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RESEARCH

Energy efficiency first for homes? Public priorities, barriers and residential energy choices in six European countries

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Abstract The Energy Efficiency First (EE1st) principle has become an important element of European Union energy and climate policy, requiring energy efficiency to be considered and prioritised where it is more cost-effective or socially beneficial than supply-side alternatives. However, EE1st is primarily a top-down policy, planning and investment principle, not simply a measure of public support for energy efficiency. This article therefore examines a more focused question: how do households perceive, prioritise and evaluate residential energy measures that are relevant to the implementation context of EE1st? Drawing on a structured cross-national survey of 1,014 respondents in Germany, the United Kingdom, Poland, Italy, Denmark and Estonia, the article explores household attitudes toward selected building-related energy efficiency and decarbonisation measures, including insulation, energy-efficient windows, heating systems, heat pumps and renewable energy options. The six countries represent different institutional, welfare and energy-policy contexts, allowing for an exploratory comparison of public perceptions across diverse European settings. Findings show broad support for several residential energy

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measures, but also reveal important constraints. High upfront costs emerge as the most consistent barrier, while willingness to invest or tolerate disruption varies across measures and countries. Rather than demonstrating that EE1st has become embedded as a shared European norm, the results indicate that household acceptance of EE1st-relevant policy choices depends on how citizens perceive the differentiated costs, disruption, technology options and the balance between efficiency and supply-side solutions. The article contributes to the EE1st literature by clarifying the conditions of household-level acceptance that enable or impede the practical implementation of energy efficiency-oriented residential policy.

Keywords Energy policy · Energy efficiency · Public opinion · European Union · Europe

Introduction

As part of the European Union's (EU) ambition to become a climate-neutral economy by 2050 (EU, 2021), the EU has adopted a recast of the Energy Efficiency Directive (EED) (EU, 2023). One important element of this recast is Article 3, which requires EU Member States to assess, monitor and report on the Energy Efficiency First (EE1st) principle in their energy planning and policy activities. The EE1st principle is a policy concept requiring that energy efficiency and demand-reduction alternatives be evaluated before new supply-side investments or policy decisions are made across sectors (EU, 2024). It has become an important element of EU energy and climate policy, embedded in the EED and reinforced through the European Green Deal, the Fit-for-55 package and the REPowerEU plan (Nordensvärd et al., 2025).

The EE1st principle is grounded in the idea that reducing energy demand through efficiency strategies can often be less costly and less complex than expanding energy supply infrastructure (EU, 2026). It includes not only traditional end-use energy efficiency, but also demand-side flexibility and efficient energy conversion (EU, 2018; EU, 2023). In practice, this means that energy efficiency options should be systematically compared with investments in energy carriers and infrastructure, such as electricity, gas, heat generation, networks and storage, and prioritised where they provide greater net benefits to society.

Implementing EE1st across Europe is nevertheless challenging because national and regional contexts remain highly heterogeneous. Climate, market structures, infrastructure, housing stock and policy traditions differ considerably across countries and regions. Although the United Kingdom has left the EU, its energy and climate policy debates remain partly shaped by similar efficiency and retrofit challenges (Bergman & Foxon, 2020; Mallaburn & Eyre, 2014). In the building sector, the Energy Performance of Buildings Directive (EPBD) illustrates this tension between common European objectives and national flexibility. Significant variation exists across Member States in terms of climate, market structures and other local conditions, requiring room for national adaptation (D'Agostino & Mazzarella, 2019; Olasolo-Alonso et al., 2023).

These contextual differences have also posed challenges for defining and implementing nearly zero-energy buildings (nZEBs). The concept of nZEB was

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introduced in the EU framework through the 2010 EPBD and later refined in the 2018 recast (Directive (EU) 2018/844, 2018). While the EPBD allows Member States to develop national interpretations of nZEB targets in order to account for climate and market conditions, national definitions have often been less ambitious than the original EU-level vision. The 50% reduction target for building emissions suggested in the 2010 EPBD served as a reference point for national plans to increase nZEBs and report progress to the Commission (D'Agostino & Mazzarella, 2019; D'Agostino et al., 2021; Maduta et al., 2023).

The residential sector is therefore a particularly important area for studying the household-facing side of EE1st-relevant policy. Although EE1st is a cross-sectoral principle, many of the measures through which energy efficiency and building decarbonisation are implemented become visible to households through decisions about insulation, windows, appliances, lighting, heating systems, heat pumps, solar panels and renovation work. These choices are not only technical, but also social and economic. The energy transition has heightened concerns about inequality, with energy poverty becoming more widespread across households in different regions (Bouzarovski, 2014), exposing gendered disparities (Petrova & Simcock, 2021) and, in some cases, intersecting with domestic violence and abuse (Sovacool et al., 2021a, 2021b). Other factors shaping distributional outcomes include differences between rural and densely populated areas (Blomqvist et al., 2022a), home ownership and tenure (Blomqvist et al., 2022b), exposure to price shocks from carbon market instruments (Fragkos et al., 2021), and demographic factors in single-family buildings (Niknafs et al., 2025).

The 2021 EED revision strengthened the EE1st principle by setting binding 2030 targets and extending its scope to public, industrial and corporate sectors (EC, 2021). The recast EED, adopted in 2023, made the principle legally binding, requiring systematic consideration of energy efficiency in policy, planning and major investments (EU, 2023). However, despite the growing political and legal salience of EE1st, comparatively little is known about how households across different governance contexts perceive and prioritise residential energy measures relevant to its implementation. Existing studies have examined energy efficiency behaviour, household energy consumption and retrofit barriers (Adan & Fuerst, 2016; Firth et al., 2010; Maidment et al., 2014; Raven et al., 2025; Sola et al., 2021), but much of this work does not explicitly connect household perceptions to EE1st as a policy, planning and investment principle.

Public opinion research has also tended to examine energy efficiency as part of broader (and often top-down) energy, climate or environmental policy preferences rather than as a distinct policy priority. Stadelmann-Steffen and Eder (2021) show that public support for future energy policies is shaped by domestic policy contexts, political trust and climate attitudes. Janik et al. (2021) find that EU citizens' attitudes are structured around broader climate, environmental and energy policy priorities, including green energy, competitiveness and EU integration, while energy efficiency and demand reduction appear as one among several policy goals. Anderson et al. (2017) examines how European public opinion shapes renewable energy policy, highlighting broad environmental priorities rather than energy efficiency as a central focus of citizen preferences or policy outcomes. These studies provide important insights, but they leave room for a more focused analysis of how households perceive residential energy choices relevant to energy efficiency-oriented policy.

Recent EE1st literature has clarified that the principle should not be understood as a general preference for energy efficiency, but as a policy, planning and investment principle requiring demand-side efficiency options to be systematically compared with supply-side alternatives. Mandel et al. (2022) conceptualise EE1st as a decision-making principle that prioritises demand-side resources where they provide greater societal value than supply-side investments, while Rosenow et al. (2017) show how this principle became central to debates on EU energy efficiency policy in the Clean Energy/Winter Package. Von Malmborg (2023) further demonstrates that EE1st is politically and institutionally contested in EU energy and climate policy, particularly because making efficiency "first" requires changes in how policy priorities, costs, benefits and responsibilities are defined. Operational work by Yu et al. (2022) also shows that applying EE1st requires structured decision-making frameworks that distinguish between policy-making, system planning and investment choices. Notably, the literature has continued to frame energy efficiency

primarily through governance arrangements, policy design, and implementation challenges (Umar & Khidmat, 2026; Archer-Brown & Rosenow, 2026). As a result, research has significantly explored how EE1st policies should be implemented and the institutional barriers, but more work is needed to explore about whether households converge around the measures that EE1st ultimately depends on.

Thus, although energy-efficiency scholarship addresses household attitudes, policy acceptability, and perceptions of retrofit-related measures (Faure et al., 2022; Marmolejo-Duarte et al., 2026), the literature considered here is oriented more toward policymaking, governance, and institutional decision-making. Questions remain, however, regarding households' perceptions of energy choices relevant to energy efficiency.

In line with the above, this article does not claim to measure EE1st implementation or household internalisation of the principle. Instead, it examines EE1st at the household interface: how households perceive, prioritise and evaluate residential energy choices that are relevant to the practical implementation context of energy efficiency-oriented policy. The article therefore asks how households in six European countries assess different building-related energy measures, what barriers they identify, and how willing they are to accept costs or disruption associated with energy-efficient and environmentally oriented residential choices.

The study employs a Most Different Systems Design (MDSD) to explore household perceptions across diverse environmental governance settings (Anckar, 2008, 2020). MDSD is suitable for this purpose because it allows us to examine whether similar patterns of household perceptions appear across countries with different institutional and policy configurations. The six countries included in the survey — Germany, the United Kingdom, Poland, Italy, Denmark and Estonia — represent variation in national approaches to energy efficiency governance. Germany and Denmark are treated as coordinated regulatory-provider systems, with Denmark characterised by comparatively high public participation. The United Kingdom represents a more market-oriented and enabling approach, particularly in the post-Brexit context. Italy and Poland illustrate more fragmented governance arrangements, while Estonia combines centralised structures with comparatively lower levels of citizen trust.

The article uses Duit's environmental state framework as a heuristic device for case selection, categorisation and interpretation (Duit, 2014, 2015). This framework helps situate household preferences within broader institutional contexts by distinguishing between regulatory, organisational, redistributive and knowledge-generating dimensions of environmental governance. The framework is not used to make deterministic claims about national attitudes. Rather, it provides a way to structure the comparison and to interpret how household perceptions of residential energy choices may be shaped by different governance traditions, policy mixes and institutional arrangements.

Drawing on a structured cross-national survey of 1,014 respondents, with representative quotas for age, gender, location and income, the article examines public perspectives on residential energy use, building decarbonisation, perceived barriers and willingness to accept costs or disruption. The contribution is threefold. First, the article clarifies how households prioritise among selected demand-side, building-envelope and supply-side or technology-substitution measures, including insulation, windows, appliances and lighting, heat pumps, solar panels and district heating. Second, it compares these perceptions across six countries with different environmental governance arrangements. Third, it contributes to the EE1st literature by identifying household-level acceptance conditions that may enable or constrain the practical implementation of EE1st-relevant residential policy, while avoiding the stronger claim that household preferences demonstrate EE1st implementation or norm diffusion.

Background

Improving the energy performance of buildings has been a long-standing concern in public policy, spanning more than five decades (Economidou et al., 2020). One of the underlying drivers of efficiency policy has been the goal of achieving substantial reductions in energy use to make national economies more energy resilient, less dependent on imports, and more environmentally sustainable. Efficiency activities have been so successful that the International Energy Agency (IEA) reports that energy efficiency investments, in high-income economies, have reduced

households energy bills by up to 20% since 2000 (IEA, 2025a). If not for energy efficiency, consumers in these countries would be using (and paying for) more energy than they currently do.

Improving the energy performance of buildings has been a long-standing concern in public policy, spanning more than five decades. In recent years, however, the EU has sought to elevate the role of energy efficiency from a technical goal to a guiding principle of energy and climate governance, highlighting its multiple societal benefits (Von Malmborg et al., 2023). Multiple benefits include energy savings, emission reductions, grid investments, the creation of jobs, economic growth, affordability and improved health by improving indoor climate through retrofits (IEA, 2025b). While this political commitment has strengthened, a key question remains: what does the EE1st actually mean for households and everyday energy practices for residents?

The idea of energy efficiency as a strategic policy concern dates back to the 1970s oil crises, when it was first incorporated into European energy policy as a means of safeguarding energy security (Economidou et al., 2020). Since then, the rationale has broadened considerably. For instance, energy efficiency entered the scene in Europe as a short-term strategy to navigate the oil crises of the 1970s, gradually expanding to address environmental concerns (Foulds et al., 2022), resilience, and national security (Kivimaa & Sivonen, 2021). As a result, energy efficiency is now viewed not only as a tool for ensuring security of supply but also as a critical means of mitigating climate change. Policies and measures increasingly target both new and existing buildings, calling for transitions toward zero-energy or even zero-carbon buildings, as well as for deep renovations and accelerated renovation rates.

Globally, the building sector accounts for roughly 40% of total energy end use and 35% of greenhouse gas (GHG) emissions, with 80% related to the operational phase and processes such as heating, cooling, ventilation, and appliance use. A similar figure is seen for EU-27, with 40% (26% household and 14% services) of the energy use allocated to the building and service sectors (Eurostat, 2025). As can be seen in Table 1, the countries included in the survey differ in regard to total energy use and total GHG emissions. However, the energy use per capita as well as the sectoral distribution of energy use remains broadly comparable across countries.

On the seventh of December 2023, the European Council and Parliament agreed on a proposal to revise the EPBD. The deal included minimum energy performance standards (MEPS) (European Council, 2023). This agreement included that, in 2030, all non-residential buildings should be above the 16% worst performing buildings, and by 2033 above the 26% worst performing buildings. The renovation target for residential buildings further specifies that member states shall reduce their average energy use by 16% in 2030 and between 20 and 22% in 2035. Fifty-five percent of the improved energy efficiency should be achieved through renovation of the worst performing buildings. This centers the role of homeowners and their ability and possibilities to implement energy efficiency measures (EEMs).

Table 1 Energy use and greenhouse gas (GHG) emissions in the EU-27 and the studied countries

	Denmark[a]	Estonia[a]	Germany[a]	Italy[a]	Poland[a]	UK[b]	EU-27[a]
Total Energy use [TWh]	153	34	2153	1270	811	1542	10471
Energy use per capita [MWh/pers.]	25.7	24.9	25.6	21.5	21.9	22.2	23.3
Total GHG emissions [Mton CO2-eqv]	39	13	741	331	316	739	2907
GHG emissions per capita [ton CO2-eqv/pers.]	6.5	9.5	8.8	5.6	8.5	10.7	6.5
Energy use in building and service sector [%]	48	49	43	41	39	41	40
Energy use in industry sector [%]	17	17	27	22	21	15	25
Energy use in transport sector [%]	30	32	28	35	35	41	32

[a](Eurostat, 2025)

[b](Department for Energy Security & Net Zero, 2025)

The EU has thus become a pivotal actor in driving the transition toward a zero-emissions future, as policy competences in the energy domain have gradually shifted from member states to the supranational level (Goldthau & Sitter, 2015; Maltby, 2013; Szulecki et al., 2016). The establishment of the Energy Union deepened cooperation between member states in a policy field traditionally guarded by national sovereignty (Bocquillon & Maltby, 2020). Nonetheless, member states retain significant influence through the Council of the European Union, allowing them to assert national interests and uphold the principle of subsidiarity.

Building on the IEA's notion of energy efficiency as the "first fuel" (IEA, 2013, 2019), the EE1st principle was formally introduced into EU energy and climate policy through the European Commission's communication on the Energy Union (EC, 2015) and the Clean Energy for All Europeans legislative package (EC, 2016). It was subsequently codified in Article 2(18) of the Governance Regulation (Regulation (EU) 2018/1999, p. 15), which defines EE1st as:

> "*taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decisions.*"

The principle was further strengthened with the 2021 proposal to revise the EED (EED, 2012/27/EU), setting binding efficiency targets for 2030 and expanding its application to public, industrial, and corporate sectors (EC, 2021). Following negotiations, the European Parliament and the Council of Ministers adopted a recast EED in July 2023, making the EE1st principle legally binding (EU, 2023). This means that energy efficiency must now be systematically considered in policy, planning, and major investments decisions—specifically for projects exceeding EUR 100 million (or EUR 175 million for transport infrastructure).

Moreover, social considerations and justice are integral to policies as the energy transition from fossil fuel sources has heightened social inequalities, with energy poverty becoming more widespread across households in different regions (Bouzarovski, 2014) and even exposing gendered disparities (Petrova & Simcock, 2021). Other factors such as the differences between rural areas and more densely populated areas (Blomqvist et al., 2022a), type of ownership (Blomqvist et al., 2022b) and demographic factors for single family buildings (Niknafs et al., 2025) are also highlighted in literature.

The residential implementation of EE1st has a household-facing dimension, since many efficiency-oriented policies depend on how residents perceive, accept and prioritise measures such as renovation, insulation, heating technologies and energy-efficient appliances. However, most existing studies focus on institutional design and policy implementation, leaving less attention to how households evaluate the kinds of residential energy choices that are relevant to EE1st-oriented policy across different governance regimes (Mandel & Pató, 2024; Raven et al., 2025). The present study therefore does not examine whether EE1st has "taken root" in everyday life as a formal principle, but rather how households perceive and prioritise selected residential measures that are relevant to its practical implementation context.

Existing cross-national surveys show sizable public support for energy efficient homes and renovation policies in several European countries. However, these efforts either focus on smaller country sets, emphasize specific demographic subgroups, or do not anchor their analysis in the EE1st principle and environmental state theory (Czibere et al., 2020; Eurostat, 2026; Lesic et al., 2018). This study fills that gap by connecting household preferences to the residential implementation context of EE1st and to variation in environmental governance regimes.

Conceptual approach and research design

The research design of this study is organized around four core elements: survey design and structure, data collection, data analysis, and data visualization. The study adopts a MDSD to examine perceptions of Energy Efficiency among EU households across varied environmental governance contexts (compare Anckar, 2008). MDSD is well suited to this purpose, as it allows for investigating how divergent approaches to environmental governance interact with shared policy priorities and perceptions in shaping public attitudes.

Conceptual framework: a typology of environmental states

As a conceptual framework, we adapt Andreas Duit's environmental state typology as a heuristic tool for case selection and categorisation. Drawing on Duit's (2014, 2015) framework of the four faces of the environmental state, the study conceptualises national variation in terms of how states regulate, provide, enable, and politicise environmental objectives. This approach structures our paper by providing a conceptual interpretive lens through which to understand differences in national energy efficiency governance arrangements. It helps situate household preferences for energy efficiency options within broader institutional contexts, including the four faces of the environmental state: regulatory, organisational, redistributive, and knowledge-generation. One important aspect of understanding these political dimensions is recognising that there are different political governance contexts that determine how a policy mix is developed and what policies are likely to succeed or fail.

To further clarify this theory, Duit (2015) conceptualises the environmental state as having four distinct faces. First, the regulatory state relies on command-and-control policies, monitoring, and enforcement to address environmental challenges. Second, the provider state focuses on the direct provision of environmental goods and services, such as public infrastructure and waste management systems. Third, the enabling state seeks to facilitate and incentivise sustainable practices through market-based instruments, subsidies, and partnerships with civil society and private actors. Finally, the state functions as an arena of political contestation, where environmental priorities are shaped through negotiation and struggle among diverse interests and actors. These four faces rarely exist in isolation; rather they combine in hybrid forms across different national contexts, reflecting broader variations in state traditions and governance regimes (Duit, 2014, 2015). Nevertheless, these dimensions are pivotal to comprehending how states structure their governance with regard to environmental issues. Hence, the environmental state framework provides the theoretical underpinnings for interpreting household preferences, which may be shaped by shared institutional environments and policy frameworks across the surveyed countries.

Building on an adapted version of Duit's (2014, 2015) environmental state typology, Denmark and Germany come closest to what Duit calls "established environmental states". Both combine strong administrative institutions with comprehensive regulatory frameworks and long-term policy continuity. Denmark stands out for its close cooperation between municipalities, citizens, and the state, which embeds energy efficiency in everyday governance and community life. Germany, drawing on its corporatist traditions, maintains dense policy networks and a clear institutional structure that supports efficiency and decarbonisation. In both cases, energy efficiency aligns with broader societal values of trust, collective responsibility, and sustainability.

In the United Kingdom, environmental governance follows what Duit describes as an "enabling state logic", emphasising markets, behavioral incentives, and voluntary standards. The country's departure from the EU has reinforced this orientation, increasing national discretion and reducing the degree of coordination with European partners. While this provides flexibility in policy design, it can also fragment regulation and weaken long-term strategic coherence in energy efficiency.

Italy and Poland illustrate more "fragmented governance patterns", where administrative complexity and political instability limit the consistent application of energy efficiency goals. Competing policy priorities—such as affordability, economic competitiveness, and energy security—often overshadow efficiency initiatives. As a result, citizens' engagement with efficiency measures tends to be more situational and dependent on incentives rather than embedded in everyday practice. Estonia, like other post-socialist contexts, represents a more centralised yet uneven form of environmental governance. It combines a strong state apparatus and rapid digital modernization with lower public trust and limited redistributive mechanisms. While efficiency policies are well-articulated at the national level, their success often depends on EU support and external funding rather than deeply rooted in domestic institutions.

Survey design and data collection

A structured questionnaire was initially developed in English and subsequently translated into the respective local languages of each country to ensure that

all respondents could fully comprehend the questions and participate without language barriers. The questionnaire was designed to include a broad mix of question types — including Likert-scale items and ranking questions — in order to capture a wide range of perspectives and responses.

Data collection was conducted between June and August 2025 with the support of Norstat, employing quota sampling to ensure representative coverage across key demographic dimensions, including age, gender, income, education, and geographic region. The final dataset comprises 1,014 completed responses from members of the general public in the six European countries, with a focus on public perceptions of energy use and the decarbonisation of buildings.

The questionnaire included questions specifically related to the decarbonisation of buildings. These addressed topics such as measures to reduce carbon emissions, challenges and barriers to implementing efficiency solutions. In addition, respondents were asked about their willingness to pay for carbon reduction or energy-saving measures, as well as their willingness to tolerate potential disruptions at home or work to achieve greater energy efficiency.

To ensure the quality and reliability of the data, several measures were implemented. A pilot survey involving 50 participants was conducted to identify and address potential issues related to translation, programming, or country-specific localisation. Following minor revisions, the main survey was launched. Further quality control measures included the removal of duplicate IP addresses, filtering out invalid geolocation data, and reviewing responses completed in unusually short time frames to maintain consistency and validity.

Data analysis and visualization

All data analysis, including statistical procedures, was performed using SPSS (IBM, 2023) and Python. The survey data consisted of a variety of variable types. Demographic items were captured as categorical variables, whereas questions related to decarbonisation included categorical, numerical, and Likert-scale variables. Some items employed Likert scales in both rating and ranking formats, and these were subdivided into multiple components to facilitate more detailed analyses.

To analyse this diverse dataset, several statistical techniques were employed, including correlation analysis and Analysis of Variance (ANOVA). Both methods are inferential, going beyond simple data description to test relationships or differences between variables within the sample, and to enable inferences about a larger population. Correlation analysis assesses the strength and direction of relationships between two variables, while ANOVA examines differences between group means to determine whether the means of three or more groups differ significantly. Both methods are parametric and involve calculations of variance and covariance, performed in SPSS for each survey question and for each country. Key statistical measures examined included mean differences, standard errors, significance levels, and 95% confidence intervals.

Data analysis in Python was conducted at two levels: (1) aggregating responses across all European participants, and (2) conducting country-specific analyses for each individual country. For multiple- and single-selection question types, response rates were calculated as the number of respondents selecting a given choice divided by the total number of respondents. For 5-point Likert-scale questions, both the percentage distribution of responses and the mean score were calculated. The mean score was computed as the sum-product of the response level on the Likert scale and the number of respondents selecting that level. For ranking questions ranging from 1 to 10, results were based on distribution ranks, calculated as the percentage of respondents assigning a particular rank out of the total respondents. In addition, average ranking scores were computed as the sum-product of assigned ranks and the number of respondents assigning each rank, divided by the total number of respondents.

In terms of limitations, our research design has a few. The survey relies on stated preference techniques, reporting what consumers say, rather than observing what they do through revealed preference techniques such as ethnography or anthropology. Moreover, although our national sub-samples remain nationally representative for quotas relating to age, gender, income and location, the smaller sample sizes are a limitation that was unavoidable due to resource constraints for the project.

Results: stated interest, perceived barriers, and direct actions in reducing carbon emissions

This section presents the key findings from a cross-national survey examining household opinions and behaviors regarding the EE1st principle across six European countries. The results provide a comparative perspective on how citizens in Germany, the United Kingdom, Poland, Italy, and Estonia perceive, prioritize, and engage with energy efficiency measures in their everyday lives.

Interest in decarbonising buildings and sustainable materials

The respondents were asked about their interest in home/building updates. Ten different updates were proposed, and the respondents indicated their answers on a 5-point Likert scale, ranging from not very interested (1) to very interested (5). The results can be seen in Fig. 1. The overall results show that energy efficient windows, as well as appliances and lighting received the highest average interest scores among respondents, followed by roof and wall insulation and solar panels. Low-carbon concrete, steel, and other building materials receive the lowest average rating.

A country-level analysis shows that almost all countries show similar patterns of top ranked desired technology updates. In the results from Estonia, 36% of the respondents indicated a strong interest in solar panels, which is aligned with Poland (35%). For the other countries, an even larger percentage (43–49%) of the respondents indicated a very strong interest in solar panels over other technologies.

Overall, Italian respondents showed the highest level of interest across all of the efficiency updates, followed by Poland. In Denmark, Germany and Estonia, the respondents show little interest in low-carbon concrete, steel and other building materials. A caveat worth noting is that this option does not constitute a true energy-efficiency measure, as it presupposes rebuilding, extending, or constructing new facilities. In Denmark there is also a low interest for energy efficient cooling systems. The results also show that 17% of Danish and British respondents are unfamiliar with geothermal energy.

Next, the respondents were asked how promising they consider eleven different building updates for reducing carbon emissions. The ten updates from the previous question were included, together with district heating. The respondents indicated their answers on a 5-point Likert scale, ranging from not promising (1) to very promising (5). The results can be seen in Fig. 2. The overall results for the countries show that energy efficient windows are rated as the most promising updates, together with roof and wall insulation (mean value = 4.1). Low-carbon concrete, steel, and building materials and energy efficient cooling systems received the lowest mean score.

At the country level, geothermal seems to be the technology the respondents are most unsure about. In Denmark, 24% of respondents selected "don't know", compared with 25% of respondents in the United Kingdom. Heat pumps are ranked as a more promising alternative to reduce carbon emissions than district heating in all countries, even though in Poland, Denmark and Italy, the scores are quite similar for the two options. District heating gets the lowest scores in the United Kingdom (3.4). This has been confirmed by earlier research showing public dissatisfaction with district heating given it is often run by monopolies that consumers do not trust (Sovacool et al., 2021a, 2021b).

Results from Italy for both this question and interest in updates stands out a bit. All updates receive a relatively high score ranging from 3.7 to 4.2 and from 3.5 to 4.2. Poland and Germany also show positive responses for the updates regarding reduction of carbon emissions.

In the responses from Denmark, energy efficient cooling systems receive the lowest scores (3.1). For the United Kingdom, electric heating receives a higher score than cooling systems (3.7 vs. 3.5). In Germany on the other hand, both energy efficient electric heating and cooling systems receive the lowest score (3.5), together with low-carbon concrete, steel, and building materials. In Italy, both electric heating and cooling systems receive high mean scores (3.8 and 3.9).

Perceived barriers to reducing carbon emissions

To understand the barriers for households attempting to implement measures to reduce carbon emissions, the respondents were asked to select which out of five challenges they consider the most critical. The results

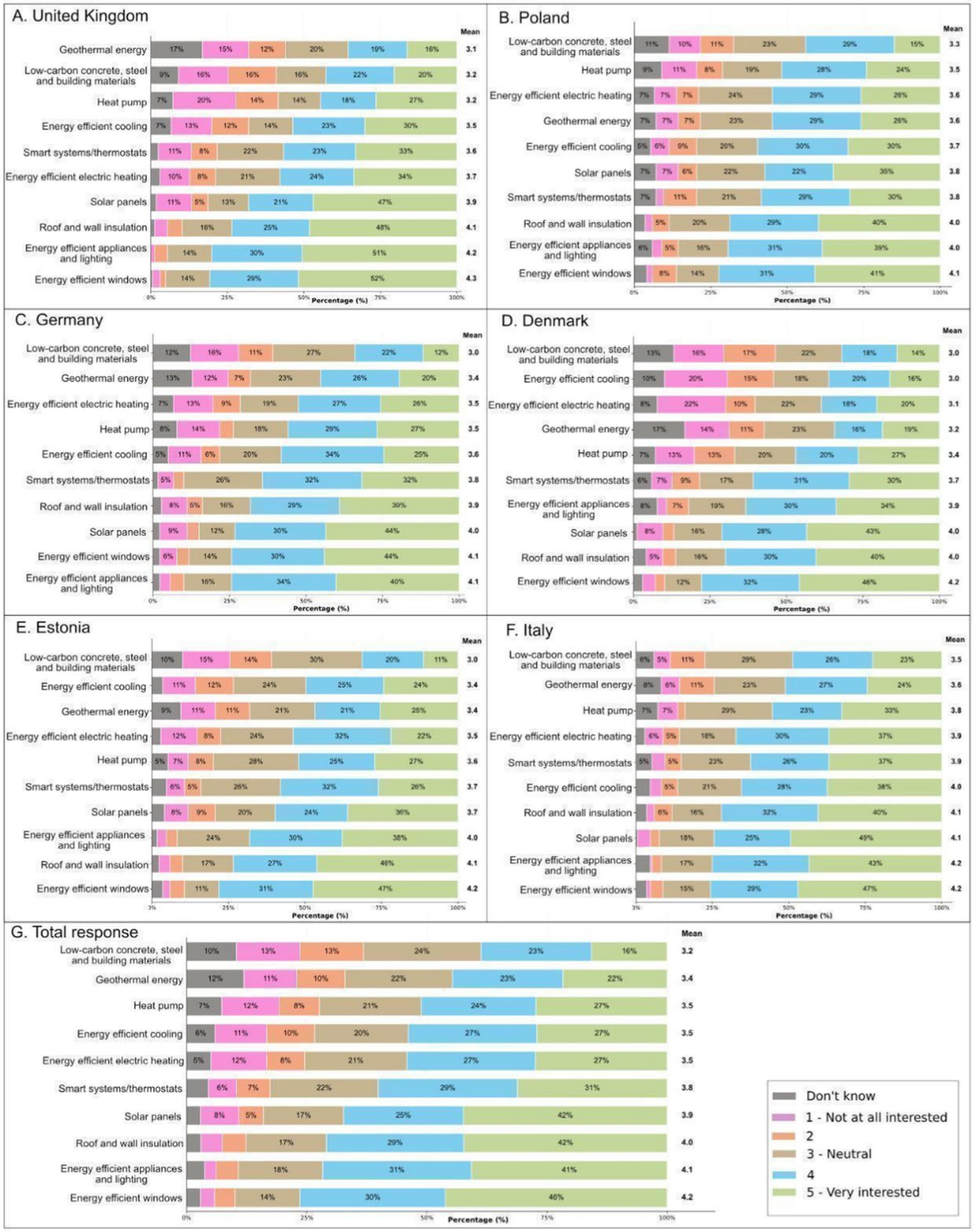


Fig. 1 Interest in home/building updates if there were no obstacles. 5-point Likert scale from not at all interested (1) to very interested (5). The results for all included countries (A-F) as well as the overall responses (G). The plots are arranged in ascending order based on mean score for each home/building updates for total responses

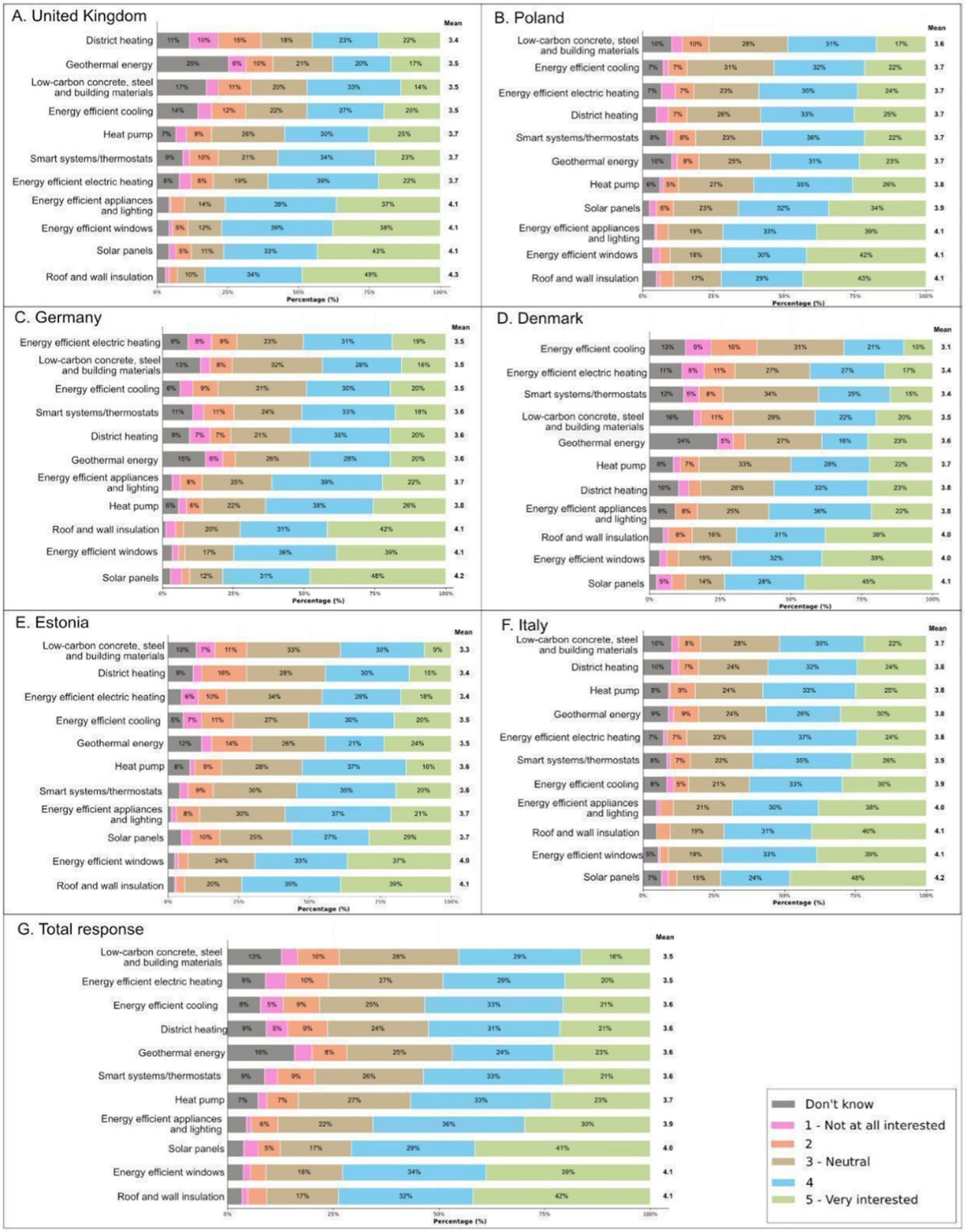


Fig. 2 The perceived promise of building updates for reducing carbon emissions. 5-point likert scale from not promising (1) to very promising (5). The results for all included countries (A-F) as well as the overall responses (G). The plots are arranged in ascending order based on mean score for each home/building updates for total responses

are shown in Fig. 3. This was consistent as high upfront costs were identified as the primary barrier to implementing carbon emission reduction measures in all countries studied. Lack of regulations was ranked the lowest of perceived challenges. In the United Kingdom, 72% of respondents viewed high upfront costs as the main barrier, compared to just 2% who chose lack of regulations. In Italy, 48% selected high upfront cost as the main barrier, with the remaining four barriers each receiving between 12 and 14%.

Willingness to reduce carbon emissions directly

Regarding the willingness to accept changes for carbon emission reduction, the respondents were asked to indicate how willing they are to put up with temporary problems, such as noise, mess or construction work, in their home or workplace to make buildings more energy efficient. They were also asked about how willing they are to pay more for a house built to be more energy efficient and how willing they are to pay more for a house built to be better for the environment. The results for all three questions can be found in Fig. 4.

There is a willingness to accept changes for carbon emission reductions among all countries studied, despite disruption during retrofits, and contrary to earlier studies that found the public mostly placed responsibility on firms or government actors, rather than individuals (Dubois et al., 2019; Moberg et al., 2019, 2021). Poland stands out in the results, with a slightly lower willingness to accept inconveniences and disruptions of construction than the other countries. Many respondents are open to paying higher upfront costs for energy efficiency or environmentally friendly materials, as long as the benefits are clear. In Italy, 30% of participants are not very willing to pay extra for homes that are either more energy efficient or better for the environment. In the UK, unwillingness is slightly higher for environmentally friendly homes (31%) compared to energy-efficient ones (28%). Danish respondents show the greatest willingness to spend more on environmentally friendly houses (80%), while both Denmark and Estonia lead in willingness to pay more for energy-efficient homes (78% and 79%, respectively).

Discussion

This study investigated how households in six European countries (i.e., Denmark, Germany, Italy, Poland, the United Kingdom, and Estonia) perceive and engage with energy efficiency dimensions related to sustainable buildings, perceived barriers, and willingness to reduce carbon emissions. The results show salient cross-national differences, yet the overall

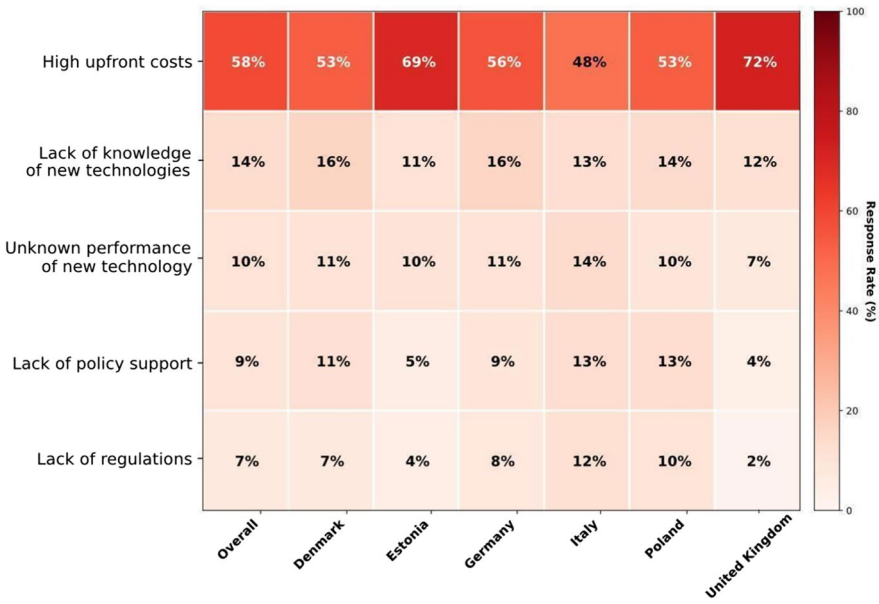


Fig. 3 The main barriers to implementing carbon emission reduction measures. The result is sorted by average response across all countries. Sample size n = 1014

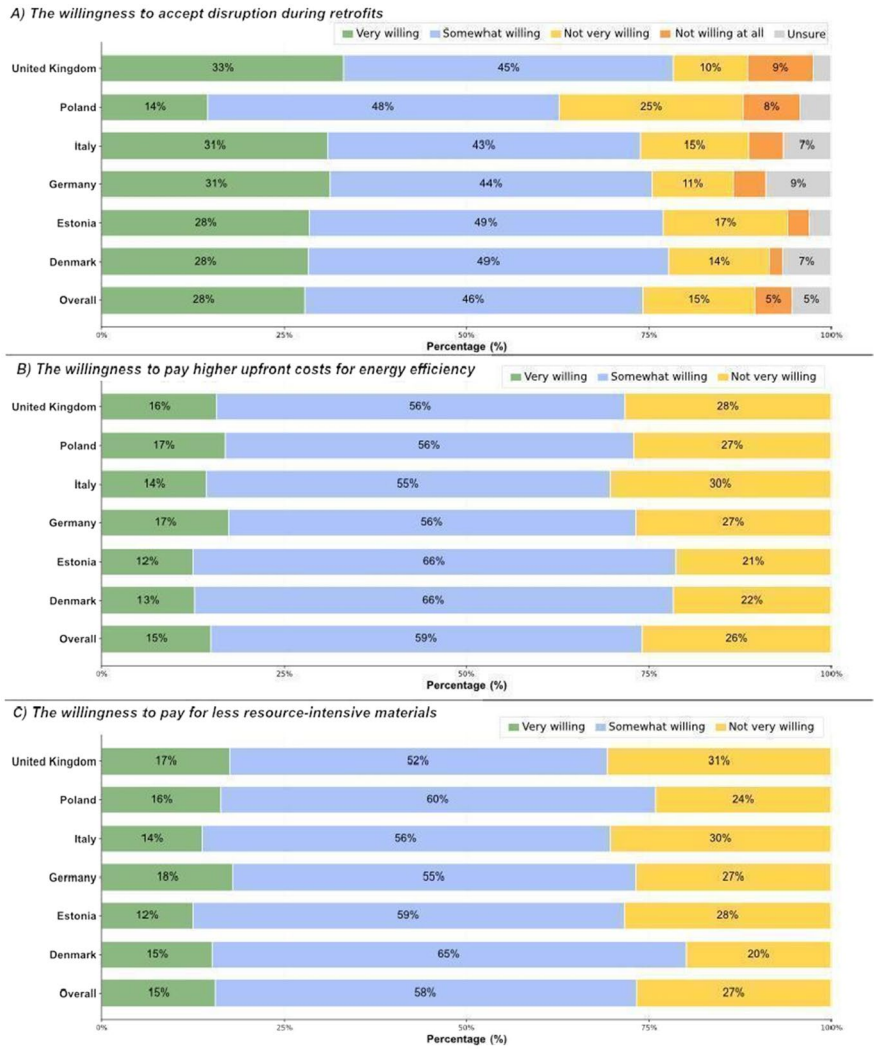


Fig. 4 Results per country and overall, for willingness to accept changes for carbon emission reduction, shown in three different charts. **A**) The willingness to accept disruption during retrofits (5 scale-very willing, somewhat willing, not very willing, not willing at all and unsure). **B**) The willingness to pay higher upfront costs for energy efficiency, and C) The willingness to pay for less resource-intensive materials (very willing, somewhat willing and not very willing). Sample size n = 1014

picture is one of notable similarity in household perceptions of selected energy-efficiency measures across the six cases. Despite institutional, cultural, and political heterogeneity, the survey suggests that attitudes toward several energy-efficient measures are broadly aligned. This finding can be read alongside broader research on Europeanisation of public opinion and policy preferences, although it should not be interpreted as direct evidence of Europeanisation or norm diffusion. Contrary to some expectations, patterns of perceived responsibility and prioritisation of efficiency measures appear relatively similar across environmental state types. While Denmark and Germany do exhibit somewhat higher willingness to pay and accept disruptions, the overall hierarchy of preferred measures and the centrality of upfront costs as a barrier are shared across all cases. This suggests that household perceptions of EE1st-relevant residential measures may be shaped by partially shared policy environments and technology repertoires, rather than by national governance regimes alone.

There have been substantial debates about whether the EU and its values are diverging or converging. Scholars such as Akaliyski (2017), Gerhards (2007, 2010) and Van Houwelingen et al. (2019) show mixed patterns of cultural convergence and divergence across Europe. While some values, such as equality and cosmopolitanism, show convergence, others, such as individual autonomy, diverge, particularly between East and West, reflecting different trajectories of

social change and cultural backlash (Norris & Inglehart, 2019). Energy efficiency may be understood as part of a policy field in which similar objectives and technologies circulate across national contexts, even while broader cultural and political differences remain. In this sense, the survey results suggest partial alignment in household perceptions of selected residential energy measures, rather than a fully convergent European public opinion.

Although some cross-national differences remain evident, the overall picture is one of notable similarity in attitudes toward selected energy-efficiency measures across the six country cases. Despite institutional, cultural, and political heterogeneity, the survey indicates that respondents evaluate several energy-efficient measures in broadly comparable ways. This finding resonates with broader research on Europeanisation of public opinion and policy preferences, but the evidence presented here should be interpreted cautiously and does not, by itself, establish causal Europeanisation.

Importantly, these findings should not be interpreted as evidence that households apply the EE1st principle in the formal policy sense. Rather, they show how households prioritise among different residential energy options that are relevant to the EE1st implementation context. The strongest support is found for visible demand-side and building-envelope measures, especially energy-efficient windows, appliances and lighting, and roof and wall insulation. Supply-side or technology-substitution measures, such as solar panels, heat pumps, geothermal energy and district heating, are also viewed positively, but with more variation across countries and higher levels of uncertainty for some technologies. This suggests that households tend to prioritise familiar and tangible efficiency measures, while their acceptance of supply-side or system-level alternatives depends more strongly on perceived costs, familiarity and national energy infrastructures. In this sense, the survey contributes to understanding the household-level conditions under which EE1st-relevant prioritisation between demand-side efficiency and alternative energy investments may be supported or constrained.

Across all countries, respondents consistently rated energy-efficient windows and appliances/lighting as the most desirable home upgrades, both receiving mean interest scores above 4 on a 5-point scale. Roof and wall insulation likewise appeared among the top four preferred upgrades in all countries, suggesting a strong cross-national similarity in how respondents assess familiar measures for reducing energy use in buildings. Even in cases of slight variation, such as Estonia's lower familiarity with solar panels, this does not disrupt the broader pattern of shared prioritisation of familiar efficiency improvements.

This consistency is further reflected in perceptions of efficiency. Across all six countries, energy-efficient windows and insulation were rated as the most promising carbon-reduction measures, each achieving mean scores of roughly 4.1. Meanwhile, updates such as low-carbon concrete or cooling systems consistently scored lowest, again suggesting broadly parallel hierarchies of what citizens view as impactful.

Barriers to implementation also exhibit striking similarities. In every country, respondents selected high upfront costs as the main barrier to adopting energy-efficient technologies, from 48% in Italy to 72% in the UK, while "lack of regulations" ranked lowest everywhere. Views on responsibility follow a similar pattern: the government is seen as the most responsible actor for enabling energy-efficient technologies across all countries, far above occupants or private actors.

While there are some national differences, with Poland marginally lower and Denmark and Estonia higher on some willingness measures, the general pattern is similar: majorities in every country are willing to accept disruptions or higher upfront costs for energy-efficient homes. Taken together, these empirical results indicate that, despite some heterogeneity, public attitudes toward selected residential energy-efficiency measures show notable similarities across the six country cases, cutting across welfare regimes, governance traditions, and political cultures.

These findings can be read alongside broader debates on Europeanisation, policy feedback and the gradual alignment of policy preferences across Europe, but they should not be interpreted as direct evidence that households have internalised EE1st as a formal policy principle. Research on Europeanisation shows that European polities, policies and economies have become increasingly interlinked, particularly in policy areas where EU competences have expanded over time (Craig & De Búrca, 2020; Schimmelfennig, 2024; Sorace, 2025). At the same time, this literature also emphasises that convergence is uneven and partial. European societies may share certain broad

political and policy reference points, while still exhibiting significant national, regional and cultural variation (Akaliyski, 2017; Gerhards, 2007, 2010; Van Houwelingen et al., 2021). The findings of this survey are consistent with such a mixed picture: households in the six country cases show broadly similar preferences for several residential energy measures, but these similarities coexist with country-specific differences in technology familiarity, willingness to pay and tolerance of disruption.

In this more limited sense, the results may suggest the emergence of a partially shared residential energy-policy environment rather than a fully Europeanised public norm. Previous research has shown that EU policy integration, crisis-driven expansion of EU competences and repeated exposure to common policy debates can contribute to cross-national similarities in policy preferences and public expectations (Boomgaarden & De Vreese, 2016; Fortunato et al., 2024; Mikulaschek, 2023; Sorace, 2025). Energy efficiency is a plausible domain for such partial alignment because EU policy has long promoted building performance, renovation, energy savings and demand reduction through directives, targets and regulatory frameworks. However, the evidence presented here does not allow us to claim that EE1st itself has become a shared household norm. Rather, it suggests that citizens in different national contexts increasingly encounter a similar repertoire of residential energy measures, including windows, insulation, appliances, lighting, heat pumps, solar panels and district heating.

This interpretation is also consistent with environmental-state scholarship. Duit et al. (2016) argue that environmental governance has expanded across advanced states, although the form and effectiveness of environmental institutions differ across national contexts. Similarly, Andrews-Speed (2016) shows that institutions shape energy-transition pathways by structuring incentives, responsibilities and opportunities for action. From this perspective, the observed similarities in household preferences may partly reflect the fact that national residential energy policies operate within increasingly similar European and international decarbonisation pressures, even while domestic institutions continue to shape how these pressures are translated into concrete policy instruments. The United Kingdom's close alignment with the other countries across several survey items is therefore interesting, but should be interpreted cautiously. It may reflect shared policy histories, similar technology markets and continued exposure to European energy-policy debates after Brexit, rather than direct evidence of EU-driven norm diffusion.

The survey also shows why household attitudes should not be equated with EE1st implementation. EE1st is a policy, planning and investment principle requiring demand-side efficiency options to be systematically compared with supply-side alternatives where they provide greater net societal benefits. Household support for individual measures such as energy-efficient windows or appliances cannot, by itself, demonstrate that households apply this principle. What the findings do show is more limited but still important: households tend to give strongest support to familiar, visible and tangible demand-side or building-envelope measures, especially energy-efficient windows, appliances and lighting, and roof and wall insulation. Supply-side or technology-substitution measures, such as solar panels, heat pumps, geothermal energy and district heating, are also viewed positively, but with greater variation across countries and higher levels of uncertainty for some technologies.

This distinction is central to understanding the household interface of EE1st. Residential energy policy does not depend only on whether citizens support energy efficiency in general. It also depends on how households perceive the relative affordability, disruption, familiarity and expected benefits of different demand-side and supply-side options. The results therefore help clarify the social and perceptual conditions under which EE1st-oriented residential policy may be easier or more difficult to implement. In particular, the consistent importance of upfront costs suggests that public support for energy efficiency remains conditional on financing mechanisms, subsidies, information and institutional support. This is consistent with research showing that policy adoption and policy feedback can shape public opinion, especially where citizens trust the institutions responsible for implementation (Mikulaschek, 2023), and is consistent with research showing that attitudes do not automatically translate into energy-saving behaviour or investment decisions.

The findings should therefore be interpreted as evidence of partial alignment in household perceptions of EE1st-relevant residential choices, rather than as proof of EE1st "in practice." They point toward

a possible policy-feedback effect in which decades of European and national energy-efficiency policy have made certain residential measures recognisable and broadly acceptable across different national contexts. Yet they also show that implementation remains mediated by structural barriers, including affordability, technology uncertainty, housing tenure, national infrastructure and differences in policy support. In this sense, the survey contributes to the EE1st literature by identifying the household-level acceptance conditions that may enable or constrain the practical implementation of energy efficiency-oriented residential policy.

Conclusion

This article examined household priorities, perceived barriers and willingness to act in relation to residential energy choices relevant to the implementation context of the EE1st principle. Drawing on a structured survey of 1,014 respondents in Germany, the United Kingdom, Poland, Italy, Denmark and Estonia, the study finds broad support for several building-related energy efficiency and decarbonisation measures. Across the six country cases, respondents tend to prioritise familiar demand-side and building-envelope options, including energy-efficient windows, appliances and lighting, and roof and wall insulation. At the same time, they also express support for supply-side or technology-substitution measures such as solar panels and heat pumps, although these options show more variation across countries. High upfront costs emerge as the most consistent barrier.

The findings demonstrate that households have not internalised EE1st as a formal policy, planning or investment principle. According to these findings, EE1st has not become embedded as a shared European norm. However, the findings do suggest that household preferences around residential energy measures show similarities across the six country cases, despite differences in political traditions, welfare arrangements, energy systems and environmental governance regimes. This pattern is consistent with the idea that European and national energy-efficiency policies may have contributed to a partially shared residential energy-policy environment, even if the survey cannot establish causal Europeanisation or norm diffusion.

The article therefore contributes to the EE1st literature by shifting attention to the household interface of the principle. EE1st remains primarily a decision-making principle for policy, planning and investment, but its residential implementation depends partly on household acceptance of the measures through which efficiency-oriented policy is enacted. The results suggest that policy design should pay particular attention to the difference between demand-side efficiency measures and supply-side or technology-substitution options, as well as to the practical constraints that shape household decision-making. Upfront costs, technology familiarity, renovation disruption and national infrastructure all appear important for understanding whether EE1st-relevant residential policies are likely to be accepted by households.

In conclusion, the survey shows that several of the residential measures associated with an efficiency-oriented transition enjoy broad public support across diverse European contexts. This creates a potentially favourable social foundation for EE1st-relevant residential policy, provided that governments and institutions address the financial and practical barriers that prevent stated support from becoming actual investment and behavioural change. Future research should examine how these stated preferences translate into real household decisions, how different policy instruments affect adoption, and whether the partial alignment observed here reflects broader policy feedback from European energy and climate governance.

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Data availability Data are available upon reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate Not applicable.

Competing interests The authors declare no competing interests.

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