ECONOMY AND FINANCE • VOL. 10. ISS. 4 • DEC. 2023 • DOI: 10.33908/EF.2023.4.3

DEMAND SIDE LIMITATIONS OF FINANCING HOUSEHOLD ENERGY EFFICIENCY INVESTMENTS[1]

A Regional approach

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ABSTRACT

The building sector represents 40% of the total energy use in the European Union. Without exploiting the energy efficiency potential of the sector, neither the Paris Agreement nor the related commitments of the European Union can be achieved. This paper takes a comparative regional approach, differentiating between Northern, Western and Central-Eastern Europe and aims to study the drivers for and barriers to residential energy efficiency investments based on the various demand side indicators related to the housing stock and financial capacity of households. This study finds that financing challenges are more striking in Central-Eastern Europe where households are more cost sensitive and risk averse. Although they are strongly motivated by higher energy bills relative to their income, they are often prevented from making the right investment decision by a number of market and behavioral failures. Public policy, meant to facilitate commercial lending activity on this market, should consider aiming at reducing the real or perceived costs of borrowing via grants, interest rate subsidies and portfolio guarantees. It could encourage households with similar risk profiles to form loan borrowing communities to spread, and thus mitigate, the risk of financing. The innovative public policy suggestions, addressing the demand side, presented in this paper and the topic in general require more research.

JEL codes: D1, G21, G28, G51

Keywords: climate finance, energy efficiency finance, energy efficiency in buildings, energy efficiency policy, financial instruments

1 The authors would like to thank *dr. Dániel Havran* for his valuable comments on this paper.

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1 INTRODUCTION

In Europe significant primary energy saving potential exists in the building sector which accounts for about 40% of the European Union's total energy consumption and for 36% of its energy related greenhouse gas emission (European Commission, 2021; EUR-Lex, 2018). While energy saving potential remains large, there is a particular challenge related to buildings since 75% of the European Union's building stock have poor energy performance despite available incentive policies (European Commission, 2019). Moreover, between 50 and 125 million people are unable to afford proper indoor thermal comfort in Europe due to widespread energy poverty (European Commission, 2009). While the low energy performance of buildings should theoretically create a strong demand for energy efficiency investments, energy and fuel poverty limits the demand as energy poor households cannot afford such investments.

Besides the flawed energy performance of homes, a number of other factors can create a demand for energy efficiency investments. The structural conditions associated with an aging housing stock in general, a lower average size of dwellings, a lower average number of rooms per dwellings, and the presence of leakage, damp and rot can all indicate a demand for energy efficiency investments just as the high running costs of dwellings indicated by consumer expenditure on electricity, gas and other fuels as a share of individual or household level income. In contrast, there are fewer constraints on the demand for energy efficiency investments in regions where households have the necessary financial capacity to pay for energy efficiency investments from savings, where they have a healthy borrowing capacity, where the share of already mortgaged dwellings is lower and where mortgage rates are affordable.

The relevant flagship European policies endeavor that Europe could achieve 32.5% energy savings by 2030 by implementing all cost effective energy saving measures following the previous target of 20% savings by 2020 (European Commission, 2014; 2009). Most recently, the European Green Deal and the 'fit for 55' package, with strong reliance on achieving energy savings aim to make Europe the first climate-neutral continent by 2050 and to reach the target of 55% reduction in greenhouse gas emissions by 2030 compared to the 1990 threshold (European Commission, 2019; 2009). While the European Union is mostly on track with its targets, critical voices are getting stronger saying that the evolving policies and targets are leaving many households behind, deepening the energy efficiency gap in the European society. One of the criticisms is that the cost of carbon permits might be passed onto tenants who cannot afford to pay for the refurbishment of their homes and so household energy bills will go up without achieving significant carbon reductions (Euractive, 2021; Clean Energy Wire, 2020; EEA, 2019). In

response, the European Commission has proposed a new Social Climate Fund to support low-income groups through energy transition from 2025 onwards (European Commission, 2021). However, this policy proposal alone might fail to address various demand side constraints to energy efficiency investments. Even if an energy efficiency measure is cost effective, it can fail to materialize due to the substitution effect of low energy prices, or to the conflict of interest between landlord and tenant in sharing the cost savings post investment, or to the collective action failure experienced by communities of apartment owners in multitenant condominiums, to name just a few demand side constraints.

This line of argument is supported by reality. Refurbishment rates are not at levels they could and are expected to be despite the substantial energy efficiency potential in residential buildings coupled with the theoretically high demand for energy efficiency investments from the customers' side, although owners and tenants should be highly motivated by several expected benefits and positive externalities (*Della Valle, N.* et al., 2022). It seems undeniable that we cannot solely rely on the theoretical premise that cost effective energy efficiency investment plans are put into action because households make rational economic decisions. Furthermore, energy efficiency policies designed over the past decades meant to address the most obvious hurdles, such as access to capital and a lack of information on the expected benefits of energy efficiency improvement of homes. It is clear that even the most successful policies cannot close the energy gap on their own.

Therefore, this study focuses on a better understanding of the demand side limitations in three different regions of Europe in order to provide critical food for thought for policy engineers, financial product designers and other experts to better serve the residential housing market. In this study the research gap is covered by showing that investment drivers and barriers differ region by region based on the state of the housing stock, the prevailing energy prices and the financial capacity of home owners and tenants. Differences and similarities require novel approaches both by policy makers and financiers if upscaling energy efficiency investment volumes in the housing sector is to become a tangible reality and not merely an expectation.

Following the introduction, our research paper will explore the relevant literature on the energy efficiency gap, and will describe the methodology we employ followed by a detailed evaluation of the critical variables we identified as having a strong impact on the demand for energy efficiency improvements in the housing sector. We will discuss the findings and their implications and present our conclusions.

2 DRIVERS FOR AND BARRIERS TO ENERGY EFFICIENCY INVESTMENTS IN THE RESIDENTIAL SECTOR

An energy efficiency gap occurs if optimal energy efficiency investments are not implemented, because households, despite the attractive return on investment, do not employ energy efficiency measures. If the expected economically optimal investments are not carried out, market failures and policy steps in to address them are assumed to be present. At present, it is rather challenging to calculate the actual energy efficiency gap, due in part to regional and national differences. Furthermore, it is equally difficult to measure and quantify the confines which prevent households from implementing energy efficiency measures. The two most cited obstacles are the lack of sufficient economic knowledge and access to capital, both of which have been at least partially addressed by policy makers, nevertheless the volume of energy efficiency investments carried out so far fails to meet expectations. With the building sector making up to 40% of the final energy consumption in the European Union, failing to close the energy gap will prevent most targets of energy efficiency and related climate change mitigation and adaptation to be achieved.

In the same timeframe, both development banks and commercial banks have been active in developing and launching energy efficiency financial instruments, backed by policies, interest rate subsidies, grants and guarantee schemes (Dobi-Rózsa, 2021; *Czakó*, 2021). However, most of these financial instruments failed to reach the level of self-sustainable commercialization and were terminated once the relevant public assistance scheme was withdrawn. Governments were successful at creating assistance schemes and facilitating policies (grants, interest subsidies, guarantees and laws and regulations) in order to (temporarily) address the two main obstacles and to facilitate commercial lending on the market. However, many of the lending programs did not last long enough to become self-sustaining partly because research into and understanding of what financial institutions face during financing such projects from the demand side was insufficient.

2.1 Related research

A great number of studies are available that describe many of the technical and non-technical obstacles to energy efficiency investments and focus on closing the aforementioned energy efficiency gap (*Carlander–Thollander*, 2023; *Palm–Reindl*, 2018; Thollander–Palm, 2013; *Backlund* et al., 2012; *O'Malley* et al., 2004; *Brown*, 2001; *Weber*, 1997; etc.). The main idea behind our line of research is the assumption that if the various constraints are identified, the stakeholders themselves can work towards overcoming them both jointly and individually and, as a result, the energy efficiency gap can be bridged. Thollander et al., (2020) provide a compre-

hensive theoretical framework for such classification. The theories of imperfect information (*Howarth–Anderson*, 1993), adverse selection (*Sanstad*–Howarth, 1994),split incentives (*Jaffe–Stavins*, 1994), access to capital (*Hirst*–Brown, 1990), hidden cost (*Ostertag*, 1999) etc., can all add valuable insight to our understanding of both the gap itself and how to potentially address it. In the same vein, *Cristino* et al. (2021) reviews 450 publications and collects a list of 105 potential issues to describe the obstacles and drivers of energy efficiency retrofit projects. The most frequently discussed financial obstacles in the literature are the high costs of investment, long payback periods and access to capital, which can be overcome by reducing investment costs, provide economic incentives and easy access to financing by governments. Tax reductions, non-refundable grants, interest rate subsidies are recommended as suitable tools for policy makers to achieve their goals.

Compared to the large number of studies discussing the various supply side financial barriers, there are fewer publications addressing various demand side constrains, including technological obstacles from the perspective of the end-user, such as the lack of easy-to-understand-and-use information on suitable technologies and technological synergies, along with their accessibility and affordability on the local market and along the supply chain. When it comes to technical impediments, there are some publications discussing the problem of technical competence, including retrofit project management skills (*Ohene* et al., 2022; Thollander–Palm, 2013). The limited number of publications on market uptake obstacles suggests that many authors are not seriously concerned about the low customer demand for energy efficiency. Some recent studies have been dealing with cultural, social and behavioral obstacles, exploring the behavioral aspect of the demand side (Della Valle N. et al., 2022; *Bertoldi*, 2020; Bertoldi et al., 2013). Resistance to change and lack of clear information on technologies, and their real or perceived impact, are the most researched in this category. Education, training, raising awareness are among the most well-known strategies in the literature to cope with the challenges.

Regarding what drives energy efficiency investments in the housing sector, the personal commitment of the owner/resident to environmental and efficiency principles, a supportive regulatory framework, economic measures and incentivizing policies such as taxes, subsidies, energy audit programs etc., are the best documented factors in the literature (Cristino et al., 2021; *Cooremans–Schönenberger*, 2019; *Chai–Yeo*, 2012). The mainstream theoretical assumption underpinning them is that households make optimal energy efficiency investment decisions, however, individuals, therefore households, often fail in practice to make such rational economic decisions (*Shubert–Stadelmann*, 2015). Such rational choice related individual and collective limitations calling for new policy approaches have been recently explored in studies (*Blomqvist* et al., 2022; *Foulds–Robinson*, 2018; Della Valle N. et al., 2022). This particular research approach suggests that beyond general econom-

ics, behavioral economics and social psychology insights should be drawn into energy efficiency policy making practices. A general observation from the relevant studies is that the volume of energy efficiency literature has become significant over the past decades. The theoretical framework of what drives and limits energy efficiency, especially from the supply side, is well understood. However, it has not evolved in the other direction. Research that goes beyond the supply side of the equation and explores why individuals and communities fail to make optimal energy efficiency decisions and how an interdisciplinary approach might help to better understand this economic phenomenon, seems especially relevant given the nature of the dilemma. However, recent studies that explore the intersectionality of individual behavior, the size of organizations and the decision making process can provide new approaches to policy makers (Blomqvist et al., 2022).

Overall, the limitations of the mainstream literature lie in the fact that even if in general terms the various obstacles to energy efficiency investments are well studied across various economic sectors, only a comparatively lower number concentrate on the residential sector and even fewer on the owner occupied residential sector. Furthermore, even if the numbers of studies dealing with the residential sector are slowly increasing, they cover a few countries only with a smaller regional scope. Equally, although the financial and policy barriers are well covered in the literature, they remain focused on the access to capital, high investment costs, long payback period, lack of information and governmental support. They do not address specifically how energy efficiency financing instruments should be better structured to serve the households' needs and how policy could be better designed to develop and implement such financial products.

The objective of this study is to introduce new thinking around how to best combine various policy elements in order to better respond both to the needs of households themselves and of the financial institutions serving them. We propose that considerations on the demand side limitations to energy efficiency investments should be used to inform financiers and/or policy makers on how financing instruments should be developed and deployed.

2.2 Methodology

This study takes the approach of selecting countries from Europe and dividing them into three regional categories: Northern European countries (Denmark, Finland, Norway, and Sweden) Western European countries (Austria, France, Germany, the Netherlands, and the United Kingdom) and Central-Eastern European countries (Bulgaria, Czech Republic, Hungary, Poland and Slovakia). Based on publicly available European statistics, data are collected on the housing stock, the costs of hous-

ing (running and rental costs) and the financial capacity of households in general. Based on the database, several indicators are developed to describe the quality of the housing stock and the financial capacity of the inhabitants (those who cover running costs and rent if applicable). Most recent data are available from 2018, however, some of the data date back to 2015 or in some cases to 2012. However, considering that the housing stock in general does not change much, we assume that relying on the data between 2015 and 2018 is sufficient for the purpose of this study.

Beyond the drivers discussed in the previous section, the authors will explore various physical and economic conditions that are expected to drive households to invest in energy efficiency retrofits and to employ loans to finance the investment. The first is the physical condition of the dwelling, if it is inadequate. We look at the percentage of housing units built before 1945 and between 1945 and 1969, assuming that those homes require renovation and regular maintenance work, which can include energy efficiency upgrades. Secondly, we look at the average number of rooms per person in dwellings and the average size of the homes measured in square meters. We assume that households who live in smaller homes might be motivated to alter or extend their dwellings in time, which provides an opportunity to introduce energy efficient measures. Similarly, considering the percentage of the population living in homes with the presence of leakage, damp or rot can provide motivation to fix such problems, so every time maintenance work is done on a home it also provides a good opportunity for energy efficient upgrades. Beyond the physical condition of homes, the high maintenance costs of dwellings can also motivate households to invest in energy efficiency. Therefore, the authors review the yearly energy consumption per dwelling and the percentage of income spent on fuel. For households that live in rented dwellings, we review the share of rental costs as a percentage of their disposable income.

In order to better understand the financial capacity of households, the authors also look at their borrowing capacity, in case they would need to take out loans to implement energy efficiency investments. In order to establish whether households have free capacity to take out loans for energy efficiency refurbishment, we review the share of the population owning a home, the proportion of those who have already mortgaged their homes and the average income of households. Finally, with the help of the following indicators, the authors try to describe the segments of society that would be motivated to implement refurbishments, but are not able to carry out the renovation on a market basis. In order to do so, we look at the share of households where expenditure on energy as a share of the disposable income is more than twice the national median, the percentage of arrears on utility bills, and the percentage of the population unable to keep their homes adequately warm.

This study intends to perform a system level investigation and points out challenges the participants face during energy efficiency investments. It is neither a

survey nor the exploration of individual cases. The system level approach aims to help stakeholders to save resources by avoiding similar failures.

The authors assume that there are regional differences regarding drivers to and obstacles of energy efficiency investments of households. Defining the differences in demand in the three regions, which are the subject of our observations, might also allow to define what the financial institutions will face in each region when (and if) they finance residential energy efficiency projects. For example, there might be a difference in the strength of motivation for energy efficiency investments, or a difference in appetite and ability to take out a commercial loan by the household to invest in energy efficiency. It would be valuable to understand the conditions under which households would be willing to take out a loan to finance their energy efficient investment. This study will not be able to answer this question fully, however, it intends to provide a useful conceptual approach for policy makers. Taking into account that the main policy measures used to support commercial lending are interest rate subsidies, grants and guarantees, the authors focus on those policy tools within the framework of the study.

3 DEMAND SIDE DRIVERS FOR AND LIMITATIONS TO ENERGY EFFICIENCY INVESTMENTS IN THE HOUSING SECTOR

In general, we assume that demand for energy efficiency investments is stronger where the physical condition of the building is inadequate, namely it is in need of renovation or extension. Equally, high maintenance costs, especially relative to a household's income can also motivate energy efficiency investments. In addition, the ability to mortgage a home to borrow from a bank and the ability to generate adequate income to be able to pay back the loan are also important indicators when we try to identify the potential demand for energy efficiency investments. However, there are always the energy poor, who cannot access market-based energy efficiency financing for obvious reasons. This study focuses on describing where the demand and financial capacity lies in the society to implement energy efficiency investments with the aim of being able to suggest what the important factors for households are when they consider taking a loan from a commercial bank to finance their energy efficiency needs.

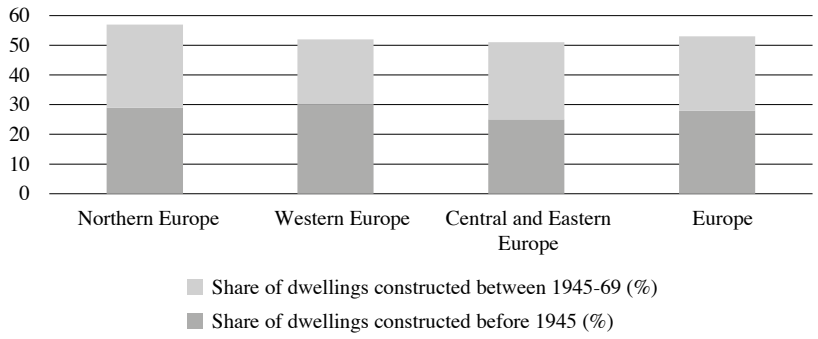
3.1 The physical condition of the dwelling is inadequate

We assume that energy efficiency decisions might be considered by homeowners when they make home renovation or home extension related investment decisions. Therefore, when we look at the demand and motivation for energy efficien-

cy improvements, we do not simply focus on the energy performance of homes. Instead, we use various indicators to characterize the physical conditions of a dwelling on the assumption that aging housing stock may increase the demand for renovations in general. Whenever a renovation project is considered by the household, the opportunity is provided to include energy efficiency improvements in it.

First, analyzing the average age of dwellings in the countries studied shows that some differences are visible between the regions. On average, 28% of the dwellings were built before 1945 and 25% were built between 1945 and 1969 and the two groups together represent just over 50% of the housing stock in Europe. The share of homes built before 1945 is the highest in Western Europe. However, when we add buildings built before 1969, Northern Europe shows the highest share of aging building stock. For the sake of this study, we prefer taking into consideration all homes built before 1969 rather than the ones built before 1945 only, because all those homes are already 50+ years old and can benefit from renovation and energy efficiency improvements. From this point of view, Northern Europe has the highest share of buildings older than 50 years. The result indicates that the demand for home improvements (including energy efficiency) could be higher in Western and Northern Europe than in Central-Eastern Europe.

Chart 1
Share of dwellings constructed before 1969 and between 1945–69 in Europe.

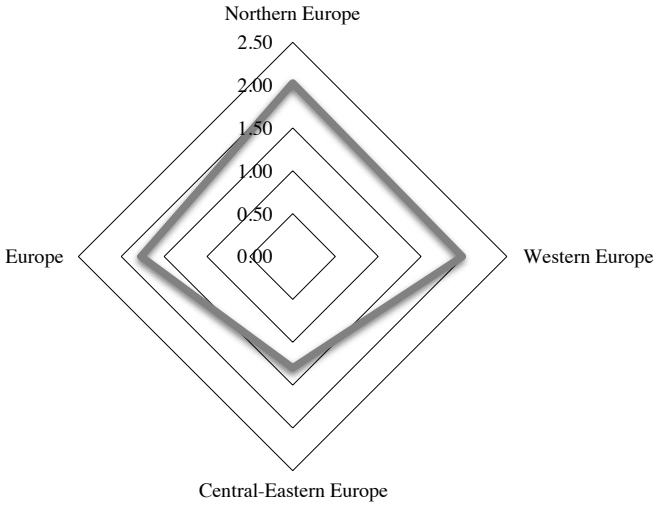


Source: own research based on Eurostat data

Second, looking at the average number of rooms per person in dwellings (2018) shows that households in Central-Eastern Europe live in homes of fewer than two rooms per dwellings on average, while Northern and Western European households enjoy more comfort having more than two rooms per units on average. Therefore, in theory, Central-Eastern European households should have a higher

demand for altering or extending their living space to achieve higher level of comfort. This fact, in turn, creates a window of opportunity to install energy efficient measures in their homes. From this point of view, Northern European households might be the least motivated in carrying out home improvement projects.

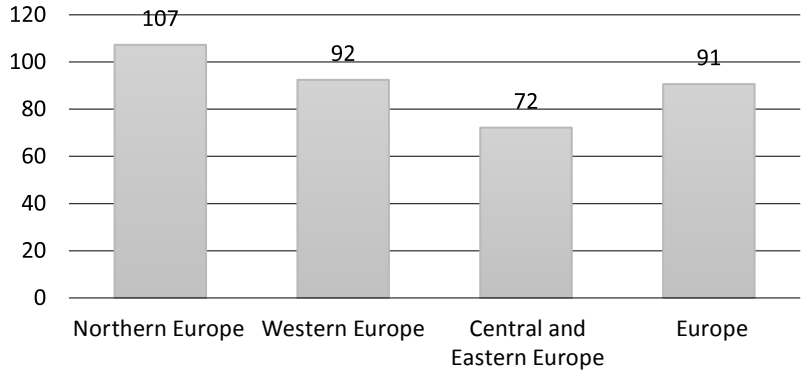
Chart 2
Average number of rooms per person in owned dwellings in Europe (2018)



Source: own research based on Eurostat data

Third, the average size of dwellings measured in square meters (2012) might also indicate the level of comfort and households living in smaller spaces might be motivated to invest in a bigger home, which creates new energy efficiency investment opportunities. In Northern Europe, the average size of dwellings is over 100 square meters. In Western Europe the average size of the homes is close to 100 square meters, except for the United Kingdom where homes are only just above 70 square meters. (This might be caused by the fact that the United Kingdom is a densely populated island nation with limited available and suitable land to build on.) Compared to them, Central-Eastern European residents live in smaller units with an average of 72 square meters in size. However, it is worth specifying that home sizes range between 45 and 75 square meters in this region, in Romania, for example, the average home measures 43.9 square meters only. The data suggest that households in Central-Eastern European countries will be the most motivated to invest in their homes to make them more comfortable.

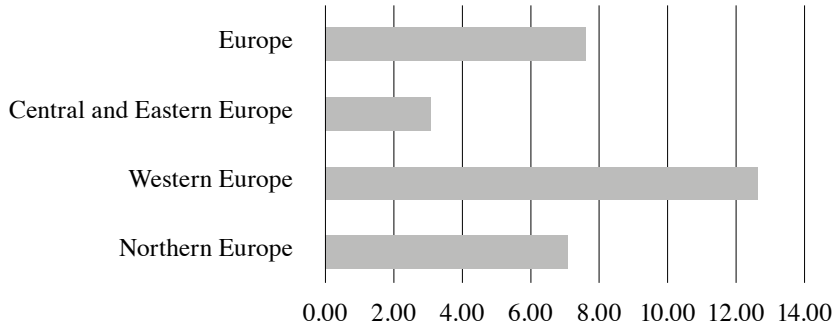
Chart 3
Average size of dwellings in Europe in 2012 (m²)



Source: own research based on Eurostat data

Fourth, analyzing the percentage of population who live in homes with leakage damp and rot (2016), Western European homes show the worst picture, followed by Northern Europe. The lowest percentage of population living under these conditions are in Central-Eastern Europe, which suggests that homes there might be well kept and looked after, and also because the housing stock in this region is the youngest (relatively) among the observed regions.

Chart 4
Presence of leakage, damp, rot in homes



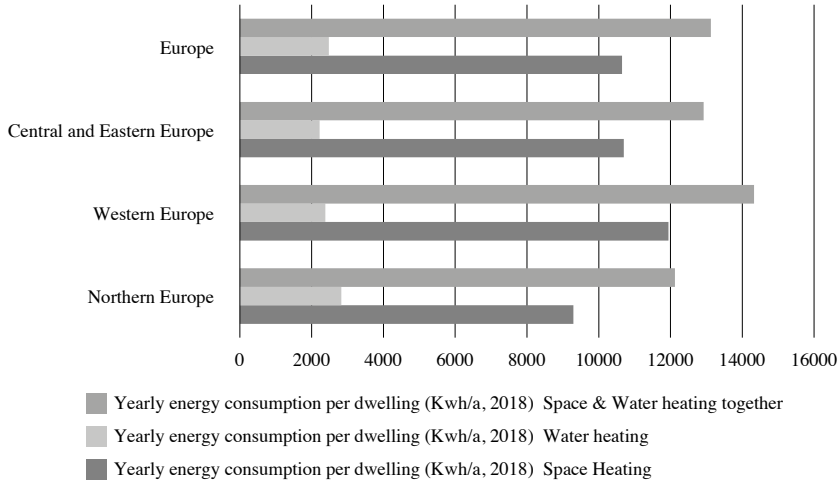
Source: own research based on Eurostat data

3.2 High running cost of dwellings

Besides the physical quality of homes, there are other factors that create demand for energy efficiency. Higher energy bills and generally high maintenance costs of dwellings relative to the income of the household can also create a demand for energy efficiency investments with the aim of reducing energy and maintenance costs. In this part of the study, we use various indicators to describe the potential demand generated by the factor of high energy and maintenance costs.

First, the yearly energy consumption per dwelling (Kwh/a/dwelling, 2018) for space and water heating shows a similar image across Europe. However, Chart 5 shows that Northern European households consume the lowest amount of energy for space and water heating followed by Central-Eastern Europe. When we take into account that, in Northern Europe, the average size of homes is 35 m2 larger than in Central-Eastern Europe, we can assume that the latter is in the most disadvantageous position and might be the most motivated to implement energy efficiency investments.

Chart 5
Annual energy consumption in dwellings in Europe

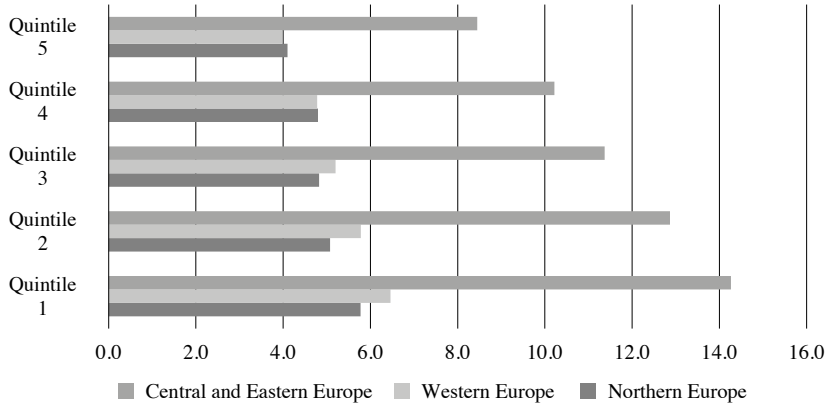


Source: own research based on Eurostat data

Second, looking at the consumption expenditure for electricity, gas and other fuels as a share of income in quintiles, Northern European households spend the lowest percentage of their income on fuel in all the four income levels of the population. However, consumption expenditure slowly increases from quintile 1 to

quintile 5, from the 20% lowest income level population to the highest 20%. Western European households spend a little more of their income on electricity, gas, and other fuels than their Northern European neighbors while Central-Eastern European households spend the most. Furthermore, as we move forward to the middle to low-income segments of the society, fuel expenditures progressively increase. It might indicate a higher demand for energy efficiency upgrades towards the middle to low-income segments of the society. The trend is most striking in Central-Eastern Europe where the poorest 20% of households spend nearly 15% of their income on electricity, gas and other fuels while the richest 20% spends nearly 9%. On the other hand, in Northern and Western European countries the consumption expenditure for fuel in each quantile is around half of that in Central-Eastern European countries'.

Chart 6
Consumption expenditure for electricity, gas and other fuels (%) 2015

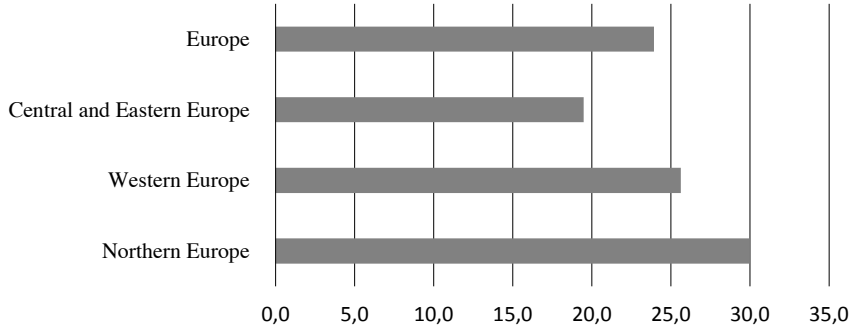


Source: own research based on Eurostat data

Third, we look at the share of rent of occupied dwellings compared to disposable household income, 2018 (as % of income spent on rent) indicator to understand how much households spend on rent as a percentage of income on average. The indicator of the population renting a home (2018, as % of population) shows that on average 27% of the population live in rented homes in the countries of observation in Europe. The rate is the highest in Western Europe where 38.8% of the population rent their homes and they spend on average 23.9% of their disposable income on rent. Compared to that, in Central-Eastern Europe only 14.8% of the population rent their homes and they spend only 19.5% of their disposable income on rent. In Northern Europe 30.6% of the people rent and pay 30% of their

disposable income on it. (Data for Norway were not available here.) Based on the indicators, we might assume that Northern and Western European households living in rented homes might be more interested in energy efficiency investments than Central-Eastern European households where only a small proportion of the population rent their homes and pay relatively low rent for it.

Chart 7
Share of rent related to occupied dwelling in disposable household income, 2018 (as % of income spent on rent)



Source: own research based on Eurostat data

Summarizing the above indicators, we can describe the demand for residential home energy efficient investments throughout Europe and we can identify the critical factors which can trigger positive energy efficiency decisions. The aging housing stock, the inadequately maintained homes and small living space can motivate households to invest in home extensions and renovation which can create a demand for energy efficiency investments as well. Based on the physical condition of the building stock, Western European countries might have higher motivation, potential and demand for energy efficiency investments, because their homes are in a worse condition than homes in Northern and Central-Eastern Europe. Compared to this, in Northern Europe homes are in better condition, larger and they consume the lowest amount of energy compared to the others reviewed in this study. Finally, Central-Eastern European households might be strongly motivated to install energy efficiency measures because they live in smaller homes with relatively high consumption of energy per square meter and even if their housing stock is somewhat younger than in Northern and Western European countries with less of damp, leakage and rot issues, they are also aging.

Comparing the regions based on the indicators describing the physical condition of homes in Table 1., we use mark + to show how pressing the problem is and how

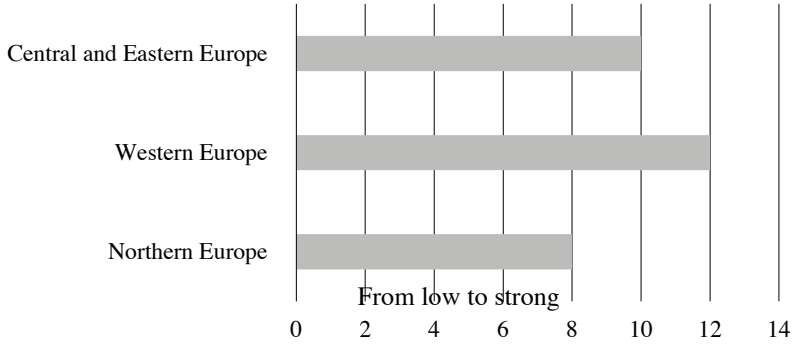
strongly households might be motivated to invest in energy efficiency. For example, the age of housing stock is a pressing issue across Europe and might generate a strong demand for energy efficiency in all regions. However, we can see more significant differences when we compare the share of homes built before 1969. There we can see that the building stock built before 1969 has the largest share in Northern Europe. Also, energy consumption is a less worrying factor in Northern Europe compared to Western and Central-Eastern Europe.

Table 1
Indicators creating demand for energy efficiency investments in regions

Region	Northern Europe	Western Europe	Central-Eastern Europe
Age of dwellings	+++	++	+
Number of rooms per person in dwellings	+	++	+++
Size of dwellings	+	++	+++
Presence of leak, damp and rot	++	+++	+
Energy consumption	+	+++	++
Fuel cost in disposable income	+	++	+++
Rental expenditures in disposable income	+++	++	+

Note: + stands for low motivation, ++ is average motivation and +++ is high motivation
Source: own research based on Eurostat data

Chart 8
Strength of motivation for energy efficiency investment



Source: own research based on Eurostat data

In order to quantify the strength of motivation for energy efficiency investments, we added the marks + from *Table 1* and placed them on a motivation scale, which shows that based on the seven indicators we discussed above, the motivation for energy efficiency investments is the highest in Western Europe and Central-Eastern Europe and the lowest in Northern Europe. In the next step, we analyze what might hinder this motivation and prevent households from implementing energy efficiency measures at an optimal level.

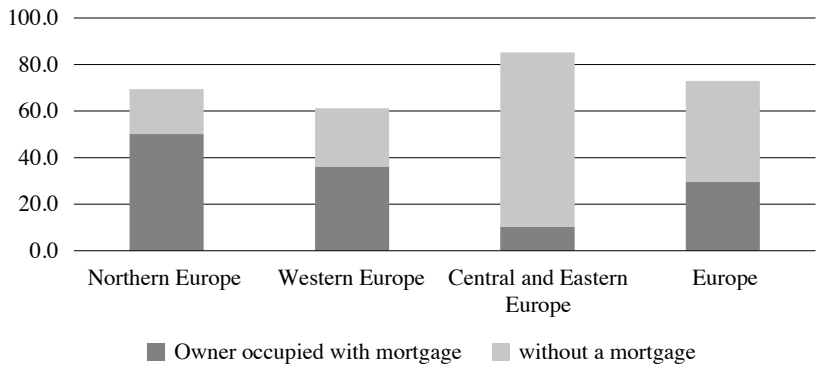
3.2.1 Financial capacity of households

Energy efficiency investments may be financed from the combination of financial savings, governmental subsidies, and commercial loans. This study would like to describe the financial capacity of households by using indicators showing the proportion of households who own their homes (owner-occupied), assuming that they are able to mortgage the unit in question. We also look at the percentage of the population that already has a mortgage or another loan to repay compared to those who are mortgage free. We review differences between regions regarding average mortgage rates, loan-to-value, loan-to-income and loan service-to-income ratios to see if there are regions where mortgage is more affordable in general. We also review the different income levels in the regions of interest as they can indicate the ability of households to enter the loan market. Finally, we check indicators related to fuel poverty. The reason is that, in addition to households that rent their homes, and therefore have no property to mortgage, there are other households that could mortgage their homes in theory but are prevented from doing so by their low income. In order to define this proportion of the so-

ciety, we look at indicators such as arrears on utility bills and an inability to keep their home adequately warm.

First, reviewing the distribution of the population by tenure status (2018, %) we find that 73% of the population own the home they live in (so called owner-occupied homes). Less than half of the population (43.5%) live in a mortgage/housing-loan free owner-occupied home, while 29.5% of the population do not fully own their homes, having a mortgage/housing-loan to repay. When we look at regional differences, we find that in Northern Europe the ratio is 19.3% (without a mortgage) to 50.1% (with a mortgage), while in Western Europe it is 25% to 36.2% and in Central-Eastern Europe it is 75% to 10.2%. In the latter region, 85.2% of the population live in owner-occupied homes and only 10.2% of the population who own their homes have a mortgage or a housing loan to repay. By contrast, in Northern Europe, where 69.4% of the population own their homes, 50.1% of the population are still repaying their loans. Similarly, but to a lesser extent, in Western Europe 61.2% of the people own their homes while 36.2% of them have outstanding repayment commitments. The figures can indicate the level of financial capacity of homeowners to mortgage or remortgage their homes to implement energy efficiency investments. *Chart 9* shows that theoretically Central-Eastern European homeowners might have the largest free capacity to mortgage their homes if they are interested in financing energy efficiency investments from loans.

Chart 9
Owner-occupied homes with a mortgage or a housing loan (2018)



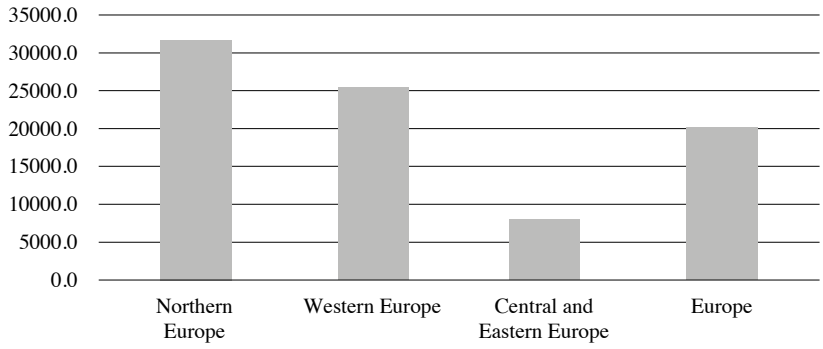
Source: own research based on Eurostat data

Reviewing the annual average mortgage rate (in %, 2018), we find that Northern Europe has the lowest mortgage interest rate at an average of 1.1%, followed by Western Europe with 1.9%. In Central-Eastern Europe in 2018 the annual aver-

age mortgage rate was calculated at 3.8%. Furthermore, in the euro zone (2018), the average loan-to-value ratio was 81% (households borrowed 81% of the purchase price of a home). This represented 4.4 times their annual disposable income (loan-to-income ratio), and those households spent 24.4% of their income on loan repayments (loan service-to-income ratio) (ECB, 2020). At the same time in Central-Eastern Europe, mortgage is not only more expensive but the conditions to take out a loan are also tighter. For example, compared to the average 81% of loan-to-value ratio in the euro zone countries in 2018, the maximum limit of the ratio in Hungary was 80% (NBH, 2023) and typical loan-to-to value ratio of a new mortgage is below 60% (EMF, 2022). Even though there is significant free capacity on the mortgage market in Central-Eastern Europe, the loans there are the most expensive and the mortgage loan conditions are the most unfavorable.

The median disposable income in the European Union (2022) is 19.883 euros. In the Northern European countries reviewed, the median disposable income is over 31 thousand euros while in the Central-Eastern European countries it is four times lower and does not reach 8 thousand euros. The low level of income in Central-Eastern Europe compared to other European countries might exclude households from this vital financing source. We also assume that the significant difference in disposable income levels between Western and Northern European countries and Central-Eastern European countries corresponds to a higher cost sensitivity of households when it comes to the cost of purchasing energy efficient technologies and /or taking a loan from a bank.

Chart 10
Median disposable income in EU27 (2022)



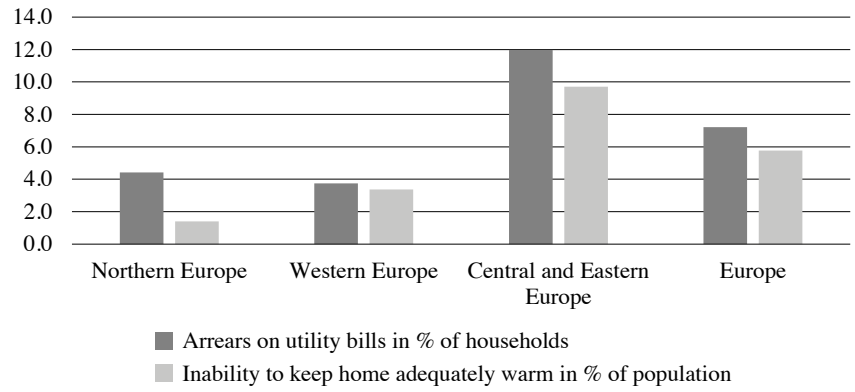
Source: own research based on Eurostat data

Finally, two other segments of the residential market must be briefly reviewed. These segments are not present on the mortgage market either because they do

not own their homes (rental market) or because they live in fuel poverty. Reviewing the rental market in the countries studied we find that 27% of households rent their homes either from the market, at market prices, or, through some social scheme, at below market rates. The main difference between the three regions is that in Central-Eastern Europe only 14.8% of the population live in rented units and the larger portion of them pay a reduced price or access housing for free. In Western and Northern Europe 38.8 and 30.6% of the population live as tenants of rented homes and most of them rent at market prices with a smaller part having access to social housing.

Looking at the indicators of arrears on utility bills and the inability to keep homes adequately warm as a percentage of households (2018), we find the most energy poor households are in Central-Eastern Europe where 12% of the households are in arrears on utility bills while 9.7% of the population are unable to keep their homes adequately warm. In Northern Europe we find only 1.4% of the population struggling with warming their homes and 4.4% of households are in arrears on utility bills. Similarly, in Western Europe 3.7% of households experience difficulties in keeping up with paying their energy bills on time and 3.4% of people struggle to heat their homes properly. These households are certainly excluded from the mortgage market. However, it is important to include them in this study because their challenging condition is also a key driver for energy efficiency investments, both when it comes to reducing their energy bills and increasing their comfort.

Chart 11
Indicators for fuel poverty (2018)



Source: own research based on Eurostat data

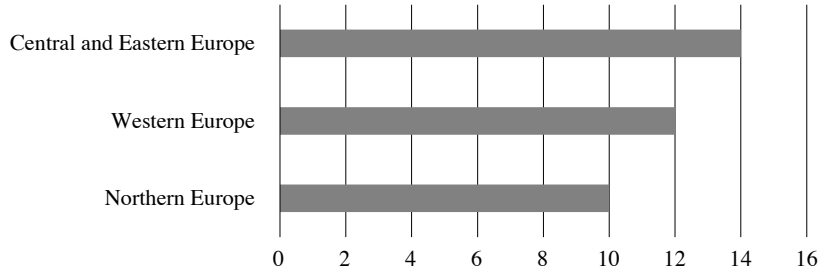
Comparing the regions based on the indicators describing the financial capacity of households in *Table 2*, we use mark + to show how pressing the problem is and how strongly households might be financially limited to invest in energy efficiency. In Central-Eastern Europe the majority of the homes are owner-occupied and free of the loan burden. However, those households might not be able to take advantage of this capacity due to unfavorable borrowing conditions and their comparatively lower income. In addition, fuel poverty is a more threatening and pressing issue. Western and Northern European households might have better financial means; however, a larger portion of the population live in rented homes where they cannot take advantage of the more favorable mortgage loan market for obvious reasons.

Table 2
Indicators for demand side limitations for energy efficiency investments in regions

Region	Northern Europe	Western Europe	Central-Eastern Europe
Ratio of owner-occupied homes	++	+++	+
Mortgage interest rate	+	++	+++
Owner-occupied households with mortgage	+++	++	+
Median disposable income	+	++	+++
Arrears on utility bills	++	+	+++
Inability to keep home adequately warm	+	++	+++

Note: + stands for low motivation, ++ is average motivation and +++ is high motivation
Source: own research based on Eurostat data

Chart 12
Limiting ability to implement energy efficiency investment from low to high



Source: own research based on Eurostat data

In order to show how strong the financial obstacle for energy efficiency investments is, we added the marks + from the Table 2 and placed them on a limitations scale, which shows that, based on the six indicators we discussed above, the constraints on energy efficiency investments are the highest in Central-Eastern Europe and lowest in Northern Europe. Overall, our comparative analysis shows that the stronger the drive, the biggest the limitation to implement energy efficiency investments (Central-Eastern Europe). Similarly, where the motivation is the weakest (in Northern Europe), the financial means are the strongest. Western European countries are somewhere in the middle, with a moderately strong demand for energy efficiency along with the presence of some important limitations, such as the sizable proportion of rented homes and a relatively lower mortgage owner-occupied market.

4 DISCUSSION

Economic measures such as profit maximizing and cost reduction and policies such as taxes, subsidies and energy audit programs drive energy efficiency investments in general. Beyond the economic measures and policies, the regulatory framework in place and the personal commitment of the end-users, such as caring for the environment, also play an important role when it comes to taking the decision to invest into energy efficiency improvements.

Beyond these considerations, general structural, functional, or aesthetic home renovations and extension projects also provide an opportunity for households to integrate energy efficiency measures into their projects. Considering that the housing stock in Europe is aging and the demand for more comfortable living conditions might increase, the demand for larger or remodeled living spaces, the

drive for renovation and home extension does exist, offering an obvious opportunity for energy efficiency investments. The older, the smaller, and in the worse condition an apartment or a house is, the greater the demand for renovation, expansion, and with it for energy efficiency investment. Beyond the physical conditions of housing, energy efficiency investments can be driven by the financial parameters of the home, such as the cost of energy and rent (if applicable) as a percentage of the disposable income of the household. The more expensive it is to run a home, the stronger the demand for energy efficiency investments.

Our research results support the conclusions of previous papers, i.e., there is significant energy efficiency potential in the housing sector across Europe. However, based on the indicators we applied in this study, the highest demand is to be found in the Central-Eastern European region, followed by Western and Northern Europe. This finding has strong implications for pan-European and European Union wide policies meant to facilitate energy efficiency and related climate mitigation and adaptation goals in the residential sector. The greater demand in Central-Eastern Europe should be fostered and built upon.

Compared to these strong driving forces for energy efficiency investments in the housing sector, equally strong or even prohibitive obstacles have been identified. Taking into account the financial obstacles, it can be established that there are noticeable differences across the regions observed. The most striking is the phenomenon that can be observed in Central-Eastern Europe, where the median disposable income of households is just around a quarter of that in Northern and Western Europe. Furthermore, Central-Eastern European households access mortgage loans under less favorable conditions, namely at higher interest rates and lower loan-to-value ratio. Which in turn requires a higher share of savings, own funds they might not possess due to a lower margin of saving potential on their lower income. In addition, the income-proportional energy bills of Central-Eastern European households are more than double those of the Western and Northern European households in all quintiles of the population. Not to mention energy and fuel poverty, which is also the most significant in this region. These findings are important for both national governments in the Central-Eastern European region and for the European Union as a whole when it comes to designing policies and financing instruments that can overcome these challenges and turn them into an opportunity for investment.

However, financial constraints exist in different forms in Northern and Western Europe as well. First of all, fewer households live in owner-occupied properties and therefore they pay market prices on rent, they also, most crucially, do not have control over investment decisions in the property. Another issue is that, especially in Northern countries, a significant portion of owner-occupied households have already mortgaged their homes and might not be able to remortgage

them to finance energy efficiency improvements. Overall, this study finds that the stronger the driving force, the stronger the limitations for energy efficiency investments. This study is not intended to calculate the extent of those barriers and limitations, since that would exceed the scope of this research.

However, it can be established based on the indicators used that in Northern Europe, compared to the other two regions, a relatively lower level of motivation and at the same time weaker financial obstacles can be observed concerning energy efficiency investments. In such an environment, the financier may find that there is no interest in residential energy efficiency loans, even though the bank would be able to finance the interested households, since neither their income nor the prevailing interest rates would be an obstacle. As the study shows, salaries are the highest here and mortgage interest rates are the lowest. The major obstacle may be that the customer can no longer take out another mortgage loan, as the household has already exhausted this option when purchasing the property, and the overall loan burden on the household is already high. What can policy makers do in this case in order to encourage energy efficiency borrowing? If we assume that the major issue is the high mortgage ratio in the owner-occupied housing market, the policy maker may apply risk mitigation tools with the aim of replacing or supplementing mortgage requirements. More innovatively, policy may consider community risk-taking instruments to spread the lending risk across households that have a similar risk profile to implement energy efficiency projects. These instruments could not only be highly innovative but also popular in advanced social cooperative cultures like Northern Europe.

Regarding Western Europe, this study observes stronger drives for residential energy efficiency investments accompanied by stronger financial challenges compared to Northern Europe. The housing stock in Western Europe is also aging rapidly and the largest proportion of dwellings with serious structural and functional problems (leakage, rot, damp, etc.,) are found here. Perhaps that is precisely the reason for the proportionally highest energy consumption. However, the energy costs relative to the disposable income of households are half of the Central-Eastern European figures, therefore, even if the dwellings waste energy, the residents can afford to pay. Compared to Northern Europe, proportionally fewer people live in their own properties here, but the homes are burdened with mortgage loans to a lesser extent, which in principle gives a greater opportunity to take out loans for energy efficiency projects. However, the mortgage interest rate in Western Europe is slightly higher than in Northern Europe, which can be a holding back force for households. Looking for an explanation as to why energy efficiency investments are lagging in the private residential sector in Western Europe, despite the fact that there is sufficient driving force for these investments,

and the financial constraints seem to be surmountable, we argue that it is worth distinguishing between households of different income levels.

It is likely that the more affluent households do not have a strong demand for energy efficiency, perhaps because they see their residential property primarily as an investment and they do not have the tools to monetize investments into energy savings as easily as they can monetize a kitchen and bathroom renovation, or property extension, when they resell their property on the market. The poorer social strata, which most likely live in rented properties, would certainly be very motivated to reduce their energy bills, especially those that have no access to social housing and rent from the private market. On the rental housing market (which is also decisive in Northern Europe) the tenant who pays the energy bill is interested in the energy efficiency investment but cannot take out a mortgage loan in the absence of ownership on the property. Where the costs of the investment are borne by the home owner, but the resident enjoys the reduction in energy costs, the split incentive hinders energy efficiency investments. In order to be able to pay for the energy efficiency investment, the landlords must increase rental fees, a measure which would not probably be very popular in the private sector and especially not in the social housing sector. Overall, financial institutions in Western European countries might be faced with the issue of a lack of interest in standalone energy efficiency loans and they may think that regular housing loans can serve the housing energy efficiency market better from the banks' perspective. Under these circumstances, the policy maker might offer interest rate subsidies to make energy efficiency loans more attractive than mortgage loans and more sustainable than non-refundable grants.

This study finds that the motivation for residential energy efficiency is probably the strongest in Central-Eastern Europe where the financial obstacles are also the strongest. Since the driving force for energy efficient investments is strong, we assume that the energy efficiency potential is the highest here, which makes this region particularly interesting from the point of view of research and EU wide policy making. If we understand the demand and its limitations, it might be possible to determine what kind of financing products, energy efficiency loans, can be created for this market and what policy instruments should be behind them. We can conclude from the research that in Central-Eastern Europe the majority of households live in owner-occupied properties, and only a small portion of this ownership pool is burdened by mortgage compared to the other two regions. This provides an advantageous position for homeowners in need of energy efficiency improvements. Due to home ownership rights, they have the decision in their own hands to invest and they probably can mortgage their home to do so, due to its value. However, these investments often do not take place and fall far short of their potential. It is conceivable that, for the reasons described in this study, Cen-

tral-Eastern European households are more cost and price sensitive compared to other regions in Europe. This means that they respond highly sensitively to the price of energy efficiency technologies and the cost of financing such investments. In addition, or precisely because of this, they are especially risk averse. As a result, the financier may find that, in theory, the demand for energy efficiency loans is definitely there, but loans are not requested by those households.

We assume that for the reason of cost and price sensitivity, households would strongly prefer predictable and affordable cost of financing, in order to be able to securely budget the cost and anchor it into their tight monthly household budgets. It suggests that these customers would opt for fixed rates, moderate, and fix monthly loan repayment installments. Moreover, due to their risk aversion, they would opt for other collaterals than mortgaging their homes for energy efficiency reasons, even if in general mortgage rates are more favorably priced than for example personal consumer loans. In addition, they may not have sufficient capital to meet the loan-to-value ratio nor can they finance energy efficiency projects on their own. These multiple contradictions may push households towards an irrational decision, choosing more expensive and riskier financing for their projects or completely preventing them from implementing energy efficiency investments. If our assumptions hold true, policy should aim to reduce the cost of financing to the level that commercial banks could offer loans with fixed and affordable monthly repayment schedules. A combination of public-budget neutral non-refundable grants and interest rate subsidies could be employed to achieve this end without distorting the market with volatile, excessive, and unsustainable grants. On the other hand, policy makers could use financial guarantee tools and community risk sharing instruments to enable banks to replace mortgage with other but equally valuable collaterals.

5 CONCLUSION

Financial barriers continue to be perceived as one of the key obstacles obstructing the implementation of residential energy efficiency investments. However, their extent varies by region. The problems are most striking in Central-Eastern European countries. Households in Central-Eastern Europe continue to be highly cost sensitive and risk averse which is further amplified by the current inflationary environment, interest rate hike cycles and unpredictably fluctuating energy prices. This paper argues that taking into account the cost sensitivity and risk aversion of households might help to better understand what financiers face when they consider financing residential energy efficiency investments. The findings of the study support the argument that where households are more sensitive to the cost

of financing (and technology), and are highly risk averse, a more sophisticated policy approach is required to enable financial institutions to serve the market and respond to the large passive demand present on it. Furthermore, besides relying on traditional policy tools, such as grants, interest rate subsidies and loan guarantees, so called portfolio guarantees could be employed, where households with similar risk profiles can form a loan borrowing community, spreading the risk of financing across the community.

According to our current knowledge, it can be assumed that a properly developed synergic policy tool could move the residential energy efficiency market out of the current suboptimal deadlock, at least in Central-Eastern Europe. In addition to the fact that financial constraints may seem less worrisome in Northern and Western Europe, they are present in a different form and also require a complex and differentiated policy approach. In countries where the rental market is meaningful and the split incentive is a major obstacle to investments in energy efficiency, the regulator and policy maker might have to consider less popular approaches and enforce energy efficiency measures on private and social landlords or accept the inevitable lack of results experienced so far.

The above challenges and opportunities should be studied further. Case studies are already available demonstrating how portfolio guarantees work in the owner-occupied residential market and how split incentives can be addressed in social housing. It would be important to study replication attempts of successful cases to understand how, if at all, it is possible to extend a successful model to other countries within a region or even outside of it.

This study is limited by the fact that demand for energy efficiency investments may be influenced by other variables in addition to the critical factors identified by the authors through their literature review. In addition to their age bracket, the particular conditions of the buildings can be determined, for example, by the time that has passed since they were last refurbished, if such a renovation had an impact on their energy performance, or by the particular construction technology employed, in case it significantly deviates from the general age bracket class reviewed in statistics. In addition, the variables employed in the study could be weighted in a differentiated manner, based on behavioral studies for example, leading to more specific conclusion. Furthermore, short term and midterm variations in inflation and world fuel prices, if not addressed by national and European level policies, could impact household energy prices, thereby modulating this variable.

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