Lisbon School of Economics & Management
Universidade de Lisboa

MASTER IN

INNOVATION AND RESEARCH FOR SUSTAINABILITY

MASTER´S FINAL WORK

INTERNSHIP REPORT

TOWARDS A SUSTAINABLE REAL ESTATE MARKET: TACKLING ENERGY POVERTY THROUGH ENERGY EFFICIENCY POLICIES IN URBAN AND RURAL PORTUGAL

MADALENA DIAS FERREIRA PEREIRA DOS SANTOS

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SUPERVISION:
PROFESSOR ANÍBAL LÓPEZ
ENG. MANUEL CASQUIÇO

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GLOSSARY

ADENE – Agência para a Energia.

AC – Air Conditioning System.

CCDR-N – Comissão de Coordenação e Desenvolvimento Regional do Norte.

DGEG – Direção Geral de Energia e Geologia.

DHW – Domestic Hot Water System.

EED – European Energy Directive.

ELPPE – Estratégia de Longo Prazo de Combate à Pobreza Energética.

EPVI – Energy Poverty Vulnerability Index.

EU – European Union.

GEE – Gabinete de Estratégia e Estudos.

HTR – Hard-to-Reach Consumers.

INE – Instituto Nacional de Estatística.

IVEM – Municipal Energy Vulnerability Index.

kWh/m2.year – Kilowatt per hour per square meter per year.

MFW- Masters' Final Work.

ONPE-PT – National Energy Poverty Observatory.

PAEMS – Programa de Apoio a Edifícios Mais Sustentáveis.

PRR – Plano de Recuperação e Resiliência.

PVE – Programa Vale Eficiência.

RCCTE – Regulamento das Características de Comportamento Térmico dos Edifícios.

RCM – Ministers' Council Resolution.

ROI – Return on Investment.

RUR - Rural-Urban Region.

SCE – Sistema de Certificação Energética dos Edifícios.

TEP – Targeted Energy Policy.

VAT – Value Added Tax.

ABSTRACT

Portugal is confronting a challenging position in Europe regarding energy poverty. It is consistently placed as the worst-ranked European country in various energy poverty indicators. The situation has now reached a severe point and requires urgent, targeted, and refined action in order to be effective and succeed. This internship report provides new insights for policy reformulation of existing programs designed to alleviate energy poverty and for the creation of new programs. These national programs are then dissected to examine two districts representing distinct scenarios: Lisbon, a mainly urban region, and Bragança, which is predominantly characterized as rural.

The investigation used a quantitative approach, by cross-analyzing data from the energy certificates issued by ADENE – Portuguese Energy Agency – with data from the above-mentioned programs. This resulted in essential revelations regarding their possible improvement and refinement, taking into account the intrinsic characteristics of each district.

The results showed an urgent need to differentiate the financing and the measures of these programs according to each type of district instead of using a national standard "one-size-fits-all" solution. This is especially relevant, as the impact of these measures produces a significantly bigger impact in rural areas than in urban regions, as their needs and challenges are very distinct. The report emphasizes the need to adapt national strategies to regional contexts, this way effectively addressing the nuanced realities of energy poverty across diverse geographical contexts.

KEYWORDS: Energy Poverty, Sustainable Real Estate, Energy Efficiency.

JEL CODES: Q48, Q43, Q58, R38, R21, R28.

Resumo

Portugal enfrenta uma posição preocupante no contexto europeu em relação à pobreza energética. É classificado como o pior país europeu em vários indicadores de pobreza energética. A situação tem vindo a atingir um nível severo e requer ação urgente, direcionada e diferenciada para ser eficaz e ter sucesso. Este relatório de estágio fornece novas ideias para a reformulação de políticas dos programas existentes projetados para combater a pobreza energética e para a criação de novos programas. Tais programas nacionais são, de seguida, examinados do ponto de vista de dois distritos que representam cenários distintos: Lisboa, uma região principalmente urbana, e Bragança, que é caracterizada como predominantemente rural.

Para tal, os dados dos certificados de energia emitidos pela ADENE – Agência para a Energia – foram analisados em conjunto com os dados dos programas acima mencionados. Tal análise resultou em conclusões essenciais sobre possíveis melhorias e refinamento dos programas, tendo em consideração as características intrínsecas de cada distrito.

Os resultados mostram a necessidade de diferenciar o financiamento e as medidas desses programas de acordo com o tipo de distrito, em vez de usar uma solução nacional "única". Isto é especialmente relevante, uma vez que o impacto dessas medidas produz um efeito significativamente maior em áreas rurais do que em regiões urbanas, sendo que as suas necessidades e desafios que enfrentam são muito diferentes. O relatório enfatiza a necessidade de adaptar as estratégias nacionais aos contextos regionais, abordando assim efetivamente as nuances das realidades da pobreza energética em diversos contextos geográficos.

Palavras-Chave: Pobreza Energética, Sustentabilidade no Mercado Imobiliário, Eficiência Energética.

Códigos JEL: Q48, Q43, Q58, R38, R21, R28.

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ACKNOWLEDGMENTS

I would like to start by thanking ADENE for the opportunity to undertake this internship with them. It was the perfect place to start my professional career, as I was welcomed with the utmost respect and care. My ideas were always listened to and encouraged, and I consistently felt like a valued member of the team. If all freshly out-of-university students were received the way I was in all companies, I believe that the world would be a happier place. I cannot thank them enough for my amazing experience there, and I would like to especially thank two people from ADENE who were the reason for the completion of this Master's Final Work: Rita Varela and Manuel Casquiço. They helped me tirelessly with the entirety of the process of writing this report. Without them, this could not have been possible.

A big thank you to my amazing supervisor, Professor Aníbal Lopez, who has been available since the first day and continuously shared invaluable insights and knowledge with me that will be paramount for the rest of my professional life.

I can only be here writing this today because of my parents, who have always been my biggest supporters and the reason why I am now completing this life milestone. They have always shown me unconditional love, and they are my biggest inspirations in life. I love them more than I am allowed to write it. Everything I am and everything I have achieved is because of them. For years they have pushed me and encouraged me to reach all the goals I want, and I am forever grateful for that. To my little sister, who has always been my partner in crime and whom I love so much.

I am eternally grateful for my four grandparents, avó Maria, avô Eduardo, avó Ester and avô Manuel, and I want to dedicate this work to them. Each one of them will always constitute a big part of my success in life, and I always hold them in my heart, even the ones that are not here anymore. They are the reason why I am who I am today, and the pure love they have always given me is almost impossible to thank for, and perhaps I will never be fully able to.

Finally, I would like to thank my boyfriend, who helped me tirelessly in the whole process, from getting the internship to emotionally supporting me during the writing of this report. Thank you for showing me that I can conquer the world if I want to, and for always reminding me to follow my dreams. I love you to the moon and back.

AI Disclosure

This internship report was developed strictly following the integrity norms and procedures of the university. For the sake of transparency, I hereby disclose that certain artificial intelligence (AI) tools were used in the making of this report as follows:

- An AI-based paraphrasing tool was utilized to rephrase selected quotes from other authors for the literature review, nevertheless ensuring that the original authors' own ideas or data were always properly cited.
- An AI-assisted grammar-checking tool was used to improve readability while always ensuring my original content and ideas.
- A generative AI tool was consulted for outlining and brainstorming purposes only. All final writing, thoughts, synthesis and critical analysis are my own work.

Nonetheless, I have assured that the employment of AI tools has not jeopardized the integrity and originality of my work. All sources of knowledge, whether traditional or AI-assisted, have been properly cited in accordance with the guidelines. This report was prepared with an ethical approach to AI research and writing in mind, and I take full responsibility for the ownership of its content.

Madalena Santos, 22/12/2024

1. INTRODUCTION

Energy poverty, defined by the European Parliament as the condition where households are unable to afford essential energy services necessary for maintaining a minimum standard of living and good health, including sufficient heating, cooling[1], lighting, hot water, and energy for powering appliances (Directive 2023/1791), is a growing socio-economic issue in Europe.

In Portugal, the combination of low wages, high energy costs, and obsolete construction have greatly aggravated this issue (Palma & Gouveia, 2024). Recent data from Instituto Nacional de Estatística (INE, 2023) shows that around 21% of the Portuguese population is unable to maintain a comfortably warm temperature in their homes, placing the country among the worst in Europe for energy poverty in this year. Moreover, INE (2023) reports that 38.3% of the Portuguese population is not comfortably cool in the summer, which shows the severity of the issue compared to its European member-states. Moreover, this problem is worsened by the existence of what is often called "hidden energy poverty", which takes place whenever households purposefully use less energy to avoid excessive costs, this way becoming invisible in the statistics (Sequeira et al., 2024). Combating energy poverty is essential for reaching long-term sustainability objectives and promoting social justice (Horta & Schmidt, 2021). This comes as paramount for Portugal as the country is committed to meeting its climate commitments under the EU's Green Deal (Resolução do Conselho de Ministros 11/2024; Fundo Ambiental, 2024). Poor energy efficiency in buildings not only increases energy poverty but also surges energy consumption and carbon emissions, which presents a significant barrier to national decarbonization goals (Palma & Gouveia, 2024).

Some public policy instruments have been put in place to tackle this issue, such as the Efficiency Voucher Program (PVE)[2] and the Support Program for More Sustainable Buildings (PAEMS)[3]. However, the clear impact of these measures has yet to be studied, as obtaining the necessary data presents a significant challenge and existent energy poverty indexes do not get yearly updated.

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[1] The expression "cooling" is henceforth used in this report referring to "cooling down" the temperature of a building to a comfortable temperature in the summer season.

[2] See: https://www.fundoambiental.pt/apoios-prr/c13-eficiencia-energetica-em-edificios/06c13-i01-programa-vale-eficiencia-ii.aspx (retrieved on 20-09-2024)

[3] See: https://www.fundoambiental.pt/apoios-prr/c13-eficiencia-energetica-em-edificios/05c13-i012023-paes-2023-1-aviso.aspx (retrieved on 20-09-2024)

Furthermore, given the severity and dimension of the problem, there is clearly a lack of measures in Portugal, which in themselves are currently disproportional to the problem at hand (Gouveia & Félix, 2024). Most importantly, there has not been a comprehensive study on how the current impact of these public policy instruments can aid in improving newer versions of these programs. This becomes especially relevant when analyzing the existing energy certificates issued and the disparities between rural and urban regions. The limited number of such instruments only exacerbates the problem. Therefore, the report of the activities conducted during the internship aims to analyze **how can the existing energy poverty alleviation programs (i.e., the PAEMS and the PVE) and the energy certificates issued between 2021 and 2024 help design future instruments to tackle energy poverty in urban (Lisbon) and rural (Bragança) Portugal?**

This report cross-analyzes the concrete needs for the targeting of energy poverty measures with an analysis of the energy performance of buildings across two distinct regions: Lisbon and Bragança. This is crucial for comprehending how national government initiatives can transform energy efficiency at a regional level (Gouveia & Félix, 2024). These regions have been selected due to their significantly different performances in the existing indexes measuring energy poverty, as well as for their socioeconomic and meteorological contrasts. Lisbon, as the capital and largest city, features a very high population density, modern infrastructure, and stronger economic performance (GEE, 2024b). Although the city has a relatively modern housing stock, it still encounters challenges, particularly regarding cooling during the summer months. Conversely, Bragança, located in northeastern Portugal, has a colder climate and a much lower population density than Lisbon. This district faces its own set of challenges, including a higher percentage of elderly residents - nearly 35% - and lower income levels (GEE, 2024a).

This research seeks to uncover how these instruments can better address regional disparities. It will also assess whether the investments and upgrades fostered by these policies are economically viable and advantageous for families in rural and urban areas. This is key for refining future public policy, as it ensures that future financial tools and incentives are adapted to the specific needs of different regions, fostering a more equitable and effective energy transition across the country.

The study will be possible due to the analysis of the energy certificates issued by ADENE during this period, which are then used to estimate the economic benefits of the suggested infrastructural improvements, such as better insulation, energy-efficient heating and cooling systems, and the installation of renewable energy sources. The report is divided as follows: first, a literature review on the state of the art on energy poverty and its policy instruments; then a methodology section with a review on the type of data used and a detailed socioeconomic analysis; followed by the results of the study conducted with the data provided by ADENE; and finally, the discussion with limitations and recommendations for ADENE and the conclusion. Within the scope of the Master's degree in Innovation and Research for Sustainability, this internship report constitutes a MFW for the degree in question and corresponds to a summary of the activities and tasks in the Department of Industry and Energy Transition at ADENE – Portuguese Energy Agency.

1.1. The Company and Internship Overview

ADENE (*Agência para a Energia*) is a Portuguese public institution created in 1988 to promote energy efficiency, sustainability, and innovation in the energy sector. It is responsible for managing the National Energy Certification System for Buildings (SCE), which ensures that buildings meet energy efficiency standards, promoting improvements in the built environment. ADENE also plays a key role in the management of Portugal's energy labeling system for appliances and products, which helps consumers make informed choices based on energy performance (ADENE - Agência para a Energia, 2024).

The internship took place in the Department of Industry and Energy Transition (Departamento de Indústria e Transição Energética), dedicated to supporting the industrial sector in its efforts to achieve energy efficiency and sustainability standards. This department creates policies, puts programs into action, promotes innovation in energy technologies, and encourages the adoption of digital solutions and smart energy management systems. It also focuses on training industry professionals on best practices for energy management and ensuring compliance with energy regulations (ADENE - Agência para a Energia, 2024).

The main activities carried out during the internship included the analysis of the main public policies implemented against energy poverty, the comparison between the two districts, the collection and processing of energy certification data provided by ADENE, the assessment of the economic impacts of recommended energy efficiency improvements in homes, and finally, the development of practical recommendations to reduce energy poverty. Additionally, I attended the inauguration of the National Energy Poverty Observatory (ONPE-PT) on October 11th 2024, and developed tutorial videos for energy consumers and professionals on how to thoroughly read energy bills.

1.2. Articulation with the Masters' program

Throughout the Masters' program, practical concepts were taught and used in this report and in the overall assigned tasks in the company. Multiple courses were revealed to be important, particularly the course of Sustainability Sciences and Policy. In this course, I learned how to analyze important environmental, social and economic challenges related to local and global business practices, as well as EU sustainability-related regulations and policies, which was crucial for this report. I applied my theoretical knowledge of these concepts and skills to a real-world scenario, as both energy poverty and energy efficiency are crucial sustainability concerns regulated by recent EU policies and guidelines. The public policy programs analyzed in this report also aimed to target climate change mitigation, as both essentially promoted and quantified the reduction of CO_2 emissions of participating households. A substantial part of my investigation tasks in the company involved analyzing energy certificates, mainly focusing on variables such as energy consumption, energy class, construction period, type and size of dwelling[4], CO2 emissions, estimated investment costs and estimated saving costs.

To work with this data, the course of Evaluation and Management of R&I Projects also revealed essential for the results, as it allowed me to view it in a project management landscape, by calculating the ROI and the Break-Even period, methods and concepts which were all taught during these classes.

[4] For further concept clarification, dwelling is defined in Cambridge Dictionary as "a house or place to live in" (Cambridge University Press and Assessment, n.d.)

2. LITERATURE REVIEW

2.1. Energy Poverty, its causes and impacts

Energy poverty affects nearly a quarter of the global population (Bouzarovski, 2014). The concept was initially defined in the UK by Boardman (1991) with a different designation, 'fuel poverty'. It refers to the incapacity of affording adequate warmth, specifically when a household spends at least 10% of its income on energy expenditures. This definition triggered the development of entirely new state policies addressing the issue. After that, Healy and Clinch (2002) undertook the first efforts to research fuel poverty at a broader European level, by updating its definition to make it comparable between member nations, using both objective and subjective indexes. What started as the incapacity of families to heat their homes appropriately (Bouzarovski, 2018), turned into a broader concept, as current authors view it as a more comprehensive inability to obtain basic energy levels for comfort and wellbeing, by also including cooling services in the summertime (Horta & Schmidt, 2021; Palma & Gouveia, 2024). It is often automatically linked to economic poverty and material deprivation, while in reality, it is a distinct concept (Rodrigues et al., 2019). Overall, it is a concept that has struggled throughout the years to find a common and consensual definition. In 2023, the European Parliament finally defined it as

> (…) a household's lack of access to essential energy services, where such services provide basic levels and decent standards of living and health, including adequate heating, hot water, cooling, lighting, and energy to power appliances, in the relevant national context, existing national social policy and other relevant national policies, caused by a combination of factors, including at least non-affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes.

In: European Parliament & Council (2023), p. 31.

The above definition of energy poverty will be used consistently throughout this report. Several European studies on energy poverty, such as the study by Kashour and Jaber (2024), have been conducted in order to ascertain its causes and effects, visible in **Figure 1** and in **Figure 2** by Pye et al. (2015).

To address this issue at the European level, some initiatives were created, such as the PowerPOOR project, which appeared with the aim of addressing energy poverty through support programs that empower citizens and promote joint energy initiatives (PowerPOOR, 2023a).

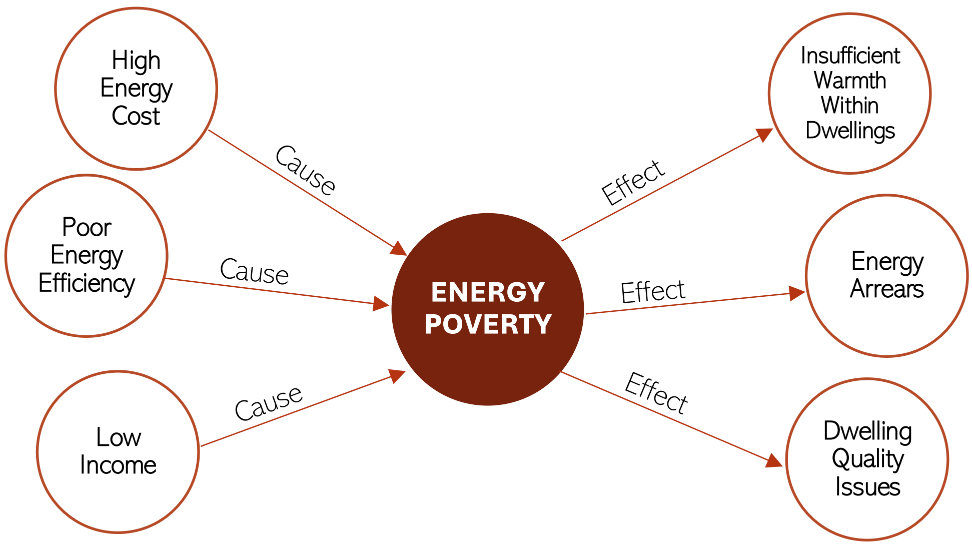

Figure 1 - Energy Poverty conceptual framework

Source: Kashour and Jaber (2024)

Additionally, an emerging type of energy user has been appearing in the literature, the "hard-to-reach" consumers (often abbreviated as HTR), which refers to users who are challenging to engage in energy efficiency programs or interventions, since it is hard to identify them. In fact, the Ministers' Council Resolution (RCM) 11/2024 (Resolução do Conselho de Ministros 11/2024) notes that low-income families are not the only ones affected by energy poverty, since households that restrict their energy use to save money also suffer from it. According to Sequeira et al. (2024), a substantial share of the EU population may be classified as HTR energy users, with several profiles accounting for as much as 30% of the population.

Additionally, many studies conducted across EU nations have concluded that the rural nature of a region plays a major factor in increased vulnerability to energy poverty (Aristondo & Onaindia, 2018; Sokołowski et al., 2020; Bouzarovski & Herrero, 2016).

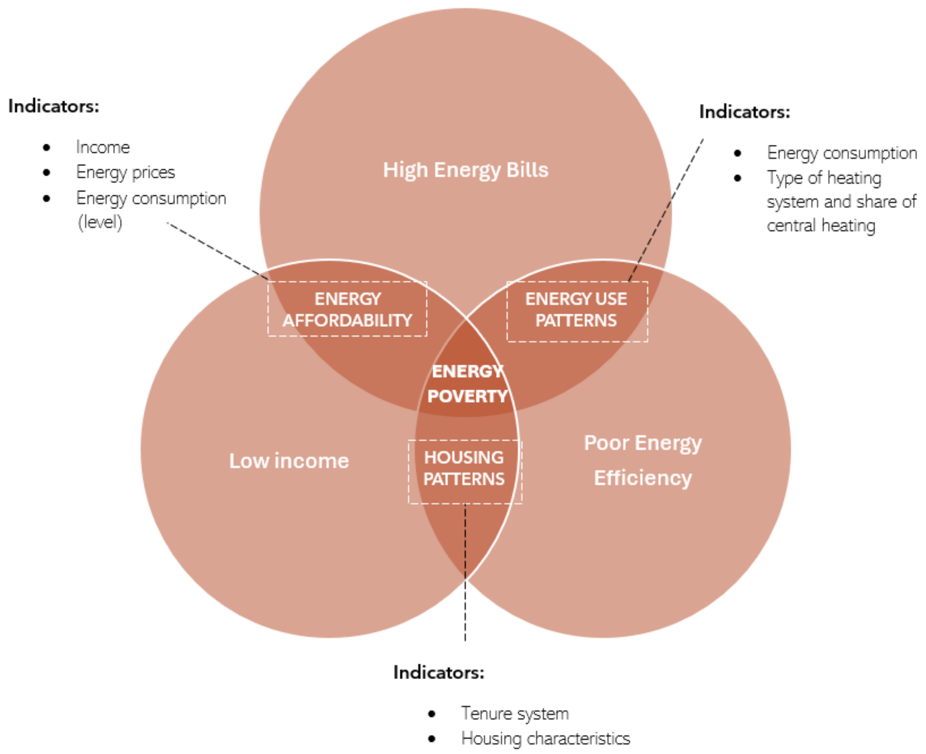

Figure 2 - Drivers of energy poverty and key indicators

Source: Pye et al. (2015)

2.2. Policy instruments in the EU

In recent years, energy poverty policies in the EU have been evolving. According to Bessa and Gouveia (2022), there are four essential elements for effective policies to address energy poverty: Measurement, Definition, Type of Policy, and Funding and Financing. Firstly, measurement serves to contextualize the issue. Secondly, the definition of energy poverty is crucial for identifying the target groups affected. Thirdly, the type of policy is determined by the instruments it employs. And finally, funding can be evaluated according to the direct and indirect stakeholders impacted by the policy, as well as the various instruments used (Bessa & Gouveia, 2022).

The Energy Roadmap 2050 and the Europe 20-20-20 Strategy, which seek to radically enhance energy efficiency, cut greenhouse gas emissions by 20%, and increase renewable energy by 20%, serve as the main guiding principles for these programs (Bouzarovski, 2017).

Across its member states, there are many similarities in the policies adopted. To develop a unified strategy against energy poverty, several of them align municipal, national, and European directives using a multi-level governance approach. This alignment is necessary to make sure that policies support larger EU objectives, including those stated in the European Energy Directive (EED), in addition to being effective at the national level (Bessa & Gouveia, 2022). The EU has, in fact, recognized energy poverty as a significant issue and developed the Targeted Energy Policy (TEP), which mandates that Member States identify vulnerable consumers and implement protective measures (Bouzarovski, 2017).

Overall, the European Union has successfully mainstreamed energy poverty into its larger energy policy agenda by encouraging dialogue and action among Member States despite data availability obstacles and many programs' non-binding character (Bouzarovski, 2017). Across EU countries, enhancing building energy efficiency has been a common topic throughout these strategies (Bessa & Gouveia, 2022).

2.3. The Portuguese case

As depicted in **Figure 3**, according to Eurostat (2024), Portugal has the highest percentage of households that are unable to keep their homes adequately warm (20.8%), along with Spain.

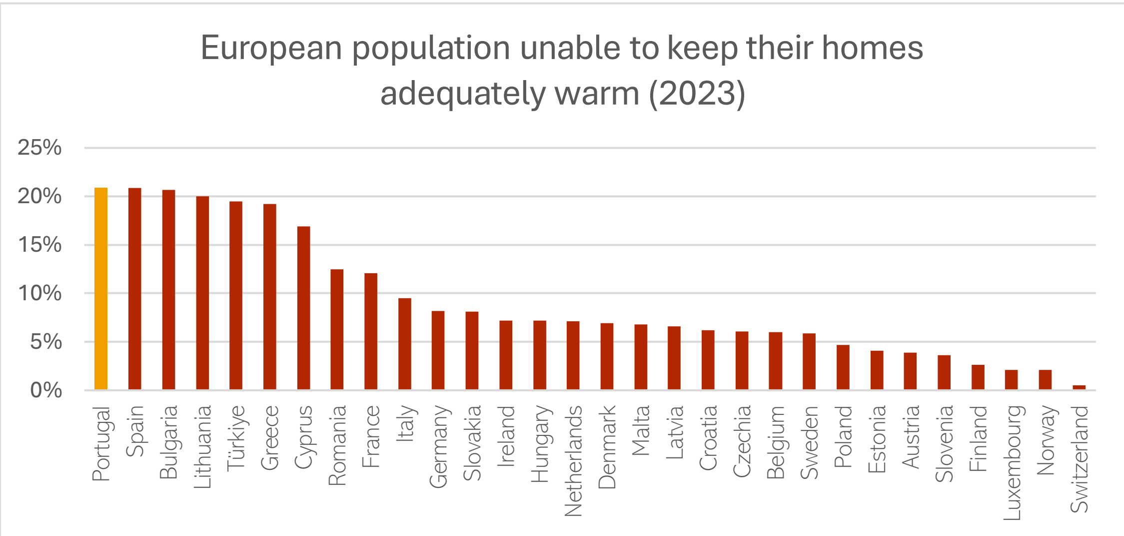

Figure 3 - Population unable to keep their homes adequately warm in 2023

Source: Eurostat (2024)

The evolution of this indicator shows a consistently pessimistic outlook. As shown in **Figure 4**, the proportion of people unable to keep their homes adequately warm decreased linearly until 2021, when it started increasing to the initial values of the time period (INE, 2023). This is related to both an increase in inflation, which increased by 7.83% in 2022 compared to the previous year (Pordata, n.d.), and a spike in energy costs in the country, starting in the second semester of 2021 (Observatório da Energia et al., 2024). Additionally, Portugal has become increasingly more energy-dependent in the last few years, increasing by 5 p.p. from 2020 to 2022, according to the latest report by Observatório da Energia et al. (2024).

Furthermore, and not less relevant, the Summer also represents a challenge, with 38.3% of the population living in dwellings that are not sufficiently cool (INE, 2023).

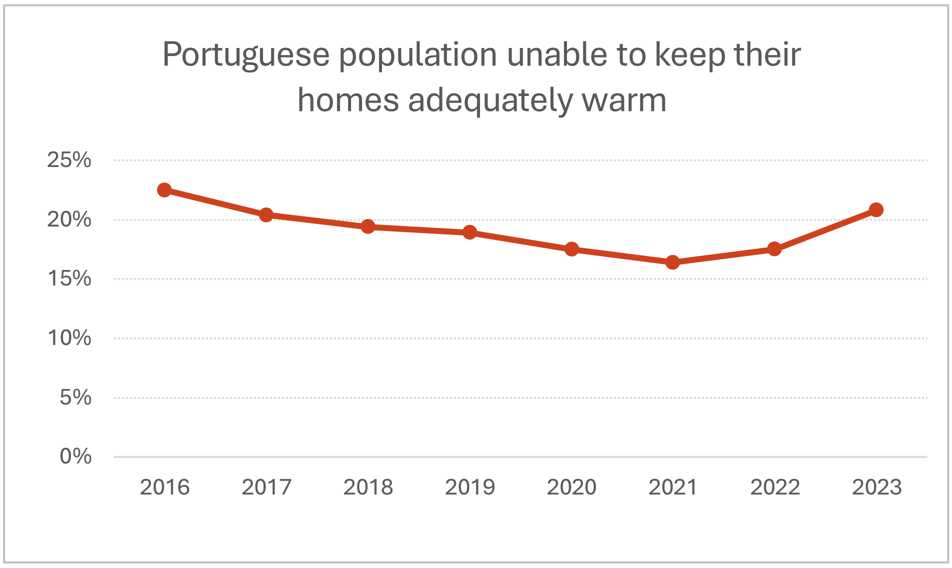

Figure 4 - Evolution of the percentage of the Portuguese population unable to keep their homes adequately warm

Source: INE (2023)

In terms of positioning, it is important to note that from 2022 to 2023, Portugal changed its position from the fourth worst to being the first. In fact, according to the most recent data, shown in Figure 5 (Eurostat, 2023a), around 55% of the Portuguese population lives in a dwelling that is not comfortably warm in Winter.

Horta and Schmidt (2021) argue that the specific characteristics of energy poverty in Portugal include housing access and quality, infrastructure and equipment, dealing with cold and heat (households tend to use low-cost measures to deal with extreme weather), energy costs, and income levels. This highlights the relevance of energy poverty studies and interventions in the country, as was addressed by the Ministers' Council Resolution (RCM) No. 11/2024 (Resolução do Conselho de Ministros 11/2024). In this council, the Portuguese government created the National Energy Poverty Strategy 2023-2050 (**ELPPE**), whose strategy aims to "eradicate Energy Poverty in Portugal by 2050, protecting vulnerable consumers and actively integrating them into energy and climate transition, which are intended to be fair, democratic and cohesive" (*Direção Geral de Energia e Geologia* [DGEG], 2023). This strategy is not free from critics, as Gouveia and Félix (2024) pointed out in their analysis that they found insufficient measurement indicators, a demand for a broader definition of energy poverty, and an inadequate focus on fiscal policy and housing access.

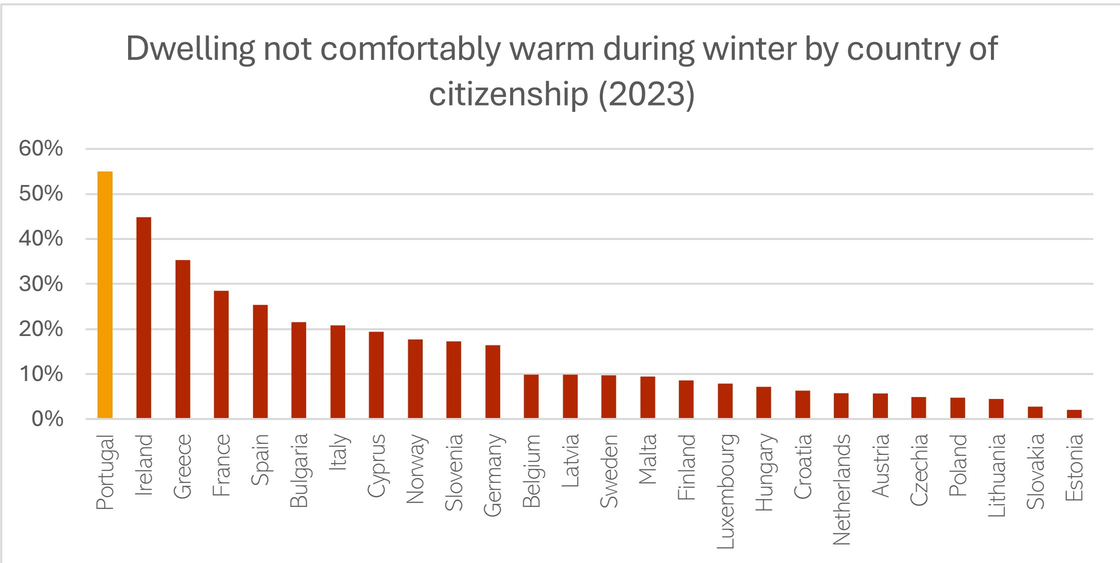

Figure 5 – Percentage of people living in a dwelling not comfortably warm during winter by country

Source: Eurostat (2023a)

Furthermore, Despacho 2404/2024 created the National Energy Poverty Observatory (ONPE-PT)[5], with the main goal of "tracking the evolution of energy poverty at a national

[5] See https://onpe.pt/ (retrieved 20-11-2024)

level" (Despacho 1335/2024). **TABLE I** showcases the key strategic indicators used to measure energy poverty in Portugal, along with the goal values for the near future:

TABLE I - Key strategic indicators that measure energy poverty in Portugal

Indicator	Reference Value	2030	2040	2050
Population living in homes without the capacity to keep the house adequately heated	17.5% (≈1.8 million people) **2020**	**10%**	**5%**	**<1%**
Population living in uncomfortable non-cool housing during the summer	35.7% (≈3.7 million people) **2012**	**20%**	**10%**	**5%**
Population living in housing with problems of leaks, humidity or rotten elements	25.2% (≈2.5 million people) **2020**	**20%**	**10%**	**<5%**
Households whose energy expenditure represents +10% of total income	1,202.567 (≈3.0 million people) **2016**	**700,000**	**250,000**	**0**
Percentage of residential buildings with lower energy classes	69.6% **2020**	**50%**	**40%**	**30%**

Source: Despacho 1335/2024 (2024) p. 74.

According to Palma and Gouveia (2024), the main causes for the high levels of energy poverty in Portugal are low wages, high energy prices and the energetic inefficiency of buildings, since a significant portion of buildings in Portugal were built before the energy performance regulations of 1990. As is visible in **Figure 16** in the Appendix, 30% of the population in Portugal lives in a dwelling with damages such as a leaking roof, damp walls, floors or foundation, or rot in window frames or floor, which places the country as the 3rd worst in this aspect. The maps in **Figure 17** and **Figure 18** in the Appendix also allow an easier comparison to its fellow member-states.

2.4. Energy poverty indicators in Portugal

Currently, there are two leading indicators for measuring energy poverty in Portugal, which will be shortly reviewed in this section.

2.4.1. Energy poverty indexes

Two main indexes currently measure energy poverty in Portugal. The EPVI (Energy Poverty Vulnerability Index) was created by Gouveia et al. (2019) and analyzes energy poverty geographically, differentiating heating from cooling needs on high-resolution spatial maps. On the other hand, the IVEM (Municipal Energy Vulnerability Index) focuses solely on heating. It measures the probability that an individual cannot keep adequate heating at an aggregate municipal level[6]. It is important to note that both indexes rate non-coastal northern regions (such as Bragança) as having the highest levels of energy poverty in continental Portugal (**Figure 19** in the Appendix).

2.4.2. The SCE Certificates

Additionally, the SCE (National Energy Certification System for Buildings) system assesses a property's energetic performance on a scale from A+ (very efficient) to F (very inefficient), with eight different categories in total. It considers minimum thresholds for comfortable temperatures, with 18ºC in winter and 25ºC in the summer. It is overall a useful tool for learning about the energy requirements of a certain building for space heating, water heating, and cooling, as well as potential renovation projects that can be implemented to improve the current energy class (ADENE, 2023; Despacho 1335/2024). The SCE certificates are of mandatory issuance for: new buildings; existing buildings subject to renovation costs superior to 25% of the value of the building; existing commercial buildings with an area equal to or greater than 1000 m^2 (or 500 m^2 in the case of shopping centers, supermarkets and indoor pools); buildings owned and occupied by a public entity with an area greater than 250 m^2; and lastly dwellings for sale (ADENE, 2023). Between 2014 and 2022, from 1.7 million energy certificates, only 17% of the households were qualified as very efficient (i.e., with an efficiency class A and A+), while 66.3% were classified as C or less (**Figure 20** in the Appendix).

[6] "Municipal" refers to a less aggregated administrative division than a district, symbolizing local government power and the decentralization of the Portuguese State (AMA, n.d.).

2.5. Policy instruments in Portugal

To reach the objectives of the National Energy Poverty Strategy 2023-2050 (**ELPPE**), some public policy instruments were created (Gouveia & Félix, 2024; Resolução do Conselho de Ministros 11/2024). For this analysis, two main programs were chosen: the PVE (Efficiency Voucher Program) and the PAEMS (More Sustainable Buildings Program). These two instruments are financed by the Recovery and Resilience Plan (PRR) and are shortly reviewed ahead to offer a general understanding.

2.5.1. Program for More Sustainable Buildings (PAEMS)

The Program for More Sustainable Buildings seeks to advance sustainable building practices by providing financial incentives directed both at individuals and organizations. This includes funding projects or activities that contribute to climate change mitigation. The Environmental Fund (Fundo Ambiental[7]), established to promote sustainable development and environmental regulations, oversees the operationalizing of this program. The financing package, which has a total budget of €30 million, intends to improve building energy efficiency. If their eligible expenses total at least €5,000 (VAT excluded), each beneficiary is eligible to receive up to €7,500 (Fundo Ambiental, 2023). To guarantee that the funds are used efficiently to accomplish the intended environmental results, the program places a strong emphasis on meeting qualifying requirements, which include submitting thorough documentation and abiding by tax laws (Despacho 6070-A/2021, 2021). Some barriers that may oppose this type of program include a lack of specialized human resources with the necessary skills to serve as mediators and the inability of energy-poor households to overcome initial investments (European Energy Network, 2023).

2.5.2. Efficiency Voucher Program (PVE)

To address energy poverty among economically vulnerable households whose income prevents them from making investments to improve the energy efficiency of their homes, the government established the Efficiency Voucher Program (PVE) (Fundo Ambiental, 2024). This program serves as a complement to the latter (PAEMS), as economically

[7] See: https://www.fundoambiental.pt/ (retrieved on 28-10-2024)

disadvantaged people lack the funds to pay for the work in advance, so PVE makes sure that a voucher is issued in advance and can be used to purchase energy-efficient equipment and solutions as well as interventions in the surrounding area aimed at improving the energy efficiency and thermal comfort of homes (Gouveia & Félix, 2024).

It was first implemented in 2021, with an initial allocation of €32 million, which was associated with the issuance of 20,000 vouchers, with a unit value of €1300+VAT. This first phase closed with 16,000 vouchers awarded when 23,000 had been requested. Since its goals were not achieved, the second phase of the program was reformulated and reopened in 2023, with an allocation of €104 million associated with the issuance of 80,000 vouchers. This phase also allowed each beneficiary to benefit from up to a maximum of 3 Vouchers totaling €3900+VAT, instead of only 1, like in the first phase, along with a broader scope of eligibility (Fundo Ambiental, 2024). The new criteria cover residents in Continental Portugal who live permanently in the dwelling and are beneficiaries of the Social Electricity Tariff or other minimum social benefits (as shown in

TABLE II).

Policy Instrument	Year(s)	Objective	Main Features	Public Target	Advantages	Disadvantages
PVE	2021–2024	To fund energy efficiency improvements in the homes of vulnerable families	Vouchers worth €1,300 for upgrades	Economically vulnerable families	Supports long-term efficiency upgrades; addresses structural issues in homes	Limited to 3 vouchers, which may not cover extensive renovations; requires participation from beneficiaries
PAEMS	2021-2024	Advancing sustainable building practices by financing projects or activities that contribute to climate change mitigation	Grant up to €7,500, when total eligible expenses equal at least €5,000	Any homeowner wishing to improve the energy efficiency of their dwelling	Promote improvements and efficient construction of buildings	Lack of specialized human resources; requires upfront costs; inability of poor families to overcome initial investments

TABLE II - Comparison of the main features of each program

Source: elaborated by the author based on Fundo Ambiental (2023)

A downside that characterized the first phase of the PVE program was the extensive bureaucratic process that it involves, since the evaluation of the eligible candidates constitutes an extensive and complex process, with multiple steps. However, this issue was addressed in the second phase, as in this process the role of "Facilitators" was created, which created a greater support and proximity to both beneficiaries and candidates. Moreover, the suppliers of the required interventions used to receive only one payment located at the end of their renovation work in the first phase, whereas in this second phase they receive 20% of their payment at the beginning of their work, which also encourages more suppliers to adhere to this program (Fundo Ambiental, 2024).

The criteria and measures of each program are compared and summarized in **TABLE III**.

TABLE III - Comparison of the main criteria and measures of each program

	Criteria	Measures
PVE	• Beneficiary of the Social Electricity Tariff (TSEE) or • Another minimum social benefit (solidarity supplement for the elderly, social integration income; social disability pension; supplement to the social benefit for inclusion; social old-age pension; social unemployment benefit)	• Heat pumps • Biomass boilers • Photovoltaic panels • Solar thermal systems • Efficient windows • Exterior and roller entrance doors (1st phase only) • Thermal insulation (1st phase only)
PAEMS	• Any individuals who own existing and occupied residential buildings, with their status regularized with the Tax and Customs Authority and Social Security, may apply	• Efficient windows • Thermal insulation • Heating, Cooling or DHW Systems • Photovoltaic panels • Water Efficient Use Devices

Source: elaborated by the author based on Fundo Ambiental (2023)

However, many authors and official authorities agree that these policies are not nearly enough to solve the problem, since they are more consumer protection-focused rather than tackling the root causes of energy poverty (Horta & Schmidt, 2021). The main obstacles identified by Gouveia and Félix (2024) were the identification of the most vulnerable families, energy costs and energy literacy.

The ministers' council in Resolução do Conselho de Ministros no. 11/2024 and Gouveia (2024) argue that this issue is intensified by hidden energy poverty, where households deliberately under-consume energy to avoid unaffordable bills. **Figure 21** in the Appendix shows the main barriers to the implementation of measures against energy poverty, from a study conducted across 14 European countries, where the identification of the most vulnerable families and the investment needed are clearly the most prominent ones (European Energy Network, 2023). The scale goes from 1 to 5, where 5 constitutes the most important barriers and 1 the less relevant ones.

Clearly, the national stock of existing buildings generally lacks the capacity to provide adequate energy performance conditions, especially those related to thermal comfort, ventilation, and good indoor air quality. This is supported by an analysis conducted as part of the ELPRE (Long-term Strategy for the Renovation of Buildings in Portugal), which found that there is some degree of thermal discomfort in the existing building stock for more than 95% of the year, with the exception of multi-family buildings built after 2016 (Direção Geral de Energia e Geologia [DGEG], 2024; Despacho 1335/2024).

All in all, energy poverty has only recently been specifically defined, as its definition generated controversy due to its complexity and multidimensionality. Existing studies have evaluated the factors that affect it. However, there is still limited research on the impact of financial instruments and targeted public policies aimed at alleviating energy poverty in Portugal at a regional level. So far, we know only the concrete numbers of households that were beneficiaries of these measures at a national level. In fact, there has not been a comprehensive study conducted on the current programs and how they can be improved using data from energy certificates. Clearly, there is a knowledge gap on how these instruments and policies can better address the individual challenges faced by different regions in Portugal in improving energy performance in buildings. Each region, whether urban or rural, presents its own challenges, and the same policy may have a completely different impact in diverse contexts within these regions.

3. METHODOLOGY

3.1. Procedures and Data Analysis

This study consists of a quantitative analysis, which allows for scalability and generalization for other regions of the country, efficient processing of the data in Excel, and a more precise visualization of the data through various graphs and charts. However, it may fail to capture each region's full socioeconomic contextual scenario and the complete impact of individuals facing energy poverty in their homes. The secondary data sources included specific data from the PVE and PAEMS programs and a dataset containing all energy performance certifications (SCE) issued from 2021 to 2024. This large dataset includes detailed information about the construction period, dwelling size, energy class, and other housing characteristics. Furthermore, complementary data from official channels was used for a broader essential socioeconomic and meteorological analysis. Using secondary data provided significant time savings essential for the brief internship period, while also facilitating a longitudinal and comparative analysis across multiple years. However, this method presents some limitations, such as the limited representability of the universe of the total existing housing stock, since they constitute a very low portion. Additionally, the lack of certain direct correlations between variables (like SCE certificates and the PVE/PAEMS programs), impairs causation research. Despite these limitations, the analysis of the secondary data provided by ADENE allowed for an efficient and comprehensive investigation into the interactions between different energy efficiency policies. This analysis also included an examination of broader patterns and important insights that may help in (re)designing these same programs. For disaggregation of the data, three different divisions were used throughout the analysis, and alternated depending on the variable:

1. **Aggregated “Before 1990” and “After 1990” –** since the first regulations on energy efficiency in housing (RCCTE) were only introduced in the year 1990, paving the way for the improving the thermal performance of buildings, focusing on insulation and energy consumption reduction (Decreto-Lei 40/90).
2. **Disaggregated with 5 different time points** - Before 1960 (Pre-Regulation Era); 1961-1990 (Pre-Energy Regulations); 1991-2000 (Post-RCCTE); 2001-2005 (Strengthened Energy Standards); Post-2006 (Post-SCE).

3.2. Socioeconomic Analysis

To present a general context of the two regions and explore fundamental intrinsic characteristics that may influence the study, an analysis of the socioeconomic context follows.

3.2.1. Social Analysis

It is clear in **TABLE IV** that Lisbon and Bragança have radically distinct social, demographic and geographical characteristics. The district of Lisbon has a population of 2,355,867 (representing 22.1% of the entire Portuguese population). In contrast, only 122,739 people inhabit the district of Bragança (1.2% of the total population). The latter has a population density of 18.5 inhabitants/km^2, which is very low compared to the 824.3 inhabitants/km^2 in the Lisbon district. According to the Rural-Urban Region Framework (RUR)[8], introduced by Zasada et al. (2013), this low population density is typical of a predominantly rural region, characterized by scattered and smaller low-density settlements. Lisbon, on the other hand, is considered a high-density urban region (monocentric[9]) since it has a core city area and a very high population density (Zasada et al., 2013). Additionally, the urban typology map developed by CCDR-N[10] characterizes the urbanization degree of every Portuguese municipality. It indicates that all the municipalities composing the district of Bragança are predominantly rural, while all the areas pertaining to the district of Lisbon are characterized as predominantly urban. It is based on this characterization that the analysis was conducted. For a clearer view of the degrees of urbanization in the EU and in the entire Portuguese territory, see **Figure 22** in the Appendix.

[8] RUR is a spatial framework used for classifying urban-rural relationships across different regions in Europe.

[9] "Monocentric" is another denomination for an urban region with one core city area, associated with high density urban areas (Zasada et al., 2013).

[10] CCDR-N is the Commission for Northern Regional Development and Coordination.

TABLE IV - Social comparison between the two districts

Indicator	Lisbon	Bragança
Area (km²)	2,816 (3.1%)	6,599 (7.2%)
Population	2,355,867 (22.1%)	122,739 (1.2%)
Population Density (inhabitants/km²)	824.3	18.5
Number of municipalities	16	12

Source: elaborated by the author based on GEE (2024a) and GEE (2024b)

3.2.2. Economic Analysis

From an economic perspective, **TABLE V** shows that Lisbon households may have greater financial capacity to afford updates or renovations in energy efficiency. This includes participation in programs like PAEMS, which require an initial upfront investment from the participants and a non-repayable SCE certification issued by ADENE. In fact, the district of Lisbon accounts for 35.5% of Portugal's GDP, while Bragança contributes only 0.8%. Furthermore, the percentage of the population receiving social integration income in Bragança (2.6%) is higher than the national average of 2.5%, whereas Lisbon's population remains under that level (2.3%). This data shows the proportion of economically disadvantaged populations and purchasing power disparities between the two districts.

TABLE V - Economic comparison between the two districts

Indicator	Lisbon	Bragança
GDP as a % of Portugal's GDP (2022)	35.50%	0.80%
Number of Enterprises	362,252	805
Average Monthly Earnings (Tertiary Sector, Men)	€1,701.1	€858.2
Average Monthly Earnings (Tertiary Sector, Women)	€1,445.3	€843.2
Recipients of social integration income / Resident population	2.3%	2.6%

Source: elaborated by the author based on GEE (2024a), GEE (2024b) and INE - Contas Nacionais

On a tax aggregate view (**Figure 23** in the Appendix), Bragança has overall lower income levels, with most of its aggregates being focused on one of the lowest brackets (5,000€ - 10,000€). On the other hand, Lisbon has a higher proportion of taxpayers with higher earnings, particularly those in the €19,000–€32,500 and over €32,500 income groups, suggesting a wealthier population[11]. This is particularly relevant because it has been proven before that energy poverty in rural areas increases as economic inequality increases (Wang et al., 2024).

3.2.3. Meteorological Analysis

Within the same macroclimate, the districts of Lisbon and Bragança have several meteorological differences (refer to **TABLE VI**).

TABLE VI - Meteorological comparison between the two districts

Indicator	Lisbon	Bragança
Climate classification	Mediterranean with maritime influence (Csa[12])	Mediterranean with continental influence (Csb[13])
Location	Western Portugal, coastal	Northeastern Portugal
Altitude	77 m	690.7 m
Average Daily Maximum Temperature (annual)	21.4º C	18.4º C
Average Daily Minimum Temperature (annual)	13.5º C	6.8º C
Rainfall	765.8 mm	772.7 mm

Source: elaborated by the author based on IPMA (n.d.)

[11] Income data taken from the 2021 census (INE, 2022).

[12] Temperate climate with warm summer, under the Köpen climate classification (IPMA, n. d.).

[13] Temperate climate with dry and mild summer, under the Köpen climate classification (IPMA, n. d.).

Lisbon is located in western Portugal, at a relatively low altitude, very close to the ocean, and therefore with a coastal type of climate and maritime influence. Bragança, on the other hand, lies in the northeastern region of the country, with a more continental-influenced climate (see map in **Figure 22** in the Appendix for the location of both districts). It is therefore expected that the higher temperature averages and lower thermal amplitudes will cause Lisbon to demand lower heating costs but perhaps greater cooling costs. In accordance, households in Bragança are expected to have higher heating costs (refer to the climatological maps in **Figure 25** in the Appendix).

3.2.4. Building stock characterization

The Portuguese housing market has suffered some important modifications throughout the years through regulation (refer to **Figure 6**). The different phases include:

1) Before 1990 – Buildings required a high energy consumption for heating and cooling without any major energy efficiency regulations that ensured thermal comfort.
2) 1990 – The first regulations in Portugal (RCCTE - Regulation on the Thermal Behavior of Buildings[14]) established minimum thresholds that ensured thermal comfort.
3) 2006 – Implementation of more detailed and comprehensive regulations (improvement of RCCTE[15]) with better insulation and better energy-efficient heating and cooling systems. Start of integration of renewable energy sources.
4) Nearly-Zero Energy Buildings – the newest buildings are designed to minimize energy needs through renewable energy, advanced insulation, and other measures.

The age distribution of buildings in both districts is similar. There was a construction-boom between 1960 and 1990, before the first energy efficiency regulations were implemented. It can be concluded that the majority of the housing stock in both districts is essentially composed by non-regulated constructions (**Figure 24** in the Appendix).

[14] See: https://diariodarepublica.pt/dr/detalhe/decreto-lei/40-1990-334611 (retrieved 25-11-2024)

[15] See: https://diariodarepublica.pt/dr/detalhe/decreto-lei/80-2006-672456 (retrieved 25-11-2024)

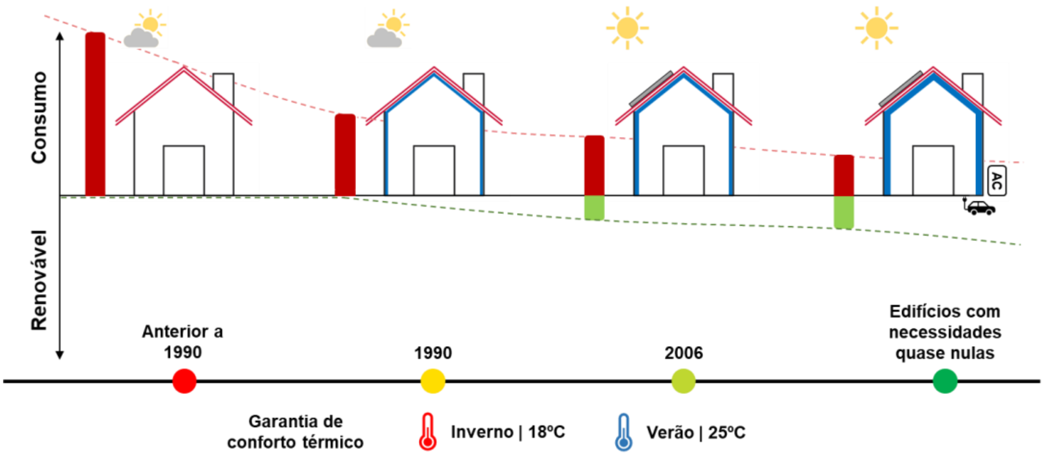

Figure 6 - Evolution of the national housing stock throughout the years

Source: ADENE (2021)

When we look at a broader picture of the prevalence of different types of heating and cooling systems in each district (**Figure 7**), it is important to note that 35% of Lisbon households do not have any kind of heating system. In comparison, 22% own an Air Conditioning (AC) cooling system, which shows the district's milder climate. In Bragança, heating systems are more prevalent, with a notable 15% having a central heating system and 17% with a fireplace, the latter constituting a traditional heating method commonly used in rural areas.

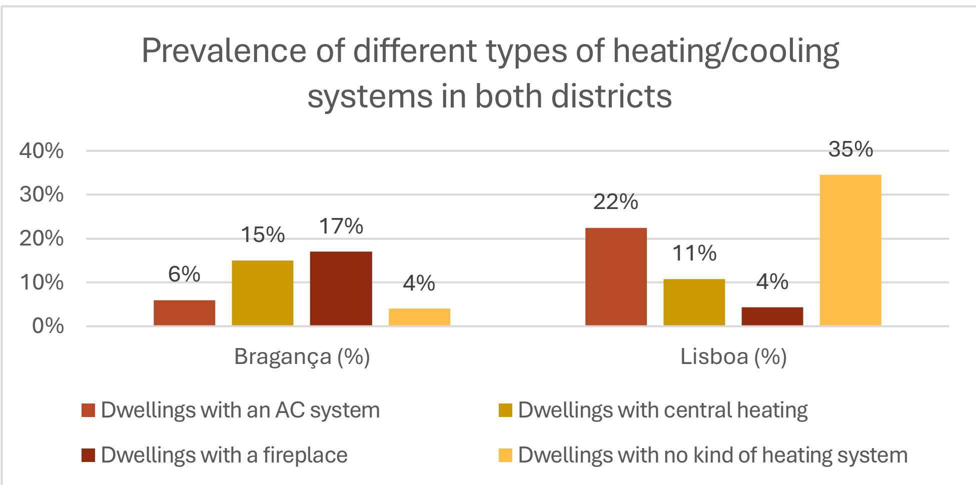

Figure 7 – Heating and cooling system prevalence by district

Source: elaborated by the author based on INE (2022)

4. RESULTS

4.1. Policy implementation: PVE and PAEMS

To start the analysis, the two programs were analyzed and compared, along with their effects and measures.

4.1.1. PAEMS- Program for More Efficient Buildings

The PAEMS program awarded higher financing in Bragança than in Lisbon, as shown in **TABLE VII**. The portion of supported dwellings in Lisbon was 1.2%, compared to 1.4% in Bragança. It is also important to note the significant difference in the energy reduction that the measures caused in Bragança (60%) compared to Lisbon (26%).

TABLE VII - Overview of the results of the PAEMS program in each district

District	Total (average)	Supported dwellings	Total CO^2 avoided (tons/year)	Energy reduction (MW/year)	Energy reduction (%)
Bragança	1 766.741 €	713 (1.4%)	963	12303.9	60%
Lisbon	1 590.561 €	11690 (1.2%)	2985	38127.7	26%

Source: elaborated by the author based on ADENE & Fundo Ambiental (unpublished-a)

When examining the individual measures included in this program (see **Figure 26** in the Appendix), it is clear which measures rule over others in each district. In Lisbon, the replacement of non-efficient windows leads with (60%) of its total measures, and in Bragança the most requested measures were both the installation of heating, cooling and DHW (Domestic Hot Water) systems (constituted 60%) and the installation of photovoltaic panels (~45%).

4.1.2. PVE- Efficiency Voucher Program

At first glance, the number of paid vouchers for the PVE program appeared to be proportional to the population sizes of each district. However, in this program, the total average value of each voucher was higher in Lisbon than in Bragança (refer to **TABLE VIII**).

TABLE VIII - Overview of the results of the PVE program in each district

District	Total (average)	Total number of paid vouchers
Bragança	1 504.57€ €	269
Lisbon	1 591.76€	1916

Source: elaborated by the author based on ADENE & Fundo Ambiental (unpublished-b)

Regarding the frequency of the measures, the majority of the vouchers in Lisbon were once again used for window replacement, while in Bragança they were mostly used for the installation of heat pumps. This follows the same trends as observed in the PAEMS program. There is an overall low adoption of other measures (see **Figure 27** in the Appendix).

TABLE IX sums up both programs:

TABLE IX - Comparison of the results of both programs in each district

Most prominent measure in each program		
District	**PVE**	**PAEMS**
Bragança	Installation of heat pumps (50%)	Installation of heating, cooling and DHW systems (60%)
Lisbon	Replacement of non-efficient windows (72%)	Replacement of non-efficient windows (60%)

Source: elaborated by the author

4.2. Energy Certification Analysis

To address the initial research question, all certificates issued between 2021 and 2024 in the districts of Lisbon and Bragança were analyzed. The database consisted of 230 698 certificates, with values for heating, cooling, CO_2 emissions, Total Average Estimated Investment Costs, Total Average Estimated Savings, and Size and Type of dwellings, among others.

Energy classes

In both districts, most dwellings are concentrated in lower energy classes (C, D, E, F). Regarding district differences, Lisbon dwellings are more focused on two classes only (C and D). In contrast, in Bragança, the classes are less concentrated and more distributed, even though the lowest class (F) is the most frequent (**Figure 8**).

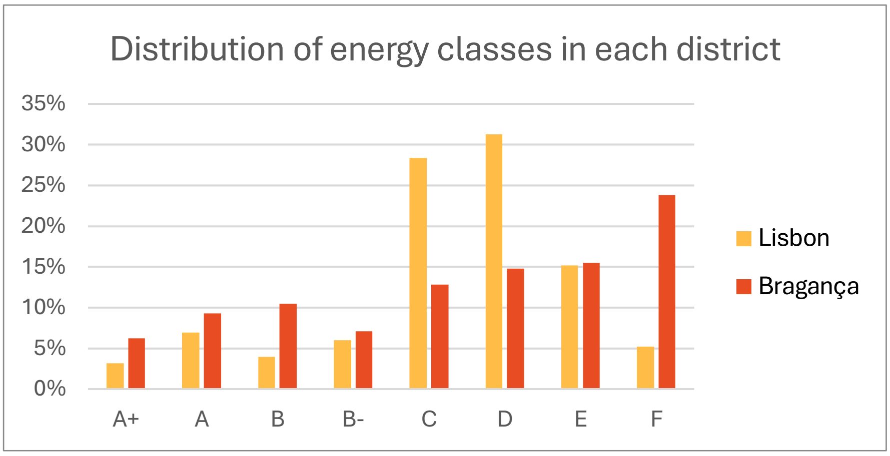

Figure 8 – Distribution of energy classes in both districts

Source: elaborated by the author based on ADENE (unpublished)

Energy Class Distribution by Construction Period

When disaggregating these classes by the construction period, two different time marks were chosen: Pre-regulation (Before 1990) and Post-regulation (After 1990). The pre-regulation scenario looks significantly worse in Bragança than in Lisbon, when more than 50% of dwellings in Bragança built before energy efficiency regulations are classified as F (the lowest energy class). Therefore, the situation in Bragança improved drastically after the regulations, where now only 17% of dwellings (built after 1990) belong to the F class. The situation did not change significantly in Lisbon, as most classes remain at a similar frequency to before the regulations, with only a further increase in concentration in the C and D classes (refer to **Figure 9**).

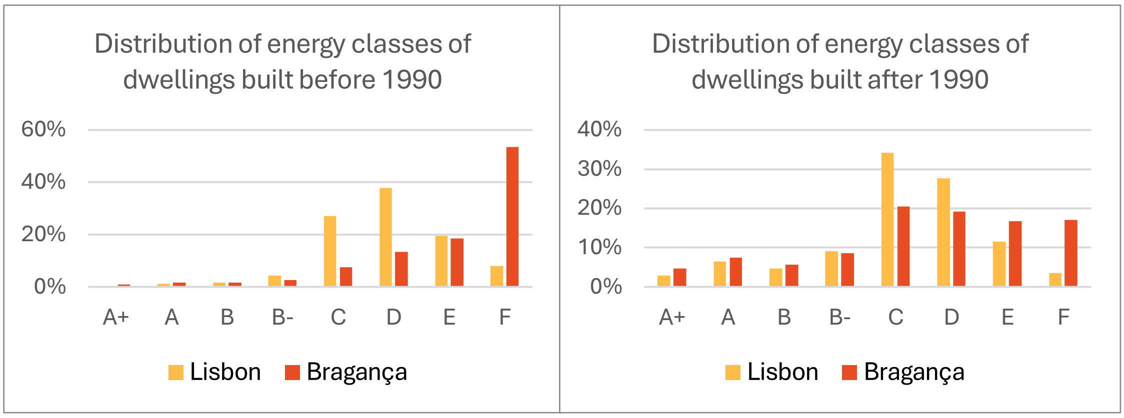

Figure 9 - Energy class distribution of dwellings built pre- and post-1990 by district

Source: elaborated by the author based on ADENE (unpublished)

Energy consumption for heating and cooling

In Bragança, dwellings spend more energy on cooling and heating (on average) than in Lisbon. Regardless, the true disparity comes in heating, where the average household in Lisbon spends 66 kWh/m^2.year compared to 161 kWh/m^2.year in Bragança. This higher energy consumption is influenced by the climate, since the lower temperatures and higher thermal amplitudes in Bragança require more heating to reach the comfortable reference temperatures of the SCE than in a milder climate like Lisbon. In cooling, the difference in energy spent on average is minimal. However, it still showcases the severity of energy poverty levels in the latter region (see **Figure 28** in the Appendix). When examining the data at a disaggregated level by construction period, it is evident that newer buildings demand progressively less energy for heating (**Figure 10**).

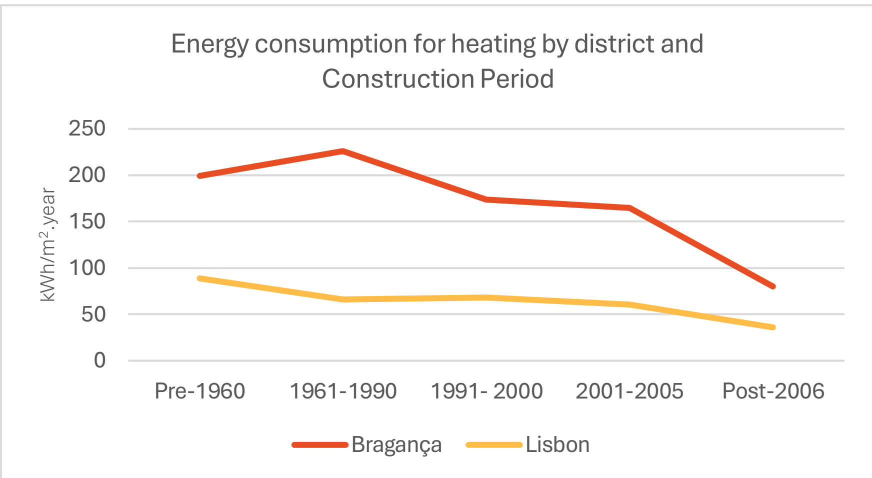

Figure 10 - Energy consumption for heating by district and construction period

Source: elaborated by the author based on ADENE (unpublished)

However, in Lisbon, this decrease was negligible compared to the significant decline of energy consumption for heating in Bragança, where it dropped from more than 200 kWh/m^2.year to only 80 kWh/m^2.year on the most recently built homes.

Regarding cooling, the trend observed between districts shows an opposite evolution from the latter. Bragança's decrease is minimal, with a 2 kWh/m^2.year difference from homes built before 1960 to the most recent buildings. In contrast, Lisbon shows a more dynamic change, decreasing 5 kWh/m^2.year from pre-1960 households to homes built in the 1990s. However, since the 2000s, the cooling energy needs of Lisbon households have doubled again, surpassing the demands of Bragança in the most recent buildings, reaching an all-time high (**Figure 11**). The most recent buildings in Lisbon spend more energy on cooling down than the ones built before 1960.

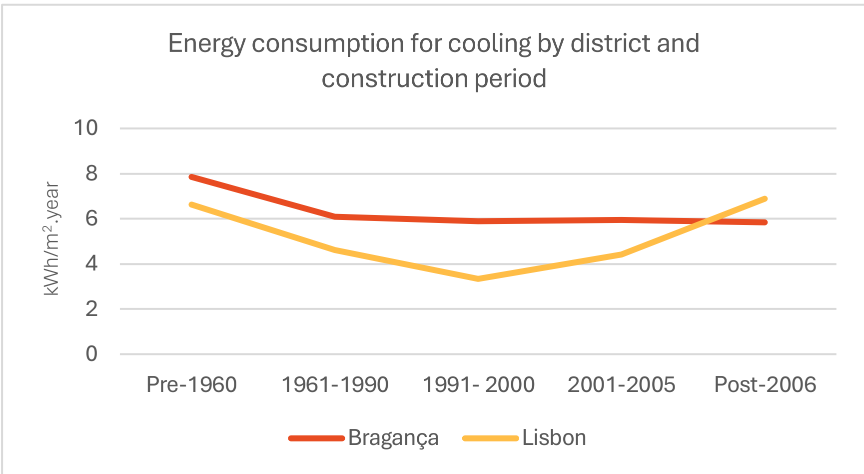

Figure 11 - Energy consumption for cooling by district and construction period

Source: elaborated by the author based on ADENE (unpublished)

CO_2 Emissions

Bragança has consistently higher levels of CO_2 emissions, due to its colder climate and subsequent higher reliance on heating systems. However, emissions have shown a pronounced decrease over time. In contrast, emissions in Lisbon have remained mostly stable, with a mild reduction from 3 tons/year to 1 ton/year.

In Bragança, this decrease was more drastic, going from 8 tons/year in households constructed before 1960 to 2 tons/year in the most recent buildings, almost catching up to the average level in Lisbon (**Figure 12**).

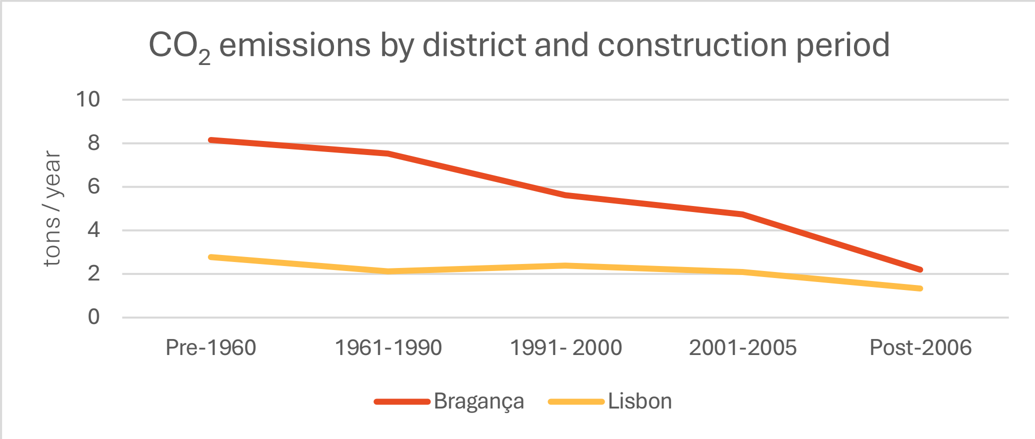

Figure 12 - CO2 emissions by district and construction year

Source: elaborated by the author based on ADENE (unpublished)

ROI – Return on Investment

The return on investment (ROI) in Bragança is significantly higher than in Lisbon, indicating that the same amount of investment is recovered more quickly, particularly in pre-regulation properties built before 1990 (**Figure 13**).

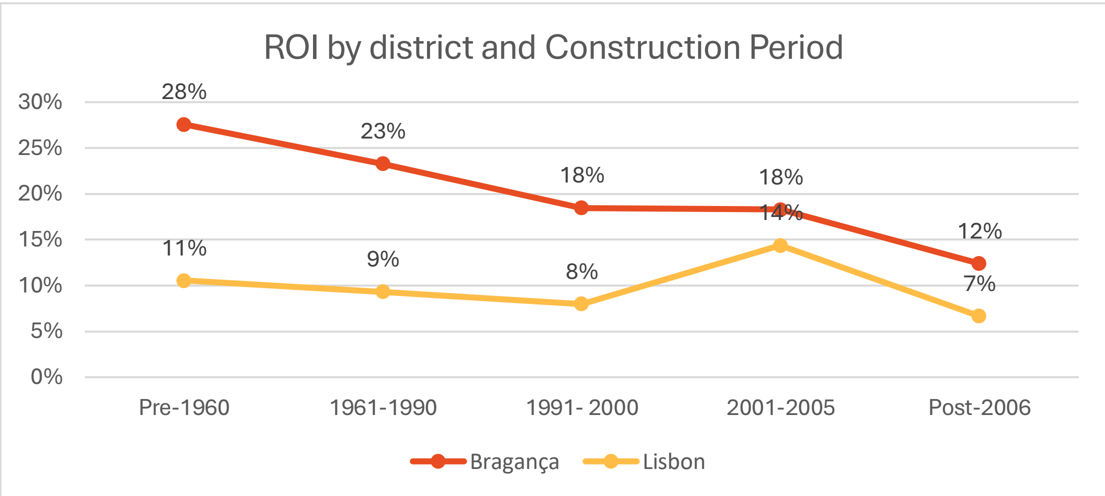

Figure 13 - ROI by district and construction period

Source: elaborated by the author based on ADENE (unpublished)

Recovering the investment costs for the energy efficiency renovations suggested in the certificates takes more than half of the time in Lisbon than in Bragança. For dwellings built before 1960, it takes about 10 years to recover the investment made in Lisbon, whereas Bragança only takes around 4 years.

In properties built during the 1990s, the recovery period in Lisbon extends to 13 years, while in Bragança, it takes only 5 years to regain that money through savings on the annual energy bill (**Figure 14**).

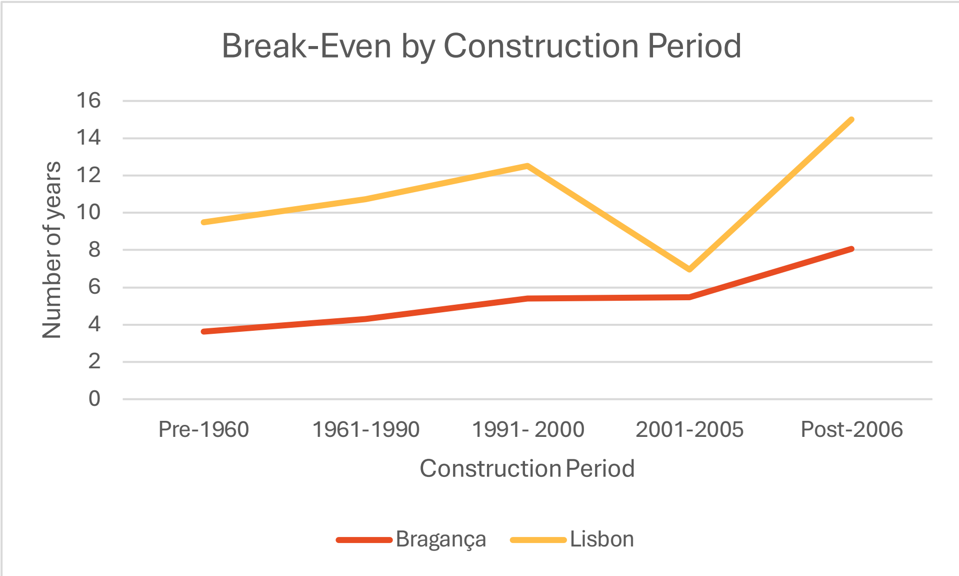

Figure 14 - Break-Even by Construction Period, by district

Source: elaborated by the author based on ADENE (unpublished)

In total, investments in energy efficiency measures in Lisbon homes take, on average, 11 years to recover, while Bragança dwellings only take 5 years to get a return back in savings (**Figure 15**).

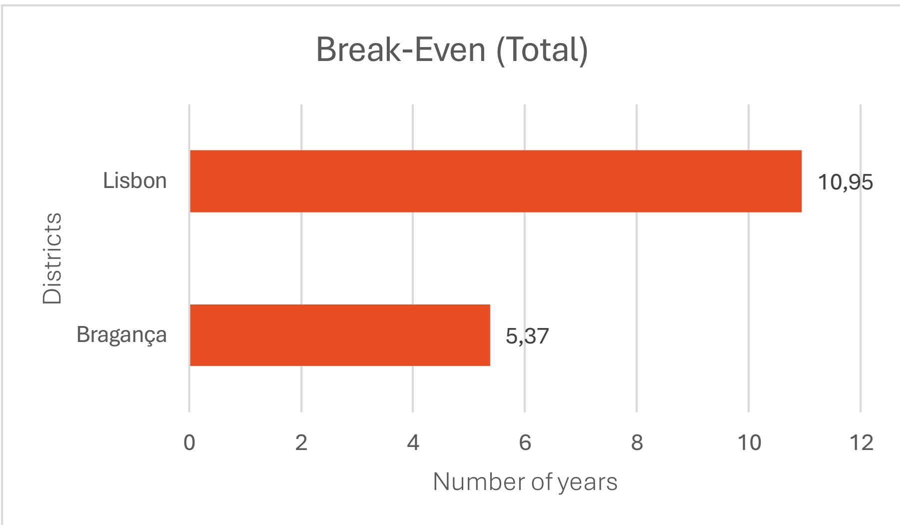

Figure 15 – Total Break-Even by district

Source: elaborated by the author based on ADENE (unpublished)

5. DISCUSSION

During this internship, a research analysis was thoroughly conducted to ascertain how the existing energy poverty programs, specifically the PVE and PAEMS, along with the data from the most recent energy certificates (2021-2024), can contribute to the development of new or improved public policy instruments in both rural and urban contexts. In both programs, the preferred measures in each district followed similar patterns: in Lisbon, the replacement of non-efficient windows, and in Bragança, the installation of heating, cooling, and DHW systems. This is significant since it shows exactly what areas in each district need the most energy poverty financial alleviation measures (refer to **TABLE X**).

TABLE X - Comparison of main results by district

District	Energy poverty most expressed need	Most frequent energy class	CO2 Emissions (tons/year)	Energy consumption (kWh/m^2/year)	Energy reduction potential	Break-Even point for recovery of investment
Bragança	Lack of heating, cooling and DHW systems	F	5,03	161	60%	5 years
Lisbon	Non-efficient windows	C and D	2,22	66	26%	11 years

Source: elaborated by the author

This tendency is understandable, as we also consider the meteorological differences between the two districts, with harsher winters in Bragança and a milder climate in Lisbon. Furthermore, it is important to note that one of the programs (PAEMS) showed a big difference in the energy reduction after the application of the measures between the two districts, with a 60% of energy reduction in Bragança compared to a modest 20% reduction in Lisbon. These results not only highlight the measures that are most critical to each region, but also the massive impact that they have on a rural region like Bragança. This is crucial to policymakers and energy agencies like ADENE, in national and

European contexts, when creating such financial instruments, i.e. deciding on target regions and what measures to expand financing on.

The situation is indeed concerning, as the SCE certificates show that most Portuguese households have very low energy ratings. This supports the assumption in the existing literature and the 2021 census, which characterized the Portuguese housing stock as mostly built in a time before any energy efficiency regulations were in place, an era where energy efficiency was not accounted for. In Bragança, most certificated dwellings are classified as F, the lowest rating in the scale. On the other hand, Lisbon is performing better, with most dwellings having classes C and D. After 1990, the newly imposed energy regulations significantly improved Bragança dwellings, where now only 17% belong to an F class, compared to more than half in dwellings built in a pre-regulation era. The impact of the regulations in Lisbon was, by far, not so pronounced, with only a slight and steady improvement to better energy classes.

5.1. Recommendations for ADENE

The insights provide essential recommendations for ADENE. The key aspect of the analysis is the comparison of the ROI between districts, as it was found that the estimated savings in Bragança are significantly higher than those in Lisbon, which led to a particularly interesting conclusion. The same amount of investment in energy efficiency measures in both districts takes less than half of the time to be recovered in Bragança than in Lisbon. These results indicate that programs designed to tackle energy poverty in Portugal are the most effective when directed at districts like Bragança (i.e., predominantly rural). This is due to its relatively lower income per capita, climate, and general socioeconomic context. In rural areas, existing housing tends to require more energy, which leads to higher CO_2 emissions. Additionally, residents have, on average, a lower disposable income to spend on energy bills. This indicates that such regions would benefit greatly from more financing than others, as well as from a focus on installing cooling/heating/DHW systems, as this is the most expressed need in the programs.

Energy efficiency improvement measures directed at such regions will not only have the most impact on households but also on the environment and, therefore, the government's climate goals. Nonetheless, Lisbon would highly benefit from cooling measures, since its buildings are wasting considerably more energy than those in

Bragança in the summer months. Even the most recently built dwellings are currently using higher amounts of energy for lowering the temperature of their environment than older buildings, which constitutes a valid concern.

National energy poverty alleviation programs should be tailored to each region or type of region based on the outcomes from past programs and the intrinsic characteristics of each district. For instance, the same measure in a district like Lisbon does not have the same impact in a district such as Bragança. Rural regions should not be left behind in the fight against energy poverty, as this constitutes a crucial aspect for the decentralization efforts[16] of the country. In fact, measures should be applied at a regional level instead of a national level. The existing programs should be adapted according to the urbanization degree of each district. For example, PAEMS should not demand upfront costs in predominantly rural districts. It is true that the PVE aims to address low-income consumers who cannot support these costs. However, it is failing to address those who do not benefit from any minimum social benefit yet do not have enough disposable income for these types of renovations. Another way of better-adapting measures is through the integration of the existing indexes that measure energy poverty regionally, the EPVI and the IVEM. Differentiation in measures is, therefore, the key to attain significant improvement in the energy poverty situation. In short, we can overall conclude that:

1. Targeting energy efficiency policies for rural regions brings greater benefits than targeting urban regions.
2. Investments made in renovations for improving energy efficiency of housing in rural districts can be recovered in less than half of the time than in urban areas.
3. Energy poverty alleviation measures should be applied at a regional level and not at a national level.

Overall, the programs had a significant turnout participation rate, and it is undeniable that they have already played a role in the mitigation of energy poverty. However, more robust conclusions and monitoring would be possible if ADENE gathered enough data to establish a correlation between the programs and the certificates. Furthermore, the creation of more programs is urgently needed, as Portugal remains one of the EU member-states with the least amount of energy poverty policies, even though it scores as the worst in this crisis (see **Figure 29** in the Appendix). Like Italy and Greece, perhaps Portugal

[16] See: https://diariodarepublica.pt/dr/lexionario/termo/descentralizacao (retrieved 22-12-2024)

would highly benefit from a tax relief plan for energy renovation of buildings (Martini, 2023), or a subsidy to renovate vacant buildings like it was done in Ireland to encourage the renovation of the existing housing stock (Government of Ireland, 2022). Additionally, in China, successful retrofitting strategies for existing buildings in rural areas were implemented with the aim of rural development (Tian et al., 2024). An energy efficiency obligation scheme, where the energy service providers are obligated to use their own funding to meet national energy efficiency targets while safeguarding consumers, like it was implemented in Greece, could also prove essential (PowerPOOR, 2023b).

5.2. Limitations

It is important to note, however, that the sample size is limited to the dwellings that were certificated during the chosen period, which can restrict the study since the results may not be representative of the entire region. Additionally, the sample could be biased toward households that proactively sought certification, more specifically, dwellings that are on the market or that were constructed anew, which potentially excludes those most affected by energy poverty but lacking awareness or resources to participate.

Furthermore, the ROI was calculated based on estimates of savings and investment rather than actual values, and therefore, the findings may present inaccuracies in relation to real-world conditions. Additionally, it was not possible to calculate the correlation that was intended to aid in answering the research question due to a lack of data connecting the programs and the SCE certificates. The PAEMS program requires the submission of an SCE certificate. However, there is no information concerning the supported families and the certificates submitted, as well as no data on certificates after participating in any of the programs. Essentially, the analysis presented a critical limitation on the inability to correlate these two datasets due to missing data.

Moreover, only two districts were compared in the research investigation, which may introduce some bias. The intrinsic nature of the data, as well, limits the results, as it is impossible to know whether or to what extent the beneficiaries experienced the renovations supported by the programs in actually alleviating energy poverty symptoms, and even if such data existed, it would be of a holistic nature. This is because the study relies solely on quantitative data, missing qualitative factors such as occupant behavior, perceived comfort, or hidden energy poverty.

5.3. Future Research

Future studies comparing the energy certificates of more regions of the country would help to assess whether the fundamental differences found in rural and urban contexts remain the same for similar districts to Lisbon and Bragança. Conducting longitudinal studies tracking certified homes over 5-10 years to evaluate the durability of retrofits and long-term ROI would be a valuable insight. It would be crucial to collaborate with more government agencies and fund providers of the programs (such as Fundo Ambiental) in order to merge datasets, filling the data gap that would enable a direct linkage between the programs' beneficiaries and their SCE certificates. A periodic evaluation of the renovated homes is the key to effectively monitor the impacts and results of the programs. On top of that, it would be pivotal to demand an energetic certification before and after each intervention, so that this data gap would be immediately suppressed.

Another interesting feature for a study in the future would be to incorporate qualitative methods (interviews, focus groups) to assess lived experiences of energy poverty before and after renovations. Modeling the macroeconomic impacts of large-scale energy efficiency programs, such as job creation and reduced healthcare costs (from improved housing conditions) would be a paramount tool to further assess the impact of these programs. Furthermore, benchmarking Portugal's programs against similar initiatives in other Mediterranean or EU countries to identify best practices and policy transfer opportunities would reveal to be a compelling analysis.

Lastly, incorporating the EPVI and IVEM indexes could lead to better insights beyond metrics, considering affordability, health impacts, and social equity.

6. CONCLUSION

This study aimed to assert the impacts of the PVE and PAEMS programs on Portuguese households. It assessed the impact of these programs by analyzing data from the SCE energy certificates, which provided insights on how to improve future editions of these programs and financial instruments directed at energy poverty issues, bearing in mind regional disparities. Based on quantitative and qualitative analysis, comparing a rural and an urban district allowed for a unique cross-analysis that showed significant and differing results. Households in Bragança can usually regain their investment back in the form of savings in less than half of the time than Lisbon. Therefore, it can be concluded that the financing and measures of such programs should be differentiated according to the type of region. While the small sample size may limit the generalizability of results to the entire country or other European countries, this approach provides important new insights into the situation of energy poverty in Portugal and how to improve the current programs that address it. Targeting policies for rural regions has shown in this study to bring greater benefits than when the same measures target urban regions. Based on these conclusions, ADENE and other relevant policymakers should consider restructuring these programs by introducing regional differentiation in their respective measures or even by creating entirely new programs inspired in other EU countries. Collecting more data that enables a correlation between the certificates and the programs themselves would benefit future analysis.

This study demonstrates how different regions in Portugal react to the same energy poverty programs. It compares it with the data from the latest energy certificates, which is crucial for effectively addressing the problem. With Portugal placed as the worst-ranked European nation in many indicators for energy poverty, this policy reformulation is rather urgent and much needed. By committing to these changes, we are paving the way for a more sustainable future and the well-being of all citizens. This way, we can effectively transform the energy efficiency landscape in Portuguese households and provide the country with an equitable and decentralized transition.

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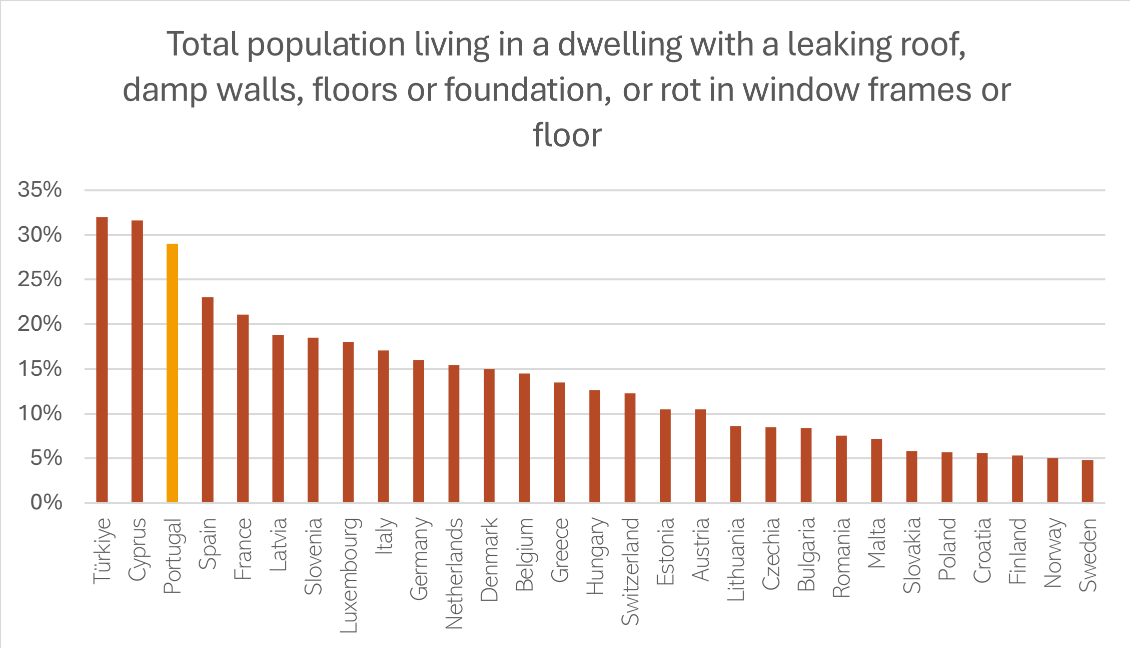


Figure 16 - Population living in dwellings with leaks, dampness, or rot in 2023

Source: Eurostat (2023b)

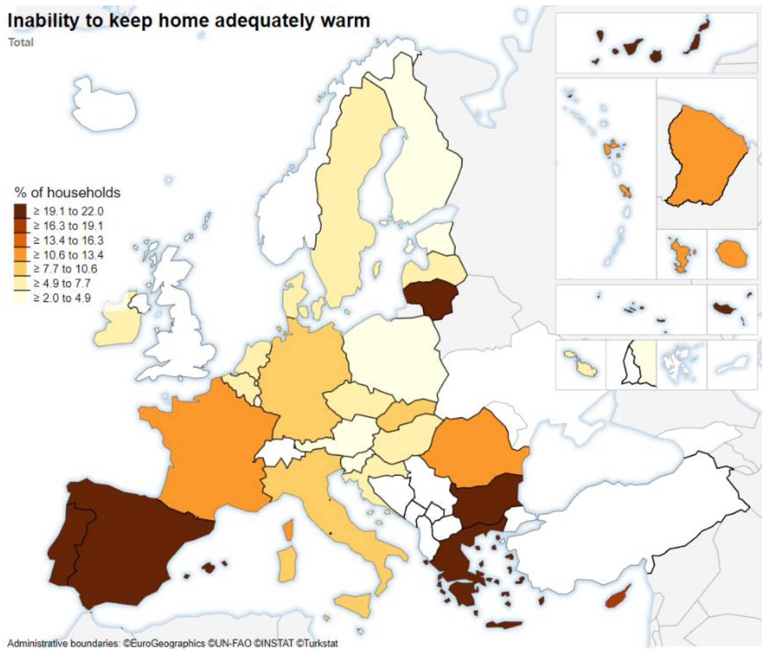


Figure 17 – Inability to keep home adequately warm in Europe in 2023

Source: EPAH (2023)

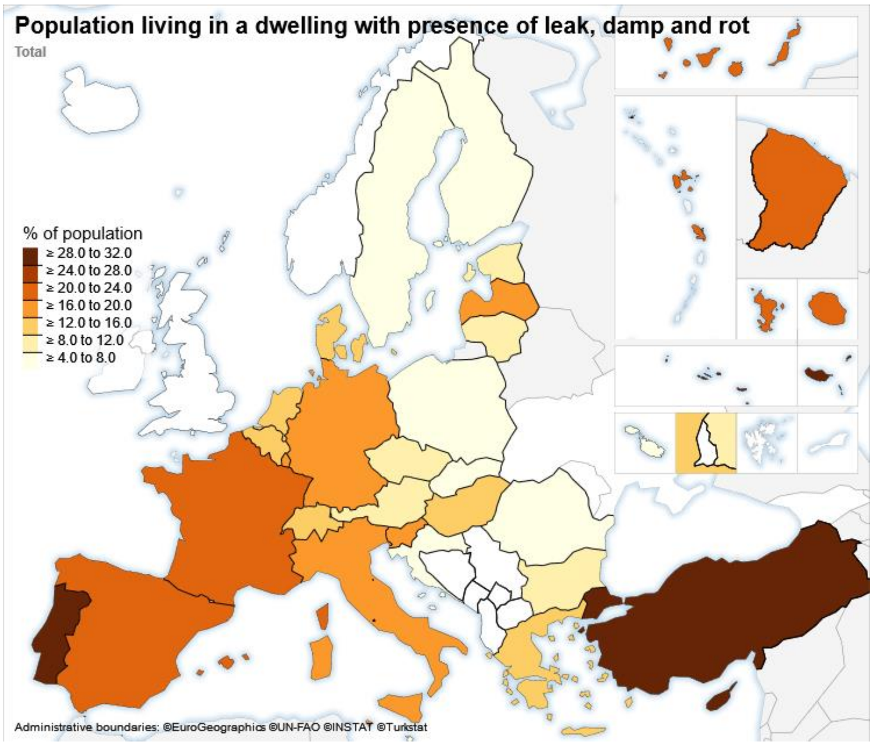


Figure 18 – Population living in a dwelling with presence of leak, damp and rot

Source: EPAH (2023)

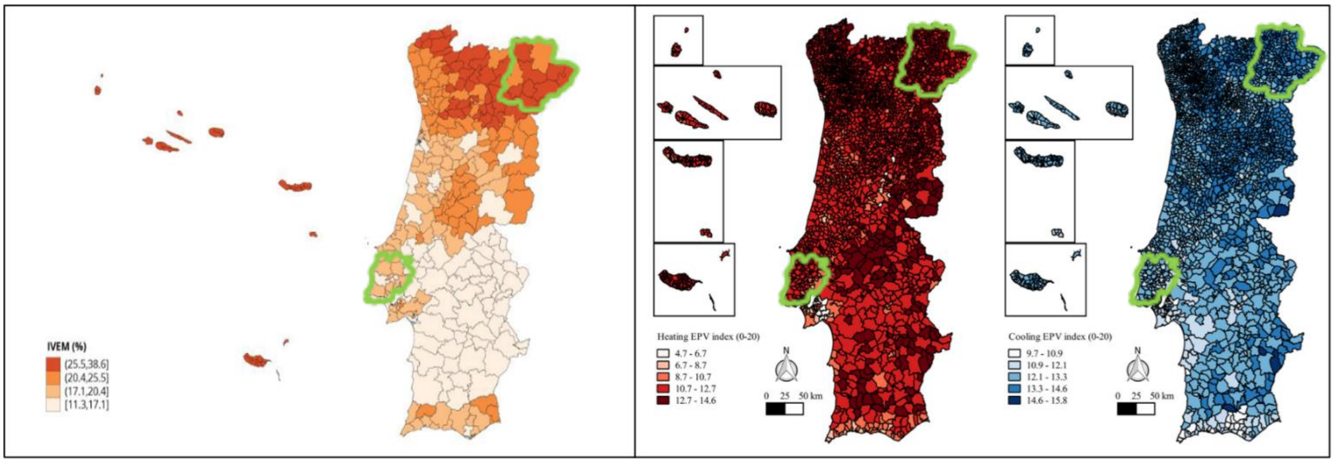


Figure 19 - Energy poverty indexes (IVEM on the left and EPVI on the right)

Note: the EPVI measures heating (left) and cooling (right)

Source: adapted from Carvalho et al. (2023) and Gouveia et al. (2019)

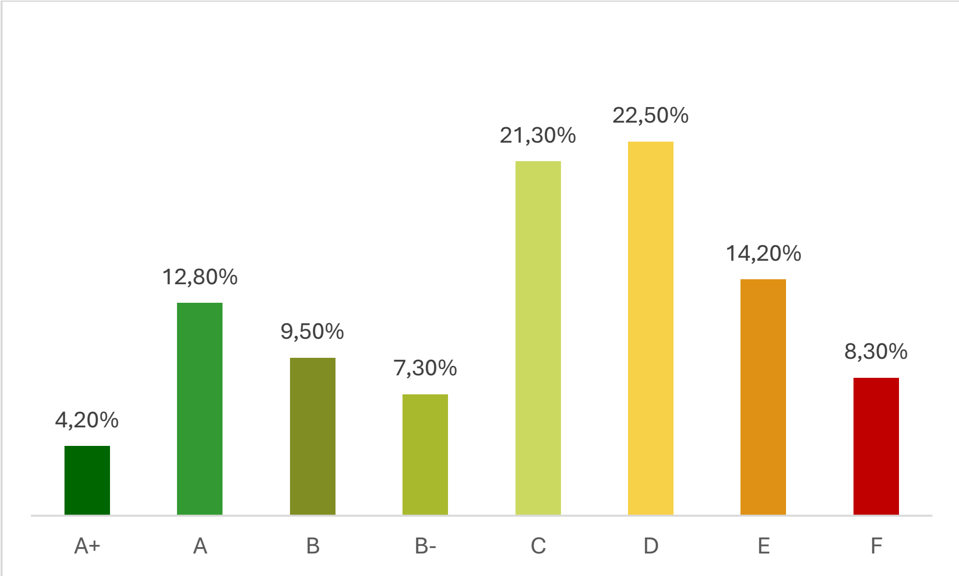


Figure 20 - Energy performance in the residential sector based on SCE until 2022

Source: adapted from ADENE (2023)

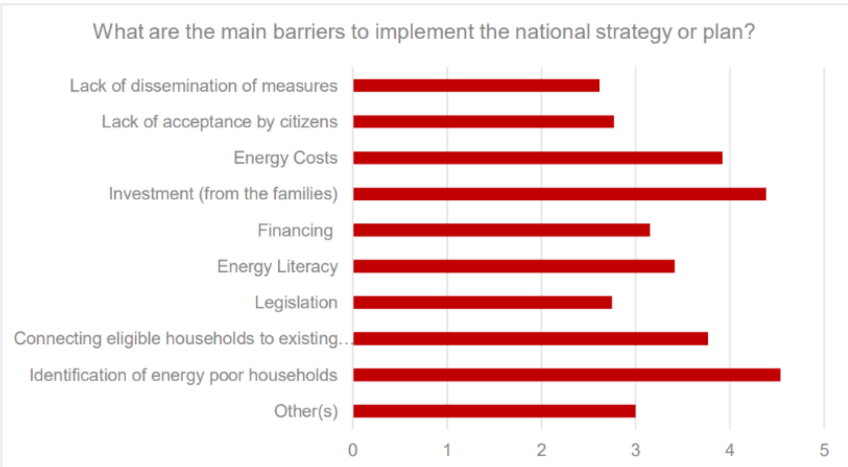


Figure 21 – Main barriers to implement the national strategy or plan in 14 European countries

Source: European Energy Network (2023)

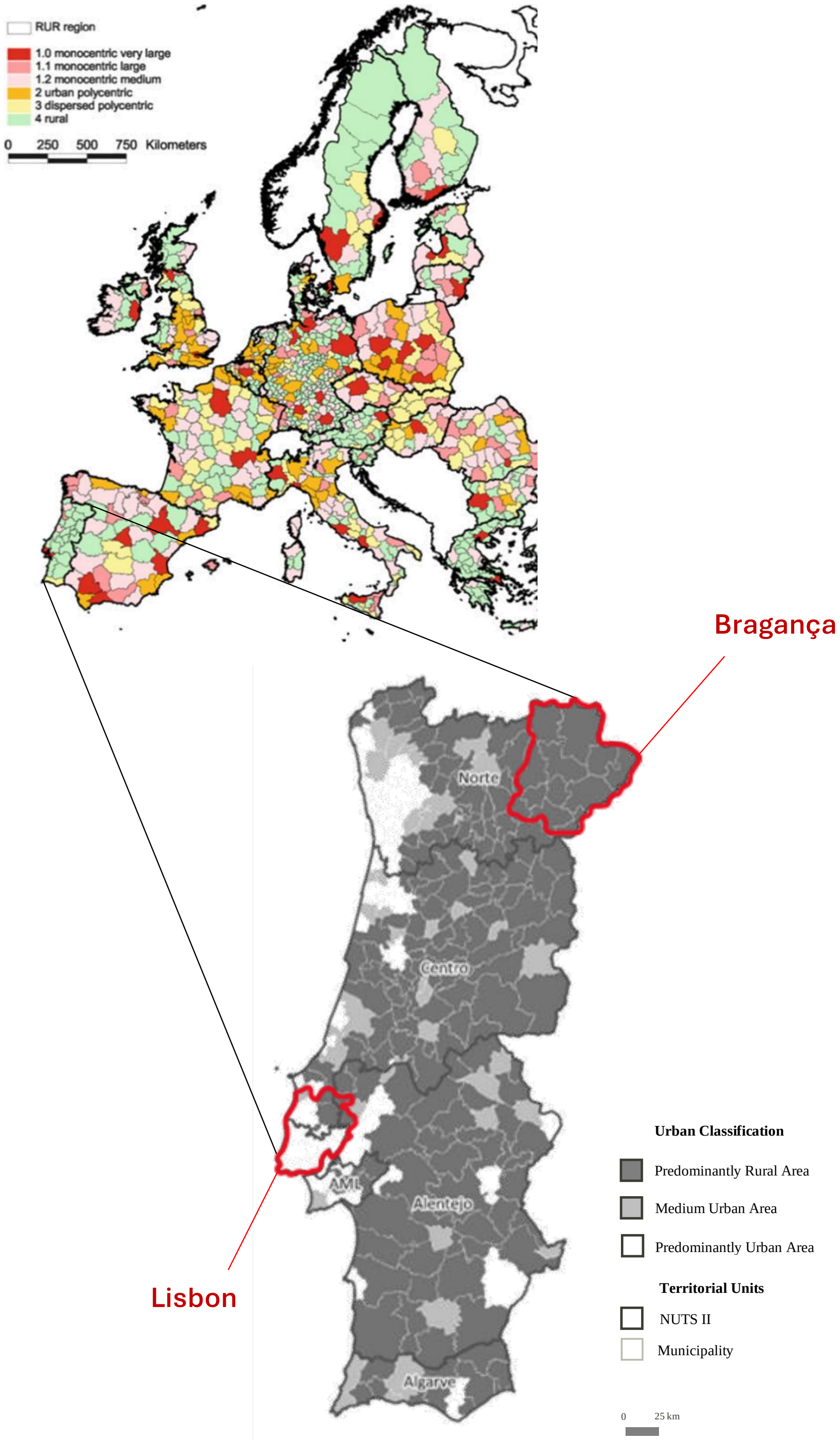


Figure 22 – Urbanization degree in EU and Portugal

Source: adapted from Zasada et al. (2013) and CCDR-N (2021)

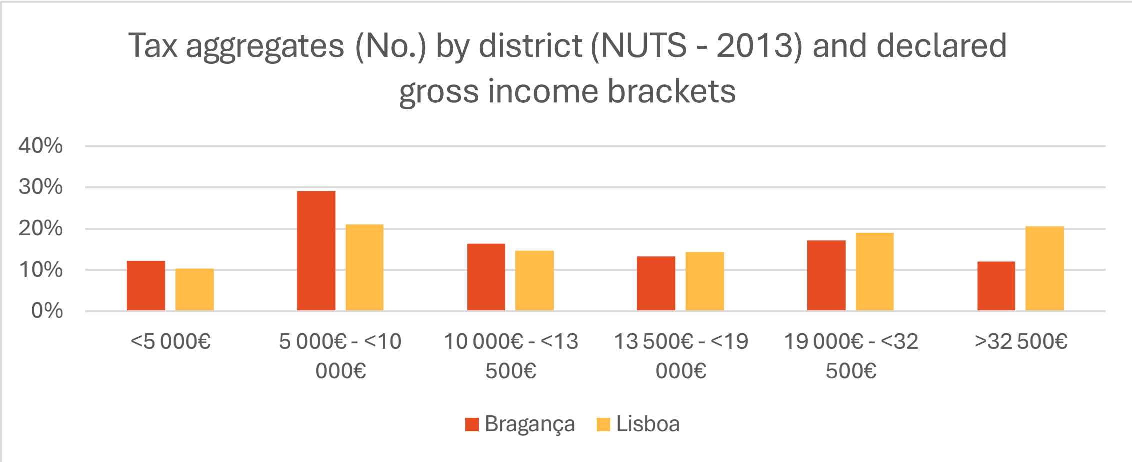


Figure 23 – Tax aggregates by district and income brackets

Source: INE (2022)

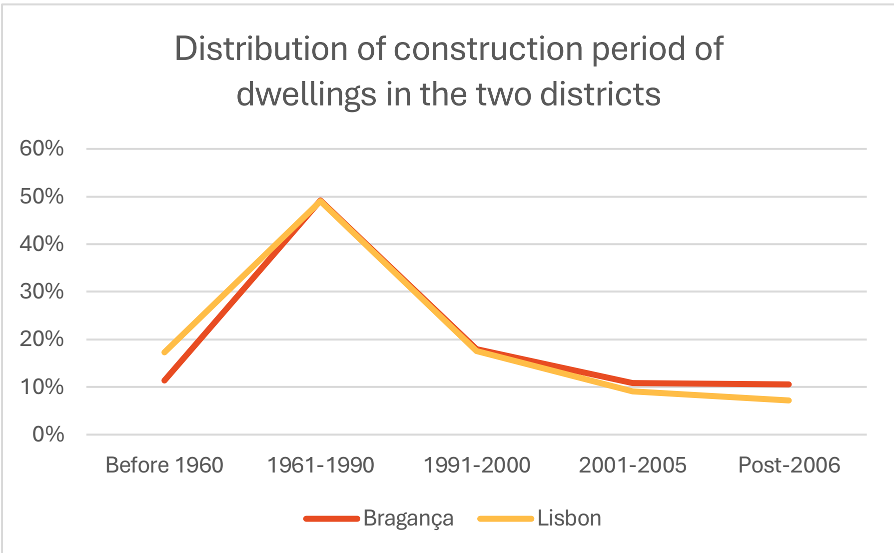
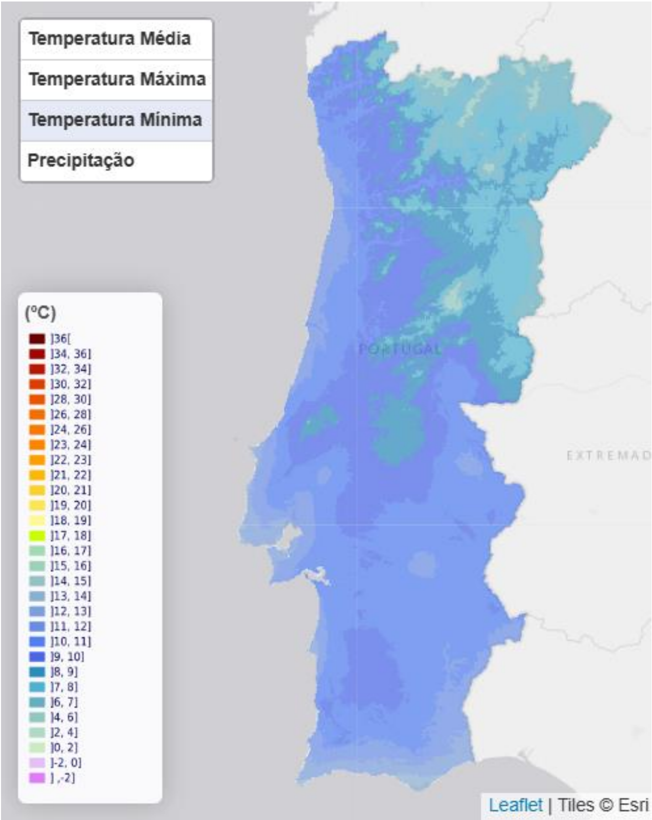


Figure 24 - Distribution of the dwelling age in the two districts

Source: INE (2022)



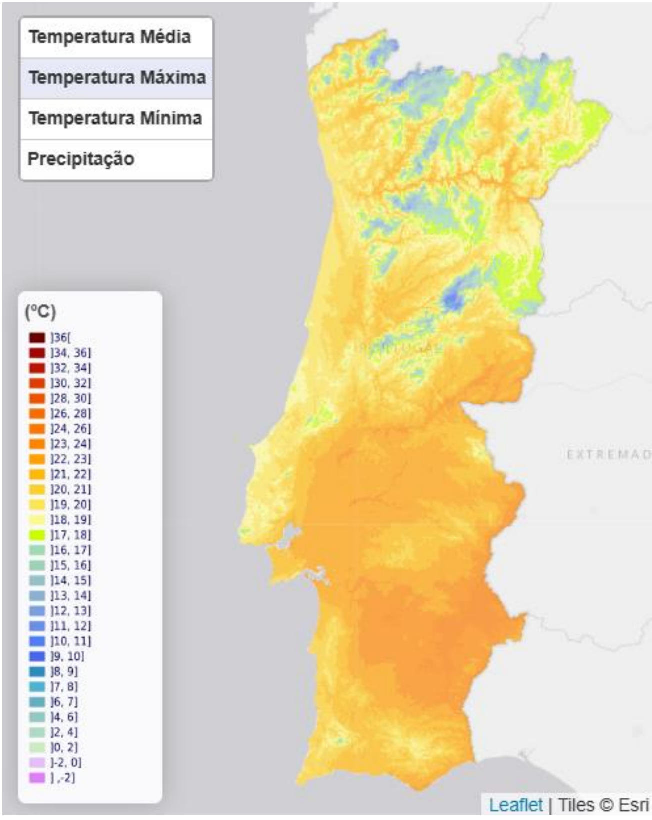
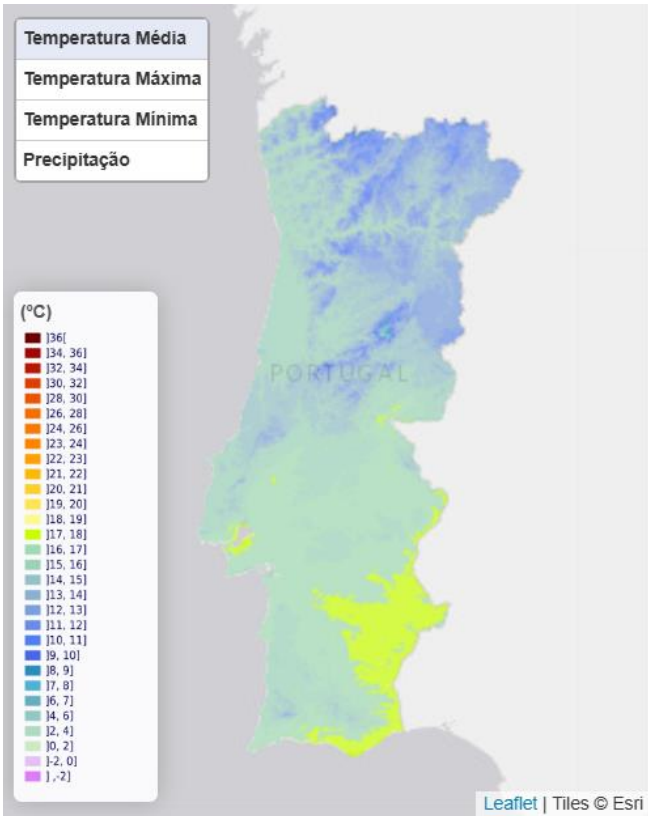


Figure 25 – Average temperatures measured between 1981 and 2010 on the national continental Portuguese territory (annual). Average of the minimum temperature (upper left); Average of the maximum temperature (upper right); Average of the average temperature (bottom right).

Source: IPMA (n.d.)



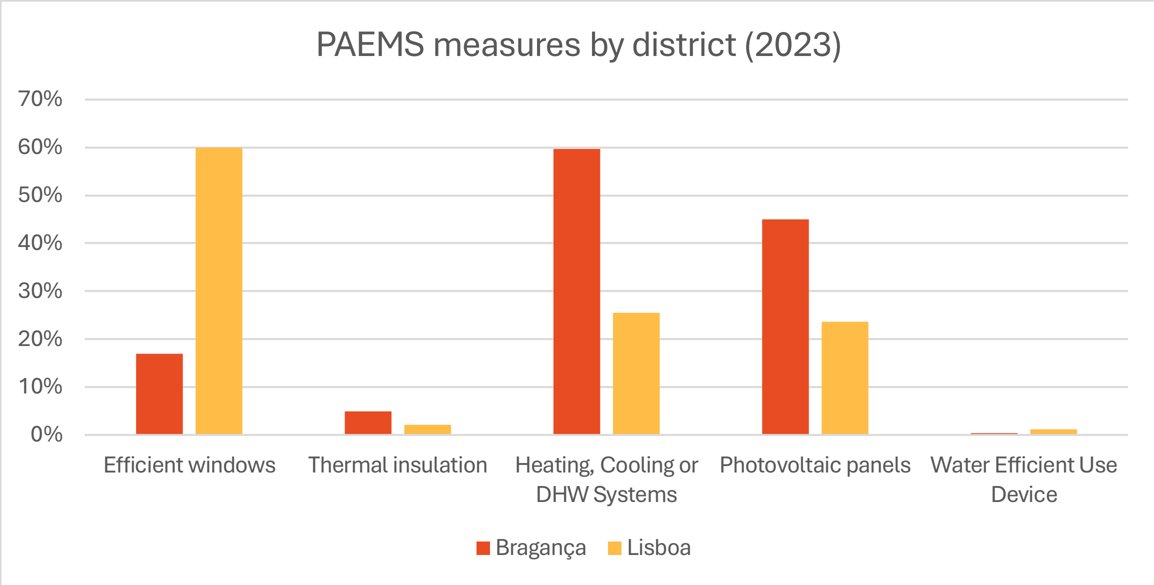


Figure 26 – Frequency of PAEMS measures by district

Source: elaborated by the author based on ADENE & Fundo Ambiental (unpublished-a)

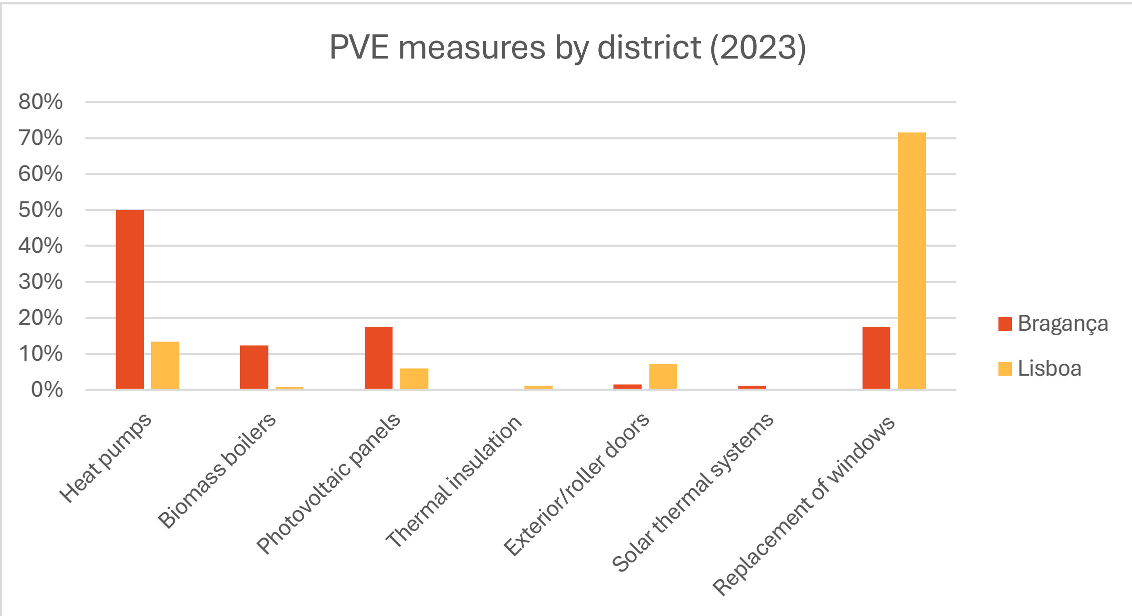


Figure 27 – Frequency of PVE measures by district

Source: elaborated by the author based on ADENE & Fundo Ambiental (unpublished-b)

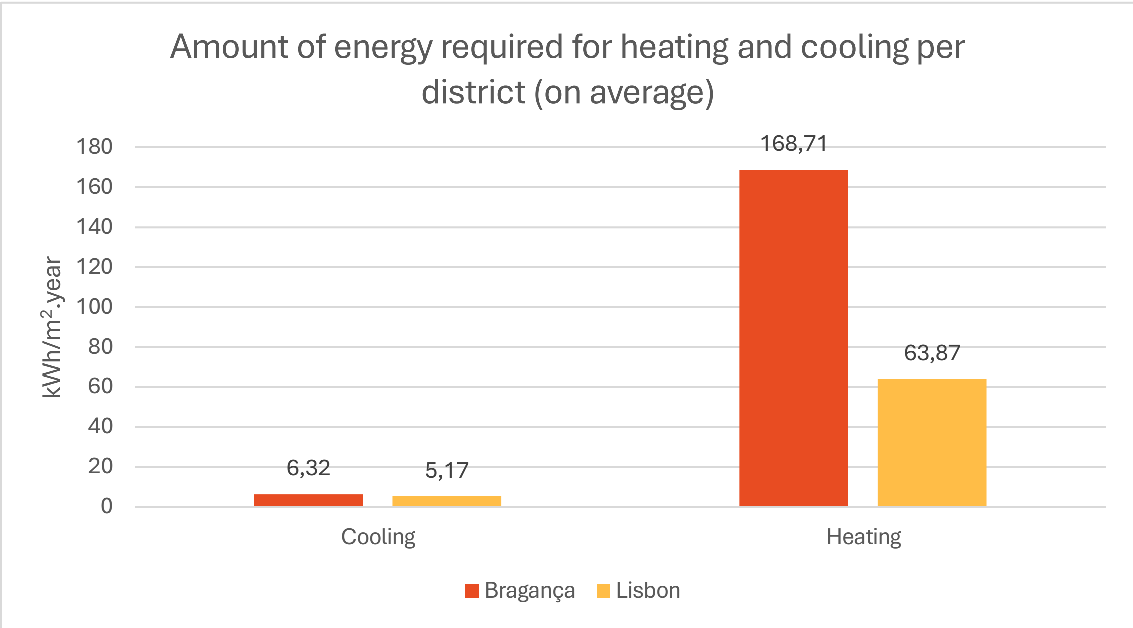


Figure 28 - Energy needed for heating and cooling by district (on average)

Source: elaborated by the author based on ADENE (unpublished)

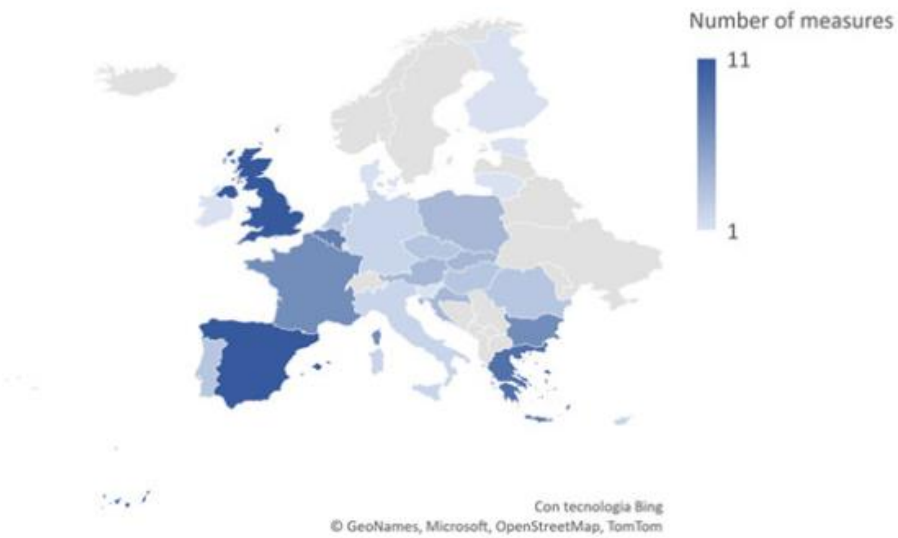


Figure 29 – Policy measures in different Member-States

Source: Martini (2023)