change is intensifying the frequency and severity of heatwaves in Europe, posing increasing challenges to maintain safe and comfortable indoor environments (Rogers et al. 2022; Boboc et al. 2024). While heat-related mortality and morbidity have long been documented (Ballester et al. 2023; Janoš et al. 2025; Zhao et al. 2021; Masselot et al. 2023), less attention has been paid to indoor overheating as chronic inequality and uneven exposure among vulnerable population and its intersection with socio-economic conditions and associated health risk (Mazzone et al. 2023; O'Brien and Leichenko 2000; Zhang et al. 2025).

Cooling needs do not rise uniformly. They intersect with long-standing inequalities in housing quality, energy performance, income, and employment, resulting in disparities to maintain safe and comfortable indoor conditions during hot weather (Falchetta et al. 2024). Increasing exposure to overheating exacerbate existing socio-economic vulnerabilities (Huang et al. 2023; O'Brien and Leichenko 2000). Recent work on cooling poverty has highlighted how poor housing, infrastructure, and access to cooling technologies shape unequal exposure to heat (Mazzone et al. 2023).

Air conditioning (AC) is often considered as a relatively low-cost and effective adaptation to overheating, and its adoption is increasing rapidly across Europe (De Cian et al. 2019; Falchetta et al. 2024). However, growing evidence suggests that AC adoption may deepen inequalities. For example, AC ownership and use are stratified by income (Davis et al. 2021), and future adoption is projected to follow existing socio-economic disparities (Falchetta et al. 2024). In addition to this, rising AC adoption has not consistently translated into reduced overheating exposure, as affordability constraints, inefficient buildings, and behavioural limitations restrict its optimal use (De Cian et al. 2025; Turek-Hankins et al. 2021).

These studies mostly focus on adoption or energy demand, rather than on households' actual ability to maintain adequate indoor thermal comfort during hot weather. Important research gaps remain. First, cross-country European evidence linking cooling inadequacy directly to health and wellbeing outcomes is limited. Second, little is known about whether increasing AC ownership over time has reduced perceived cooling inadequacy, particularly among vulnerable households.

This paper aims to fill these gaps by answering the following research question: How does the inability to maintain adequate indoor thermal comfort during hot weather relate to health and wellbeing outcomes in Europe? To address this question, the study pursues four objectives:

1. To assess whether individuals reporting difficulties in keeping their dwelling cool also report poorer general health and wellbeing;
2. To examine the effects of cooling discomfort in combination with other housing-related vulnerabilities;
3. To analyse changes in cooling inadequacy over time in the context of rising temperatures and increasing AC ownership;
4. To evaluate how AC ownership is distributed across socio-economic groups and regions, and whether disparities in access contribute to unequal exposure to overheating risks.

## 2 MATERIALS/METHODS

This section describes the data sources, key variables, and analytical strategy used in this study.

### Data source

This study uses data from two complementary datasets: the 2025 HouseInc Multinational Survey and the European Union Statistics on Income and Living Conditions (EU-SILC). The HouseInc survey was conducted between March and June 2025 across eight European countries—Belgium, Czech Republic, Estonia, Finland, Germany, Italy, Romania, and the United Kingdom—with a total sample of 14,254 respondents. The survey collected data on housing conditions, thermal comfort, adaptation behaviours, affordability, socio-demographic characteristics, self-reported health, and wellbeing, with a particular focus on marginalised groups such as low-income homeowners and tenants. Data were collected online, cleaned, anonymised, and shared with the University of Exeter by project partner IMEC, University of Ghent. To examine longer-term trends in cooling adequacy and air conditioning ownership, publicly available EU-SILC cross-sectional microdata from the 2007 and 2012 were analysed. These years were selected because they include the only EU-SILC surveys containing questions on the ability to keep the home cool during summer and AC ownership. EU-SILC provides harmonised household- and individual-level data across EU Member States through national statistical offices, with annual samples ranging from approximately 200,000 to 400,000 households.

**Key variables**
In the HouseInc survey, cooling inadequacy was defined as reporting being unable or only partially able to maintain comfortable indoor temperatures during hot weather. General health was measured using a five-point self-assessed scale, while wellbeing was captured through a continuous satisfaction score. Air conditioning ownership and cooling sources were also included as key variables. Other variables included building and housing characteristics (Energy Performance Certificate rating, dwelling type, tenure), socio-demographic factors (household type, employment status), perceived energy cost burden, and country of residence.

**Data analysis**
Data were analysed with a mixed approach. Descriptive statistics was used to examine the prevalence of cooling inadequacy across countries and vulnerable groups. Regression analysis was applied to assess predictors and health associations. Binary logistic regression was used to model the likelihood of reporting cooling inadequacy. Ordinal logistic regression was applied to self-reported general health, while linear regression was used to examine associations between cooling discomfort and wellbeing. All models included relevant socio-demographic, housing, and country-level controls.

## 3 RESULTS

**AC ownership evolution**
AC ownership increased between 2007 and 2025 in all countries analysed (Figure 1a). The largest increase occurred in Italy, where ownership rose from 37.8% to 60.7%, followed by Romania (17.2% to 47.1%). Despite this expansion, difficulties in maintaining comfortable indoor temperatures during hot weather remain widespread (Figure 1b). In 2025, over half of households in Estonia (50.1%) reported being unable to keep their homes cool, followed by Finland (30.4%), Romania (23.2%), Germany (22.9%), and Italy (19.1%). In Estonia, the share of households reporting cooling inadequacy almost doubled between 2012 and 2025 (from 26.3% to 50.1%). Regarding alternative methods for cooling, Figure 2 shows the distribution of cooling methods used across countries in 2025. Floor and table fans are the most commonly reported cooling strategy in all contexts, while ceiling fans, evaporative coolers, and heat pumps remain comparatively uncommon. The share of households reporting no active cooling is highest in northern and central European countries, ranging from 29% in Estonia to 45% in Belgium, and exceeding 30% in Germany and the Czech Republic.

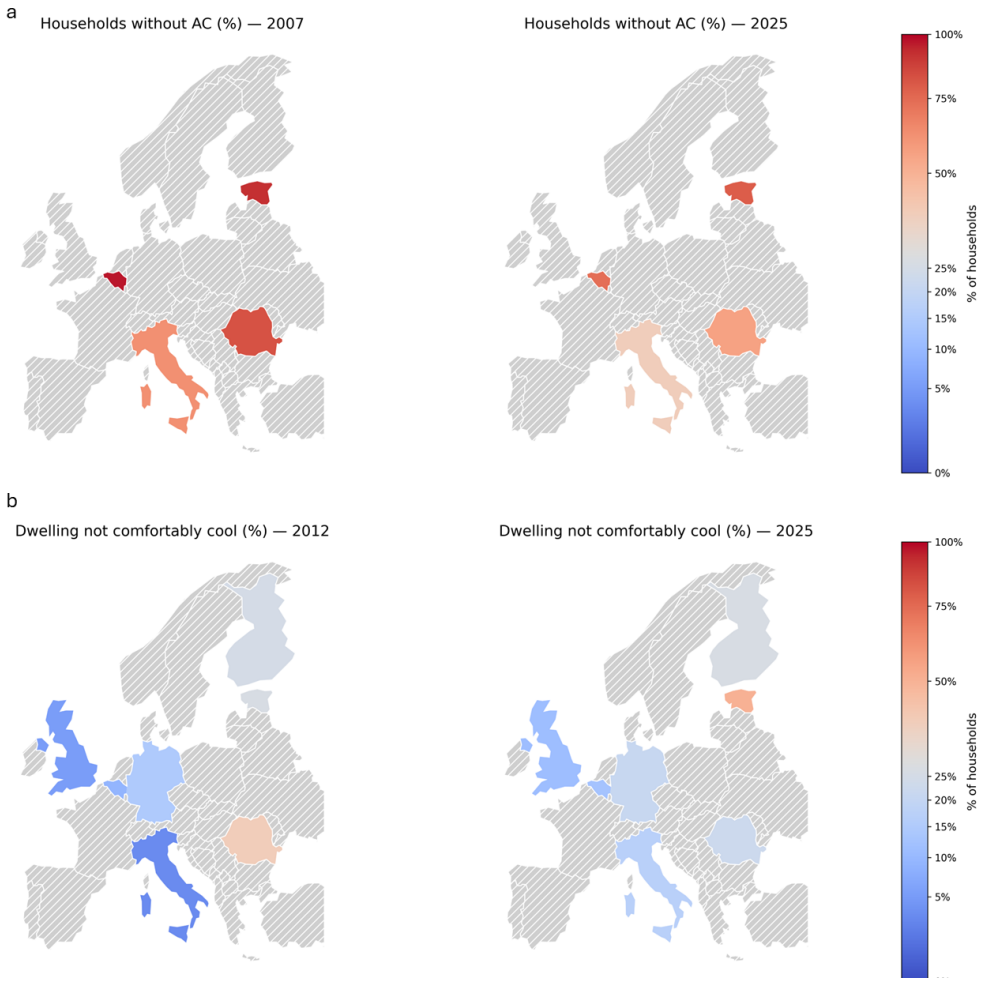



Figure 1 a) Percentage of households with air conditioning by country and year (2007–2025). b) Percentage of households reporting inability to maintain adequate cooling by country and year (2012 and 2025).

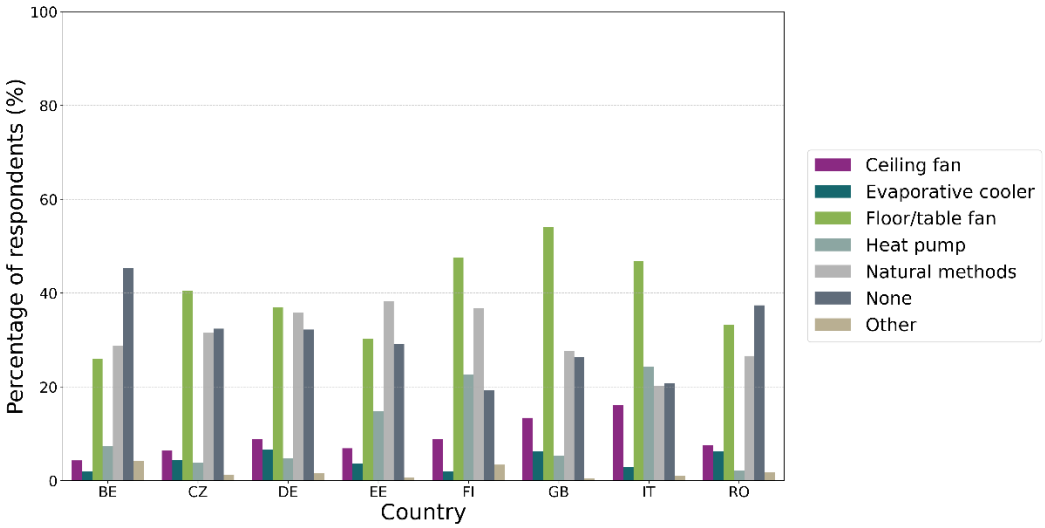



Figure 2 Percentage of respondents using different cooling methods by country. Data from the HouseInc survey (2025).

**Socio-demographic vulnerabilities and cooling inadequacy**

Cooling discomfort is unevenly distributed across socio-demographic and housing groups (Table 1). The highest prevalence is observed among household living in dwelling with poor energy performance. Among respondents in dwellings with the very lowest EPC ratings, 68.6% report some degree of cooling inadequacy, including 47.5% who are unable to comfortably cool their homes and 21.1% who report partial inability. Elevated prevalence is also observed across other low-efficiency categories, with total cooling inadequacy ranging from 61.0% to 63.3%, indicating a clear gradient between energy performance and summer thermal discomfort. Household composition is also associated with cooling vulnerability. Non-family households report high levels of cooling inadequacy, with 66.8% experiencing some difficulty in maintaining comfortable indoor temperatures, including 26.3% reporting complete inability and 40.6% partial inability. Cross-country difference are also evident. Estonia shows the highest prevalence of cooling inadequacy (63.3%), driven largely by complete inability to cool (50.6%), while the Czech Republic also exhibits high prevalence (60.4%), primarily reflecting partial inability (35.6%).

Results from the ordinal logistic regression confirm these descriptive patterns. Lower energy efficiency is the strongest predictor of cooling inadequacy, with respondents living in dwellings with the very lowest EPC ratings more than four times as likely to report cooling difficulties compared with those in high-efficiency homes ($p < 0.001$). Country-level differences remain significant after adjustment, particularly for Estonia, highlighting the role of contextual factors alongside socio-demographic vulnerability.

Table 1 Prevalence of cooling inadequacy among selected vulnerable groups reporting highest levels of heating and cooling inadequacy. Energy efficiency categories are based on self-reported responses and do not correspond to national EPC classes and descriptive labels were used instead of numeric values to allow cross-country comparison.

| **Category (selected from the whole sample)** | **Subcategory** | **Unable to comfortably cool [%]** | **Partially unable to comfortably cool [%]** | **Total [%]** |
|---|---|---|---|---|
| Energy efficiency | Very lowest | 47.5 | 21.1 | 68.6 |
| Household Type | Non-Family Household | 26.3 | 40.6 | 66.8 |
| Financial Burden | Energy Burden Level 5 | 36.9 | 28.7 | 65.6 |
| Country | Estonia | 50.6 | 12.7 | 63.3 |
| Energy efficiency | Very low | 34.6 | 28.7 | 63.3 |

**Health implications of inability to keep cool**

Cooling inadequacy is associated with poorer self-reported health and wellbeing. Respondents reporting difficulties in keeping their homes cool were less likely to report good or very good health and more likely to report fair or poor health (Figure 3a). Mean general health scores were lower among those unable to keep cool ($M = 2.92$, $SD = 0.95$) than among those who could ($M = 3.23$, $SD = 0.91$; $p < 0.001$). A similar pattern emerges for wellbeing (Figure 3b). Individuals

reporting cooling inadequacy had lower wellbeing scores on average (M = 6.67, SD = 2.19) than those able to maintain comfortable indoor temperatures (M = 7.68, SD = 2.10; $p < 0.001$), with greater variability among those experiencing discomfort.

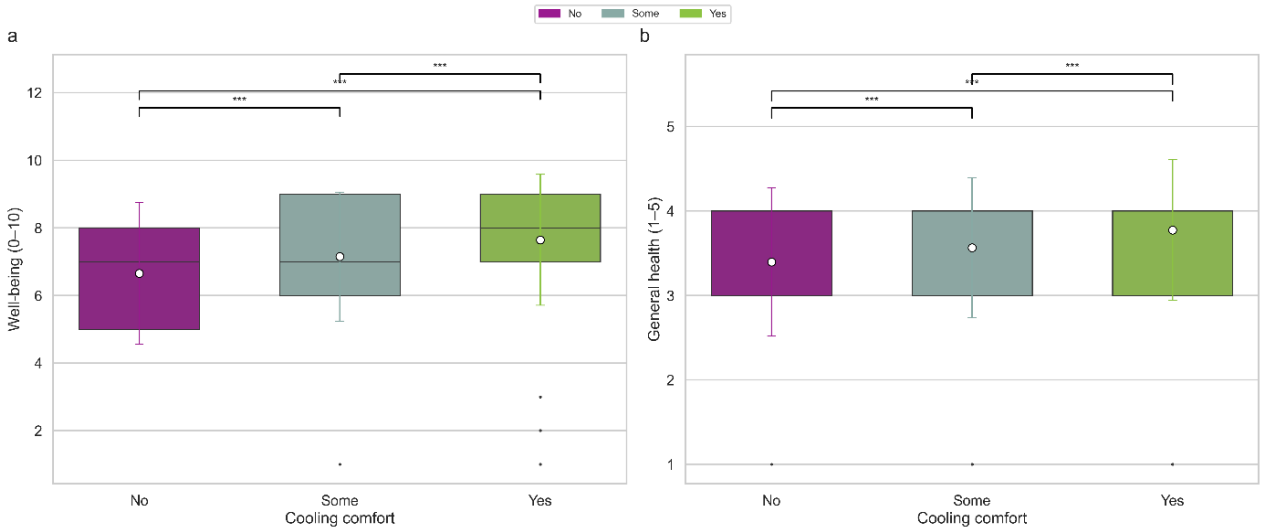



Figure 3 a) Wellbeing scores and b) General health scores by ability to maintain comfortable indoor temperatures during hot weather.

## 4 DISCUSSION

This study shows that the ability to maintain comfortable indoor temperatures during hot weather is stratified by socio-economic and housing vulnerabilities. Cooling inadequacy is closely linked to affordability constraints and poor building energy performance. These findings are consistent with earlier evidence showing that low-income households experience higher indoor temperatures in summer, even where cooling technologies are present (Cong et al. 2022).

As expected, air conditioning ownership has increased substantially since 2007 in accordance with recent projections (Falchetta et al. 2024). However, rising AC ownership has not translated into lower levels of cooling inadequacy. In Estonia, for instance, reported inability to keep homes cool nearly doubled between 2012 and 2025 despite growing AC uptake. This suggests that access alone is insufficient, particularly where poor dwelling efficiency, high energy costs, or financial burden limit the effectiveness of cooling, similarly to findings from Scott et al. (2025).

At the same time, many households continue to rely on low-cost strategies such as fans and natural ventilation, especially in Belgium, Germany, and the Czech Republic, while heat pump use is more prevalent in Estonia and Finland. These results highlight an uneven geography of adaptation, in which some populations are far better positioned than others to respond to rising temperatures.

The persistence of cooling inadequacy therefore reflects the accumulation of socio-economic and housing vulnerabilities. Groups already exposed to disadvantages such as low-income households, those living in poor dwellings, and specific household types—are more likely to experience thermal stress during hot weather, even as cooling technologies become more widespread. In this scenario, cooling inadequacy reinforces existing housing and health inequalities. Addressing rising heat exposure in Europe will thus require moving beyond

technology-centered responses towards strategies that explicitly target vulnerable households, improve dwelling performance, and reduce the financial barriers that limit effective adaptation.

## 5 CONCLUSIONS

This study shows that cooling inadequacy in Europe is not a marginal or temporary issue, but a structural condition shaped by housing quality, affordability, and socio-economic disadvantage. Growth in air conditioning ownership has not ensured protection from overheating, particularly for households living in energy-inefficient dwellings or under financial strain. These findings support a systemic cooling poverty perspective, in which thermal vulnerability accumulates across seasons and reflects wider housing and social inequalities.

As summer heat intensifies, failing to address cooling inadequacy risks reinforcing health inequalities across Europe. Effective responses must prioritise housing improvements, reduce energy cost burdens, and target support towards households facing multiple vulnerabilities to ensure healthy and equitable indoor environments in a warming climate.

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