NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTAMENT OF
ENVIRONMENTAL SCIENCES AND ENGINEERING

INÊS MONTEIRO VALENTE

BSc in Environmental Engineering

EXPLORING ENERGY POVERTY AND THERMAL COMFORT IN PORTUGUESE UPPER SECONDARY EDUCATION STUDENTS

INTEGRATED MASTER IN ENVIRONMENTAL ENGINEERING

NOVA University Lisbon
September, 2023

DEPARTAMENT OF
ENVIRONMENTAL SCIENCES AND ENGINEERING

EXPLORING ENERGY POVERTY AND THERMAL COMFORT IN PORTUGUESE UPPER SECONDARY STUDENTS

Inês Monteiro Valente

BSc in Environmental Engineering

Adviser: Dr. João Pedro Gouveia
Principal Researcher, CENSE – Center for Environmental and Sustainability Research & CHANGE - Global Change and Sustainability Institute, NOVA School of Science and Technology, NOVA University Lisbon

Examination Committee:

Chair: Prof. Dr. João Joanaz de Melo,
Associate Professor, NOVA School of Science and Technology, NOVA University Lisbon

Rapporteurs: MSc Miguel Macias Sequeira,
Researcher, CENSE – Center for Environmental and Sustainability Research, NOVA School of Science and Technology, NOVA University Lisbon

Adviser: Dr. João Pedro Gouveia,
Principal Researcher, CENSE – Center for Environmental and Sustainability Research & CHANGE - Global Change and Sustainability Institute, NOVA School of Science and Technology, NOVA University Lisbon

INTEGRATED MASTER IN ENVIRONMENTAL ENGINEERING

NOVA University Lisbon
September, 2023

Exploring Energy Poverty and Thermal Comfort in Portuguese Upper Secondary Education Students

To my grandparents.

Acknowledgments

My first and foremost acknowledgement goes to my advisor, Prof. Dr. João Pedro Gouveia. I am immensely grateful for the teachings, assistance, and reviews provided during this research. I would also like to thank for the numerous opportunities offered to me over the past one and a half year, which has been crucial in shaping my academic and professional journey. This work would have not been possible without the involvement and support of schools.

To my mother, father, and Duarte, I owe an immeasurable debt of gratitude for their unconditional support throughout this journey. I would like to especially thank my grandparents, to whom I dedicate this work, for continuously inspiring me to become the best version of myself. To Alexandre, my best best and soon-husband-to-be, you were my unwavering support system and i would not have made this without you. To my in-laws, my extended fsmiliy, for all the support. Additionally, I extend my appreciation to all my friends for being there for me during the challenging moments of my academic journey. Luana, Ana, Rafael and Rúben, thank yu for being who you are. Bruna and Rita, thank you for never giving up of me. Catarina, Alexandre, Laura and Jerónimo, thank you for all the good times. Moreover, I would like to express my heartfelt gratitude to Alexandre, who has been my unwavering support system, to Beatriz, for believing in me during times when I doubted myself, to Bárbara, for joining me in exploring energy poverty and being an exceptional work partner and to Daniel, for offering his unwavering support despite being far away.

Lastly, I want to dedicate this work to all my future students. If I have reached this point, I firmly believe that you can too. It is my hope that this work will serve as an inspiration to all of you.

"I am afraid that I must take issue with the term "fuel Poverty". People do not talk of "clothes poverty" or "food poverty", and I do not think that it is useful to talk of "fuel poverty" either" (Peter Walker, ex-Secretary State Of Energy of UK, 1985)

Abstract

Energy poverty is a growing multidimensional concern worldwide, with children and young people particularly vulnerable. This age group spends a significant amount of time in both their houses and school buildings. Still, there has been little research on the dual vulnerability to inadequate thermal comfort conditions in these two environments. In Portugal, the exposure to inadequate thermal comfort in school buildings varies due to disparities in renovation efforts: while some schools have undergone renovations to improve thermal comfort, others have not. This work aims to assess upper secondary school students' perception of energy poverty at home and thermal comfort inside classrooms. The study employed two complementary components: surveys of a statistically significant sample of students from one renovated and one non-renovated schools located in the Lisbon district for a more focused insight, and surveys from students from different schools across Portugal, to have a more exploratory perspective. The first segment of the methodology was complemented with interviews and surveys with other school stakeholders to understand their perceptions of this issue. The results indicate that between 4.2-14% of students live in permanent discomfort (uncomfortable both in school and at home). Despite the discomfort still observed in students from the renovated school, it is possible to say that the renovation attenuated this. Students with health conditions and disadvantaged backgrounds were more likely to report discomfort than those who did not. This study raises awareness of a vulnerable group and underscores the importance of studying energy poverty and thermal comfort at the local level, considering the variations between schools, socio-demographics, and climatic zones. This study provides valuable insights into the issue of energy poverty among young people. It addresses the need to incorporate this age group in energy-related policies, to involve the students in the decision process regarding the classroom' temperature and that schools are places that may serve as a refuge from energy poverty to this age group.

Keywords: Energy Poverty, Thermal Comfort, Upper Secondary Education, Portugal.

Resumo

Pobreza energética é uma problemática multidimensional, com crianças e jovens entre os grupos particularmente vulneráveis. Este grupo passa a maior parte do seu tempo no interior de edifícios (em casa e na escola) mas nenhuma investigação foi feita na dupla vulnerabilidade ao fraco conforto térmico destes dois ambientes. Em Portugal, a exposição ao desconforto térmico em edifícios escolares ocorre de forma díspar ao longo de todo o território, devido às assimetrias na renovação dos edifícios escolares. O objetivo deste trabalho é averiguar a perceção dos estudantes do ensino secundário sobre pobreza energética e conforto térmico na escola. Com esse intuito, foram utilizadas duas metodologias complementares: inquéritos em duas escolas (renovadas e não renovadas, localizadas no distrito de Lisboa) com populações estatisticamente significantes, para uma perspetiva mais direcionada do assunto, e inquéritos a alunos de várias escolas do país, de modo a ter uma perspetiva mais exploratória e abrangente do assunto. O primeiro segmento foi complementado com entrevistas e inquéritos a outros intervenientes, de modo a ter uma perspetiva integrada do assunto. Os resultados expõem que viver em desconforto permanente é uma realidade para entre 4.2%-14% dos jovens. Apesar do desconforto ainda sentido nas escolas renovadas, é possível afirmar que a renovação contribuiu para atenuar este problema. Fatores como a saúde ou a condição financeira levam a que alguns grupos de jovens sejam mais propícios a reportar desconforto que outros. Este estudo sublinha a importância de estudar pobreza energética e conforto térmico em jovens à escala local, considerando as variações entre escolas, sociodemográficas e climáticas. Realça ainda a importância de incluir este grupo nas políticas de pobreza energética, de os envolver nas decisões face à temperatura da sala de aula. Por último, proporciona um novo olhar sobre as escolas como lugares importantes para atenuar os impactes da pobreza energética neste grupo etário.

Palavas chave: Pobreza energética, Conforto térmico, Ensino secundário, Portugal.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ADENE	Portuguese Energy Agency
EU27	27 European Union Countries: Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.
EC	European Commission
EPAH	Energy Poverty Advisory Hub
ERSE	Entidade Reguladora dos Serviços Energéticos
FA	Fundo Ambiental
IEA	International Energy Agency
INE	Instituto Nacional de Estatística
Lisboa E-NOVA	Lisbon Energy and Environment Agency
NRS	Non-renovated School
OECD	Organisation for Economic Co-operation and Development
PE	Parque Escolar
RS	Renovated School
CO_2	Carbon Dioxide

1

INTRODUCTION

Environmental scientists and environmental engineers play a role in contemporary society, like the one of Cassandra in Greek mythology. Like Cassandra, who possessed the gift of foreseeing future events but struggled to convince others of her prophecies, these professionals have been raising alarm bells in recent years regarding the repercussions of climate change and the consequences of inaction. The Intergovernmental Panel on Climate Change's Sixth Assessment Report emphasized that more frequent and intense extreme events resulting from climate change will have profound effects on ecosystems, food production, water scarcity, human health and well-being, as well as urban environments. We are approaching a critical threshold where both natural and human systems are exceeding their capacity to adapt. Climate change will shape cities and exert increasing pressure upon them (UN HABITAT, 2022; Ritchie & Roser, 2018) and will have significant implications on energy consumption (Auffhammer & Mansur, 2014; Ruijven *et al.*, 2019), highlighting the need to consider extreme events in the design of energy systems (Perera *et al.*, 2020). Energy production is the most significant contributor to global CO_2 emissions (IEA, 2023), while climate change will impact energy production and demand. Approximately 87% of global electricity generated from thermal, nuclear, and hydroelectric systems relies on water availability, with around 33% of thermal power plants situated in areas already experiencing high water stress (WMO, 2022). As climate change intensifies, the demand for energy services will rise. Increasing temperatures and extreme events will mainly drive the need for cooling services (IEA, 2018; Ruijven *et al.*, 2019). Currently, the inability to access adequate energy services is already observed globally, and climate change is set to exacerbate this issue as it is expected to push 130 million people into poverty over the next ten years (Nishio, 2021). This inability, commonly referred to as energy poverty, affects an estimated 15 to 125 million people in Europe alone (EPAH, 2023a). Energy poverty is a multidimensional problem that disproportionately impacts various groups due to factors such as age, health, and income disparities, including vulnerable children and young people (Middlemiss, 2022).

In Europe, it is estimated that individuals spend approximately 90% of their time indoors (Joint Research Center, 2003). Therefore, it is crucial to assess thermal comfort not only in residential settings but also in places where people spend extended periods, such as workplaces for adults and school buildings for children. Research on thermal comfort in workplaces has revealed its significant relationship with adults' productivity and well-being (Witterseh *et al*., 2004; Ian *et al.*, 2010; Tarantini *et al* ., 2017). Similarly, in schools, indoor environmental quality parameters have been found to impact students' well-being (Dorizas *et al*., 2015; Wargocki *et al*., 2019; Wargocki *et al*., 2020; Sadrizadeh *et al*., 2022). Across Europe, the average duration of compulsory education is 11 years (Eurydice, 2022), indicating that children may be exposed to unhealthy environments during a critical development stage. This is particularly concerning considering that, in Europe, one out of three children live in unhealthy homes (The Velux Group, 2019). Although the impacts of living in unhealthy homes and attending unhealthy buildings have been studied, as our knowledge, no research has examined the intersection of these two factors.

Unfortunately for Portuguese children and young individuals, attending school may be synonymous with exposure to thermal discomfort. The school building stock in Portugal is predominantly old, with some schools dating back to the 19th century (OECD, 2012). Moreover, schools that possess energy performance certificates demonstrate low levels of energy efficiency. However, a major renovation program was initiated in 2007 to renovate 332 secondary schools out of 477 by 2015 (OECD, 2012). Nevertheless, only 176 schools were renovated (EC, 2022). To compound the issue, Portugal has one of the highest rates of energy poverty among European countries, significantly increasing the likelihood of students experiencing discomfort at school and encountering further discomfort upon returning home.

Given the importance of thermal comfort in daily life, it is imperative to undertake studies that comprehensively evaluate thermal comfort levels in residential settings and other locations where individuals spend substantial amounts of time. Such research endeavours aim to foster an enhanced comprehension of thermal comfort, leading to the development of more effective solutions for improving energy efficiency and formulating more impactful policies to assist vulnerable consumers. Additionally, these studies contribute to the preparation of resilient infrastructures that can effectively address the challenges posed by climate change and ensure a sustainable future for future generations. Studies focusing on younger populations aged 15-18 are particularly noteworthy, as the existing energy poverty body of literature primarily concentrates on adult or elderly subjects (Teariki et al., 2020; Mohan, 2021). Indeed, this age group offers considerable potential for investigations on thermal comfort, as researchers have indicated that individuals within this range can provide more reliable assessments of their thermal sensations compared to younger cohorts. Despite the significance of studying perceived energy poverty and thermal comfort within the 15-18 age group, research in this area remains scarce, with no study to date having simultaneously examined vulnerability to energy poverty and vulnerability to inadequate thermal comfort within the home environment.

1.1 Problems and Objectives

In response to the identified research gap, this study aims to evaluate the perceptions of energy poverty at home and thermal comfort in schools among upper-secondary education students. This assessment was conducted using two distinct and complementary methodologies. On the one hand, a survey was administered to a randomly selected sample of secondary education students. On the other, surveys were conducted in two schools, one renovated and one non-renovated, situated in municipalities characterized by vulnerability to energy poverty (as determined by the energy poverty vulnerability index developed by Gouveia *et al*. (2019)). In these two schools, the student surveys were supplemented with surveys targeting the teachers, interviews with the school board, and measurements of classroom temperatures. This comprehensive and rigorous approach aimed to provide a comprehensive and robust understanding of the issues. Considering the aim defined, the specific goals defined are:

I. Assessment of energy poverty vulnerability of young people (15-18 years old);

II. Assessment of the thermal comfort in schools of this age group;

III. Assessment of the student's population, which perceives to live in permanent discomfort;

IV. Analysis of the perception of other school-related stakeholders of this issue;

V. Impact of schools' renovation on the thermal comfort of students;

VI. Characterization of the student population who report experiencing discomfort regarding gender, health, and socioeconomic status.

1.2 Document Organization

This work is organized into eight sections, which constitute the main section of the study and are complemented by appendices and bibliographic references. Thus, the eight sections are structured as follows:

- Section one: Provides a brief introduction to the topic and objectives of the present study;
- Section two: Presents the topic of energy poverty, including definitions, causes, vulnerable groups, current status in Europe and Portugal, and respective European and national policies;
- Section three: Reviews existing literature on thermal comfort. It presents the main methodologies used to calculate thermal comfort in school studies, as well as some studies on thermal comfort conducted in schools and their key findings;
- Section four: Describes the functioning of education in Portugal, providing an overview of the number of schools and students, energy classification, and energy consumption of Portuguese schools compared to other schools in Europe. It discusses energy efficiency initiatives in schools and presents the program for the modernization of secondary schools. It also provides a legislative framework for school buildings regarding thermal comfort regulations;
- Section five: Presents and justifies the methodology used in this study, as well as the selected case studies;
- Section six: Presents the obtained results;
- Section seven: Discusses the results, comparing the two schools and discussing the results obtained on the mixed sample of students with other work done in this area;
- Section eight: Presents the conclusions derived from the discussion. It also discussed the limitations of this work and presents points for Improvement In future work.

2

ENERGY POVERTY

2.1 Definition and Causes

The central focus of this work is a complex, multidimensional and with unagreed definition among the scientific community. It is an issue intricately linked to the context and to gender, income, and health (Middlemiss, 2022; Stojilovska *et al.*, 2022). Its complexity is because it is a private issue (related to the residential sector) and is associated with the dynamics of time, space, and culture (Bouzarovski, 2017). Public recognition of the problems related to the lack of access to energy is also recent, and for a long time, only the UK and Ireland have recognized the problem. In the last decades, the issue has come up for debate in both scientific and political spheres, not only in Europe but also in North America, Japan, Australia and New Zealand (Bouzarovski, 2017).

A potential comprehensive definition of energy poverty is that it occurs when a household is unable to secure a level and quality of domestic energy services (space cooling and heating, cooking, appliances, Information technology) sufficient for its social and material needs (Bouzarovski, 2017). In Europe, several definitions can be found across countries definitions. In England, a household is considered living in energy poverty (or in fuel poverty as commonly referred to in the UK) if they are living in a dwelling with an energy efficiency rating of D or below and if their disposable Income (Income after deducting housing costs and energy expenses) is below the poverty line (Hinson & Bolton, 2023). In Wales, Scotland and Northern Ireland, energy poverty is evaluated based on the 10% Indicator, whereby a household is classified as energy poor if it is compelled to allocate more than 10% of its income towards fuel expenditures (Scottish Government, 2017; NEA, 2023; Welsh Government, 2021). Scotland and Wales further distinguish severe energy poverty, which encompasses households spending over 20% of their net income on fuel expenditures (Scottish Government, 2017; Welsh Government, 2021). The European Commission defines energy poverty as a "situation in which households cannot access essential energy services and products" (EC, 2023a). The Portuguese National Strategy to tackle energy poverty 2021-2050, currently under revision, addresses that energy poverty is the inability to maintain the dwelling with an adequate level of essential energy services due to a combination of low income, low energy performance of the dwelling and energy costs (Ministry of the Environment and Energy Transition, 2021).

In addition to the definitional variations, there are nuances in the terminology employed to describe this issue. It is common to encounter both the terms "energy poverty" and "fuel poverty." Bouzarovski and Petrova (2015) posit that the choice between these terminologies is influenced by geographical location, with "energy poverty" typically used in research conducted in developing countries, while "fuel poverty" is associated with policies and research from developed nations. In developing countries, energy poverty is linked to limited electrification and a lack of access to modern cooking facilities, resulting in reliance on traditional biomass for these purposes (Li *et al*., 2014; Bouzarovski and Petrova, 2015). Using such fuels is associated with indoor air pollution, which impacts human health, including heart and respiratory diseases and even premature death. In fact, indoor air pollution was responsible for 3.2 million deaths in 2020 (WHO, 2022). Apart from indoor air pollution, the lack of electricity is also associated with lower levels of education (Bridge *et al*., 2016; Daka and Ballet, 2011). It is estimated that around 2.4 billion people worldwide rely on these types of fuel (WHO, 2022). Alternatively, the term "fuel poverty" is commonly employed in research conducted in developed countries. Despite that, in the context of this work, the term “energy poverty” will be used as the inability to access energy services, in line the European commission definition.

Despite high levels of electrification, factors such as low energy efficiency of buildings, high energy prices, and insufficient income hinder households from maintaining thermal comfort in their dwellings (Boardman, 2009). However, other socio-demographic, housing, and infrastructure factors related to these three drivers are also important to understand the problem. These factors include employment status, social conditions, family size and composition, housing tenure, age, and size of the dwelling, as well as household characteristics (Castanõrosa *et al*., 2019; Stojilovska *et al*., 2022). The interconnection of these primary causes varies significantly across contexts, both at the micro and macro level, since, even at small spatial scales such as within the same city or neighborhood (EPAH, 2022). The social-political dynamics of each country also have implications on energy and may lead to a situation of vulnerability, as observed with the COVID-19 pandemic and the war in Ukraine and its Impacts on energy prices (Jiglau *et al*., 2023). Middlemiss (2022) characterized the energy poverty experience in the global north through a literature review, concluding that people experiencing energy poverty often describe their homes as inefficient or leaky and report difficulty controlling indoor temperatures. Common coping strategies include wearing extra clothes, rationing heating to specific occasions or spaces, and going to bed during the daytime in winter. The implications of energy poverty on quality of life have prompted the development of metrics and policies aimed at measuring and alleviating this issue (Jiglau *et al*., 2023). For instance, in Europe, addressing energy poverty involves the formulation of policies that address its underlying drivers. These policies encompass measures related to income and energy prices, support vulnerable groups through social tariffs and subsidized prices, initiatives focusing on energy efficiency to improve housing conditions and reduce energy consumption, and energy and climate policies. The European Union (EU) mandates member states to define energy poverty and devise measures for its alleviation within their respective National Energy and Climate Plans (Stojilovska *et al*., 2022).

Measuring energy poverty can be challenging because of a lack of consensus on definitions or the sparse data on its underlying causes in different contexts (Pelz *et al*., 2018). Various methods have been employed to gauge the incidence of energy poverty. These include direct measurement of the level of energy services within households, such as heating, lighting, refrigeration, cooling, and more, and comparing these measurements against established standards. Another approach involves analyzing patterns of household energy expenditure across the population relative to predetermined absolute or relative thresholds. Additionally, subjective assessments of households regarding the attained level of energy services in their homes can be compiled, or self-reported data on housing conditions can be collected, indirectly providing insights into the extent of domestic energy deprivation (Bouzarovski, 2018). This information is gathered in the form of indicators. The indicators to measure energy poverty can be divided into primary indicators, such as arrears on utility bills, low absolute energy expenditure (defined as the share of energy expenditure above twice the national median), a high share of energy expenditure in income (defined as the absolute energy expenditure below half the national median) and inability to keep home adequately warm and secondary indicators, related to energy prices (e.g., fuel oil prices, biomass prices, coal prices), dwelling comfortably warm during winter time and summer time or dwellings with energy label A (EPAH, 2022). Indicators must not be utilized in isolation when assessing energy vulnerability since a single indicator cannot capture the complexity of factors contributing to energy vulnerability. This may result in exclusion errors, where eligible households are not recognized by policy and remain unsupported, as well as inclusion errors, where ineligible households erroneously receive support (Castanõ-Rosa *et al*., 2019).

2.2 Impacts of Energy Poverty

Literature has shown that living in energy poverty impacts both physical and mental health (Kose, 2019; Howden-Chapman *et al*., 2012; Liddell and Morris, 2010; Xu *et al*., 2022; Brown & Vera-Toscano, 2021; Jessel *et al*., 2019). Cold dwellings during winter have been associated with cardiovascular and respiratory diseases (Marmot Review Team, 2011; Oliveras *et al*., 2020; Dominianni *et al*., 2018) and with the suppression of the immune system, leading to a higher risk of infections (Howieson & Hogan, 2004). This condition can also exacerbate existing conditions (Marmot Review Team, 2011; Liddell and Morris, 2010). Being unable to keep the dwelling at a comfortable level has been shown to be related to the prevalence of asthma, hospital visits, and longstanding Illness (Evans *et al*., 2000) and was also associated with accidents and Injuries at home (Marmot Review Team, 2011). in extreme cases, energy poverty can have fatal consequences. This is supported by numerous studies and data that confirm an increase in mortality during extreme weather events in winter or summer compared to the rest of the year and by the fact that countries with more energy-efficient dwellings have lower Excess Winter deaths (Romero-Ortuno *et al*., 2013; Liddell *et al*., 2016; Recalde *et al*., 2019)

Regarding mental health outcomes, people living in energy poverty are more likely to report poor well-being (Thompson *et al*., 2017). Living in cold and damp housing is associated with a variety of different mental health stressors, including persistent worry about debt and affordability, thermal discomfort, worry about the consequences of cold and damp for health (Liddell & Guiney, 2015), and an impact on social life and lack of recreational activities (Bartiaux *et al*., 2018; Bartiaux *et al*., 2021)

The correlation between energy poverty and health outcomes is also evident through the observed improvement in physical and mental well-being when an amelioration of dwellings conditions, as indicated by existing literature. (Gilbertson *et al*., 2012; Liddell & Guiney, 2015).

2.3 Vulnerability Groups

Specific characteristics of households lead them to vulnerability regarding their access to energy services. Directive (Eu) 2019/944 Of the European Parliament obligated states member to take appropriate measures to protect customers, in particular, vulnerable customers, and to define the concept of vulnerable customers. The directive indicates that the definition may include income levels, the share of energy expenditure of disposable income, the energy efficiency of homes, critical dependence on electrical equipment for health reasons, age, or other criteria. In addition to individual characteristics, contextual factors may also be utilized to identify vulnerable consumers. This perspective acknowledges that vulnerability arises from the interaction between an individual’s personal traits and circumstances and the broader economic market. As such, vulnerability is a dynamic state, with consumers potentially transitioning in and out of vulnerability depending on their situation (London Economics *et al.*, 2016). Among the European Union member states, the definitions of vulnerable consumers are mainly around the receipt of social welfare and include a broad range of socioeconomic groups (Pye *et al.*, 2015). The Portuguese National Strategy to tackle energy poverty 2021-2050 (under revision) defines energy-vulnerable consumers as "energy poverty domestic energy consumer who is, in a situation of energy poverty, susceptible to the disconnection of energy services notably for reasons of health or advanced age, among others" (Ministry of the Environment and Energy Transition, 2021). In this subsection, vulnerability factors and groups are explored.

The vulnerability of women as a vulnerable group varies across different global regions. In developing countries, women bear significant responsibility for tasks such as collecting firewood and cooking, which increases their likelihood of experiencing adverse health effects associated with Household Air Pollution (HAP). These health outcomes include acute lower respiratory infections, chronic obstructive pulmonary disease, lung cancer, cataracts, and low birth weights (Putti *et al.*, 2015). Cooking with biomass in these contexts has also been associated with physical injuries among women, including cuts, broken bones, skin irritations, infections, fatigue, headaches, joint and chest pains, chronic back pains, waist pains, and spinal injuries (Putti *et al.*, 2015).

In contrast, in the Global North, women tend to spend more time at home than men (Kamp Dush *et al.*, 2018; Ervin *et al.*, 2022), increasing the probability of being exposed to inefficient dwellings and experiencing adverse health outcomes. Moreover, the gender income disparity further amplifies women's susceptibility to energy poverty, as lower income is a significant contributing factor to this problem. A pertinent example is observed in Europe, where the gender pay gap stands at 13% (EU, 2022). Furthermore, women's consumption patterns and energy habits also contribute to their heightened risk. Studies have found that women tend to consume lower levels of electricity (Räty & Carlsson-Kanyama, 2010) and may experience a lack of thermal comfort by forgoing energy services and only using them when another household member is present (Gayoso Heredia *et al.*, 2022). Consequently, existing literature identifies women in northern regions as a vulnerable group susceptible to energy poverty (Jessel *et al*., 2019; Oliveras *et al*., 2020; Petrova & Simcock, 2021; Robinson, 2019).

The elderly population, representing people aged 65 and over, are also a vulnerable group to energy poverty. This age group spends most of their time at home (Spalt *et al*., 2016), consumes more energy (Estiri & Zagheni, 2019), lives in old and inefficient dwellings (You & Kim, 2019), and/or lack of financial resources to keep their dwellings adequately comfortable (Farbotko & Waitt, 2011) since ageing represents a risk of becoming or remaining poor (UN, N.D.). These factors put the elderly population in a vulnerable position, and multiple studies show that the probability of energy poverty is significantly higher for older households (Riva *et al*., 2021; Oliveras *et al*., 2020; Tonn *et al*., 2021). Living in uncomfortable homes is especially burdensome for the elderly since it exacerbates chronic conditions (Gilbertson *et al.,* 2006), which have a high prevalence among elderly population (OECD, N.D.). Nevertheless, the stigma of getting old often inhibits older people from adopting practices that enable them to live in comfortable temperatures at home (Day & Hitchings, 2011).

Literature also identifies people living with a long-term illness or disability as a vulnerable group to energy poverty (Riva *et al*., 2021; Snell *et al*., 2015; Ivanova & Middlemiss, 2021). Households with people with disabilities have high medical expenditures and are more likely to experience poverty (The Lancet, 2019). On the other hand, people with disabilities often rely on medical, high-intensive electrical equipment on a daily basis, increasing their energy bills (Perera, 2019).

Evidence shows that children and teenagers are a vulnerable group to energy poverty. This group of people have a greater burden of cumulative exposure to energy poverty than adults, with a greater impact on their health and well-being (Teariki *et al*., 2020; Zhang *et al*., 2021). Studies identified the prevalence of respiratory conditions such as asthma in children living in a dwelling that presents damp and mold (Mendell *et al*., 2011; Antova *et al*., 2008, Platt *et al*., 1989). Mohan *et al*. (2021) found that infant (eight months to five years) respiratory health is especially sensitive to the dwelling conditions, and energy poverty was associated with 1.41 times higher odd of child's respiratory illness and 1.47 times the odds of child wheezing. A study performed in Barcelona identified that 10.6% of children were living in energy poverty. It concluded that energy poverty was strongly associated with poor health in children, poor mental health, and more cases of asthma and overweight (Oliveira *et al*., 2021). Therefore, improving indoor conditions reduces the prevalence of these conditions and the probability of fewer days off school due to asthma, improving academic achievement and reducing hospital admissions (Somerville *et al*., 2000; Howden-Chapman *et al*., 2007). Damp and mold in dwellings also affect children's mental health, with some reporting that, since their clothes constantly smell like mold, are picked on by their classmates, and their motivation to attend school is reduced (Harker, 2006). The impact of energy poverty may increase during the heating season when poor households decide between heating their house, paying for groceries, or balancing both expenses by reducing them (Thompson *et al*., 2017). Implying that, during this period, low-income households will consume cheaper food with less nutritional value, resulting in impacts on children's health and weight, with long-term consequences (Bhattacharya *et al*., 2003; Marmot Review Team, 2011).

Students, namely tertiary education students, have also been under the spotlight of energy poverty vulnerability studies. Castro & Gouveia (2023) conducted a study involving tertiary education students from Montevideo, Lisbon, and Padua. The purpose of the study was to discern disparities among students from these three locations, considering both local and exchange students. The findings indicated that students from Lisbon reported a higher degree of discomfort and Lisbon stood out as the sole location where both exchange students and local students highlighted the impact of housing conditions on their well-being. Clark *et al*. (2022) concluded that tertiary students perceive their dwellings' deteriorating conditions and lack of thermal comfort to impact their health and academic performance. A study in Poland concluded that students underheat their homes to avoid excessive costs, leading to being sick more often (Mamica *et al*., 2021). However, it was observed that tertiary students do not consider themselves as living in energy poverty (Moris & Genovese, 2018; Castro & Gouveia, 2023), but students living in dwellings activities that suggest the opposite, such as cutting back spending on energy use (Castro & Gouveia, 2023; Moris & Genovese, 2018) putting on extra clothes, hot drinks, going to bed early, cutting back spending on energy use, and cut back spending on food while reporting that their dwelling is too cold during winter months (Moris & Genovese, 2018). Students, especially tertiary students, often live in homes, and the nature of these tenancies does not incentive landlords to undertake energy efficiency improvements (Moris & Genovese, 2018). House conditions also affect teenagers' physical and mental health (Marmot Review Team, 2011; Liddell & Morris, 2010).

2.4 Energy Poverty in the European Union

Energy poverty levels vary across Europe due to contextual factors. In 2022, 6.9% of households in the EU27 countries faced challenges in adequately heating their homes, indicating a decrease from 11.2% in 2012 (EPAH, 2023a). Countries with higher shares of this indicator included Bulgaria (23.7%), Lithuania (22.5%), Cyprus (20.9%), and Portugal (16.4%) (EPAH, 2023a). Regarding other energy poverty indicators, in 2021, 6.4% of households in the EU27 countries had utility bill arrears. Additionally, 16.2% of EU households had low absolute energy expenditure, while 14.6% of EU households experienced a high share of energy expenditure in relation to their income (EPAH, 2023a).

Directive 2009/72/EC, one of the first EU directives to mention energy poverty, highlighted the need for Member States to develop national action plans or appropriate frameworks to address energy poverty and reduce the number of individuals experiencing such conditions. Member States were advised to take necessary measures to protect vulnerable and energy-poor customers in the electricity market, including social or energy policy measures related to bill payment, investment in energy-efficient residential buildings, and consumer protection against disconnection. Regulation 2018/1999, on the Governance of the Energy Union and Climate Action, instructed Member States to assess the number of households in energy poverty by considering necessary domestic energy services for basic living standards in the national context, existing social policies, relevant policies, and Commission indicative guidance on indicators. The regulation aimed to establish a common approach to measuring energy poverty while accounting for geographical dispersion. Directive 2019/944 emphasized monitoring energy poverty at the household level by Member States, using criteria such as low-income, high-energy expenditure, and poor energy efficiency. An integrated approach, combining energy and social policies, was recommended, with potential measures including social policies and energy efficiency improvements in housing.

The European Green Deal directly addresses energy poverty through initiatives like the renovation wave, which aims to increase annual energy renovations, mainly targeting buildings associated with energy poverty, to enhance the quality of life for residents (EC, 2023b). The Social Climate Fund also includes households in energy poverty as key beneficiaries (Winduto, 2022). Commission Recommendation (EU) 2020/1563 of 14 October 2020 provides detailed guidance to EU Member States on addressing energy poverty. It encompasses nine key recommendations, including adopting a systematic approach to energy market liberalization, utilizing specific indicators and criteria defined by the recommendation, integrating social policy measures with energy efficiency improvements, analyzing distributional effects of energy transition, involving public participation and stakeholder engagement, fostering cooperation among different levels of administration, utilizing Union funding programs, prioritizing support for low-income households, and exploring financing solutions such as energy service companies and performance contracts. In the same year, the resolution of 17 December on a strong social Europe for Just Transitions indicated that the EU and state members should work on eliminating energy poverty by 2030 through supporting energy efficiency investments by low-income households.

The emergence of this problem led the European Parliament to request a European unit to combat energy poverty. In response to this request, the EU Energy poverty Observatory was created, a 40-month project created in 2016 to improve the measuring, monitoring, and sharing of knowledge and best practice on energy poverty (Thomson & Bouzarovski, 2019). Subsequently, the Energy Poverty Advisory Hub (EPAH) took over in its efforts to eradicate energy poverty and accelerate energy transition of European local governments (EPAH, 2023b).

2.5 Energy poverty in Portugal

Compared to other EU countries, Portugal exhibits a concerning level of energy poverty. Approximately 16.4% of the Portuguese population faces difficulties in adequately heating their homes, placing Portugal as the 6th highest country in terms of this percentage among EU member states (EPAH, 2023a). Furthermore, 25.2% of Portuguese individuals reside in dwellings with issues such as leaking roofs, damp walls, floors or foundations, or rot in window frames or floors, which is the 3rd highest percentage among EU countries (EPAH, 2023a). Additionally, 15.1% of households in Portugal experience a high proportion of energy expenditure concerning their income, 5.3% of households have arrears on utility bills, and 6.7% have low absolute energy expenditure (EPAH, 2023a).

A joint survey by AdE-PORTO and Lisboa E-Nova examined the prevalence of energy poverty among residents of Oporto and Lisbon. In Lisbon, the survey revealed that 42% of respondents acknowledged their homes not achieving a comfortable temperature during winter, with 27% experiencing excessive cold. Additionally, 32% of respondents reported discomfort due to inadequate temperature regulation during summertime, with 22% indicating excessive heat within their homes (Lisboa E-Nova & AdE-PORTO, 2022). Similarly, in Porto, comparable outcomes were observed, with 38% of participants stating their homes did not maintain a comfortable temperature during winter and 23% expressing the same issue during summer. Among these respondents, 26% reported experiencing excessive cold in winter, while 17% faced the challenge of excessive heat during summer (Lisboa E-Nova & AdE-PORTO, 2022)

Portuguese dwellings are inefficient and can also be a driver of the energy poverty situation. Between 2004 and 2023, around 1.8 million energy performance certificates were emitted in Portugal. The performance ranking varies from A+ (highly efficient) to F (highly inefficient), and only a small proportion of Portuguese building stock is highly efficient (only 3.4% of energy performance certificates were A+) (ADENE, 2023). The energy ranking with the most prevalence is C (24.4%), and around 70% of dwellings are classified as C or below (ADENE, 2023).

Most Portuguese dwellings are equipped with space heating equipment (81.6% are equipped with them), but only around 32.7% are equipped with space cooling equipment. However, the most common space heating and space cooling equipment in Portuguese dwellings is very inefficient. In 2020, the most common equipment for space heating was a free-standing electric heater (61.2% of Portuguese homes have it), followed by fireplaces (24.2%) and air conditioning (19.2%). Space heating heat pumps and solar heating systems are still insignificant (1.1% and 0.2%). Regarding space cooling, the portable fan is the most common equipment (58.8%), followed by air conditioning (45.4%). The survey results align with this; in Lisbon and Oporto, the respondents admitted using more equipment during winter than summer (Lisboa E-Nova & AdE-PORTO, 2022).

More efficient equipment could help reduce the share of energy consumed in dwellings to space heating and cooling, consequently, the energy consumption of the residential sector in Portugal. In 2020, the residential sector represented 19,5% of total energy consumption in Portugal, consuming around 3000 ktep (DGEG & INE, 2020). Space heating represented 23,3% of that consumption, and space cooling only represented 1% (DGEG & INE, 2020).

Energy illiteracy may be one of the reasons why the Portuguese population isn't investing in more efficient equipment. Energy illiteracy can be defined as the inability to understand the issues associated with energy use and the benefits of using energy more efficiently more efficient use. Based on a survey on energy literacy, the ERSE built energy literacy index that varies from "unaware of all the aspects studied on energy literacy" with a 0 points classification to "knows all the aspects studied about energy literacy" with a 100 points classification (ERSE, 2020). The average level of energy literacy is 42.8, with 21.2% of particular consumers with a low (below 25 points) classification and 45.2% with an average (between 25-50 points) classification. Consumers with higher education and with higher monthly energy bills tend to have a higher energy literacy. The results obtained by AdEPORTO and Lisboa E-nova support this index: around 26% of the population admitted to not being informed of energy and thermal comfort matters, and 33% of the population admitted to knowing a little about those matters (Lisboa E-Nova & AdE-PORTO, 2022).

Considering the current state of energy poverty in Portugal, various plans and programs have been developed to address the issue directly or indirectly. Portugal has made an international commitment to reduce its greenhouse gas emissions to achieve net-zero emissions by 2050, as outlined in the country's Roadmap for Carbon Neutrality 2050 (RNC2050). The residential sector is a key focus of this plan, with the goal of reducing emissions by 96-97% by 2050 through the incorporation of renewable energy sources for heating and cooling by 66-68% (Ministry of the Environment and Energy Transition, 2019). The plan's objectives include promoting urban renewal and increasing energy efficiency in buildings, encouraging the progressive electrification of the sector and the use of more efficient equipment, and combating energy poverty (Ministry of the Environment and Energy Transition, 2019). Addressing energy poverty is a key objective of Portugal's National Energy and Climate Plan 2030 (PNEC 2030) (DGEG, 2023a). The plan provides a detailed analysis of the current state of energy and climate in Portugal, encompassing the five dimensions - decarbonization, energy efficiency, security of supply, internal energy market, and research, innovation, and competitiveness. It also defines national contributions and outlines policies and measures to meet the various commitments, including reducing greenhouse gas emissions, promoting renewable energies, increasing energy efficiency, and improving interconnections. A central goal of the plan is to ensure a fair, democratic, and secure transition - Objective 8 - with one of its key action points being to combat energy poverty and improve protections for vulnerable customers. The plan's measures include, among other measures, to promote a long-term strategy to combat energy poverty.

Portugal's Recovery and Resilience Plan (RRP) addresses the critical need to promote a robust recovery and prepare the country for the future through three key dimensions: economic and social resilience, digital transition, and green transition. The green transition component, accounting for 18% of the planned investments in the RRP, is subdivided into six components, one of which is "Component C13: Energy Efficiency in Buildings." This component focuses on rehabilitating buildings and enhancing energy efficiency, delivering social, environmental, and economic benefits to individuals and businesses (Minister of Planning and Infrastructure, 2021).

Most of the funding in this component is allocated to residential buildings, constituting nearly 50% of the budget. This financial support is utilized for various improvements, including passive structural enhancements in buildings like insulation application in walls and roofs and windows replacement. Additionally, it covers upgrades in equipment energy efficiency, such as investments in air conditioning/heat pumps for heating and cooling, systems for domestic hot water, and the integration of renewable energy sources for electricity production (Minister of Planning and Infrastructure, 2021). The "Vale Eficiência" program is one of the initiatives under the PRR program aimed at combating energy poverty. Its objective is to improve the energy performance and thermal comfort of homes, thereby enhancing the health and well-being of families while reducing their energy bills. The program plans to provide 100 000 vouchers worth 1 300 € plus VAT to economically vulnerable families by 2025. These vouchers can be used to invest in improving the energy performance of their permanent homes through interventions in their surroundings or by replacing or purchasing energy-efficient equipment and solutions (FA, 2023).

To address the imperative identified in the PNEC 2030 (National Energy and Climate Plan 2030) about the necessity of formulating and implementing a long-term strategy to promote building renovation, the approval of the Long-Term Strategy for Building Renovation has been undertaken (DGEG, 2023b). The principal objective of this strategy is to facilitate the transition of existing buildings into nearly zero-energy buildings, thereby achieving a decarbonized and highly energy-efficient building stock. The strategy sets forth ambitious targets, aiming to attain primary energy savings of 11% by the year 2030 and a more substantial reduction of 34% by the year 2050. Additionally, the strategy seeks to mitigate discomfort within residential dwellings by reducing the number of hours occupants experience discomfort. Specifically, the strategy aims to diminish the hours of discomfort in the home by 26% by 2030 and an even more substantial reduction of 56% by 2050. One significant facet of the strategy is its fifth line of action, which specifically addresses the issue of energy poverty. Within this line of action, a range of measures is proposed to combat energy poverty, including strategies to curtail energy consumption costs and support vulnerable households. Notably, these measures include financing mechanisms and tax benefits, among other supportive measures, to facilitate the energy renovation of homes for the most vulnerable households.

To also stated in the PNC2050, a long-term National Strategy has been developed to address Energy Poverty and is currently undergoing revision (Ministry of the Environment and Energy Transition, 2021). This strategy endeavors to combat energy poverty while safeguarding vulnerable consumers and actively integrating them into the energy and climate transition, resulting in improved thermal comfort, enhanced quality of life, better health outcomes, and increased disposable income. The strategy revolves around four primary action points: increasing energy efficiency in residential buildings through the promotion of programs, initiatives, and support mechanisms to encourage investments in energy efficiency and building renovation; reducing energy expenditure and raising awareness regarding prudent energy management practices; protecting consumers who are unable to meet their energy costs and ensuring universal access to essential energy services; and promoting information, knowledge, and education to raise awareness and disseminate best practices in energy efficiency, thereby stimulating behavioral change in energy usage to achieve energy bill savings, enhanced comfort, and environmental benefits.

An initial step in implementing this strategy was to define the proportion of the population experiencing energy poverty. The number of individuals facing energy poverty and severe energy poverty (which combines energy poverty with monetary or economic poverty) was determined by employing both primary and secondary indicators. The identification of this population was based on two criteria: the "living condition" criterion, which pertains to individuals living in households lacking the means to adequately heat their homes, and the "income vs. energy expenses" criterion, which applies to households experiencing poverty where energy expenses account for more than 10% of their total income. Based on these criteria, estimations reveal that in Portugal, approximately 1.2 million people are currently experiencing energy poverty based on the "living condition" criterion, while 740,000 individuals face severe energy poverty. Furthermore, considering the "income vs. energy expenses" criterion, it is estimated that 2.3 million people are experiencing energy poverty, with 660 thousand people enduring severe energy poverty. In general, the proposed action measures aim to:

- Strengthen capacities at the national and local levels for identification and monitoring of energy poverty.
- Establish a collaborative framework at the national, regional, and local levels, enabling unified efforts in addressing this common issue and leveraging the proximity of local stakeholders to citizens.
- Promote, support, and monitor projects of varying scales and in different areas, aligning with national priorities.
- Stimulate innovative pilot projects with local and regional impact, capitalizing on national competencies and capacities.
- Develop legislation, regulations, and normative frameworks that serve as a foundation for driving a paradigm shift in energy poverty within Portugal.
- Enhance monitoring capabilities at both the national and local levels.

To implement this methodology, a three steps approach will be used. The first step will be to identify households in energy poverty situations, followed by implementing the actions to support those households. The last step will be monitoring to evaluate the degree of compliance with the action measures and accompanying the households.

3

THERMAL COMFORT IN SCHOOLS

3.1 Definitions and Thermal Comfort Indices

Thermal comfort has been termed with different definitions. It can be described as a state in which there are no driving impulses to correct the environment by behaviour (Hensen, 1991). The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) defines thermal comfort as a "condition of mind which expresses satisfaction with thermal environment" (ASHRAE, 2010). Other definitions propose that thermal comfort is achieved when an individual's body is in thermal equilibrium with environmental factors such as air temperature, velocity, and humidity, as well as personal factors such as metabolic rate and clothing thermal resistance (Hensen, 1991). Comfort is attained when body temperatures are maintained within narrow ranges, skin moisture levels are low, and the physiological effort of regulation is minimized (Lin & Deng, 2008).

Numerous researchers have attempted to develop an index for the measurement of thermal comfort. Among them was Fanger, who formulated that thermal neutrality is controlled by physiological factors and derived a seven-parameter equation to compute thermal comfort (Rodrigues *et al*., 2008). According to this equation, a value of 0 indicates thermal neutrality, while a higher value signifies an increase in body temperature relative to the equilibrium position. Conversely, a lower value indicates a decrease in body temperature relative to the equilibrium position. Therefore, any deviation from the equilibrium position (denoted as S) leads to discomfort. Fanger's scale comprises seven levels, ranging from very cold (-3) to very hot (+3) (table 3.1). By correlating the equation with thermal sensation votes collected from over 1300 trials, Fanger developed the PMV (Predicted Mean Vote) index, which calculates the expected average value of votes for individuals based on ambient conditions, activity level, and type of clothing. Subsequent statistical analysis of observation results revealed a correlation between vote value and the percentage of dissatisfied individuals. This led to the development of the PPD (Predicted Percentage of Dissatisfaction) index that expresses the percentage of people that are thermal dissatisfied in a particular environment and varies according to the PMV in the relation depicted in Figure 3.1.

Table 3.1: Thermal sensation scale. Adapted from Rodrigues et al., 2008

Thermal Sensation	Value
Cold	-3
Cool	-2
Slightly Cool	-1
Neutral	0
Slightly warm	1
Warm	2
Hot	3

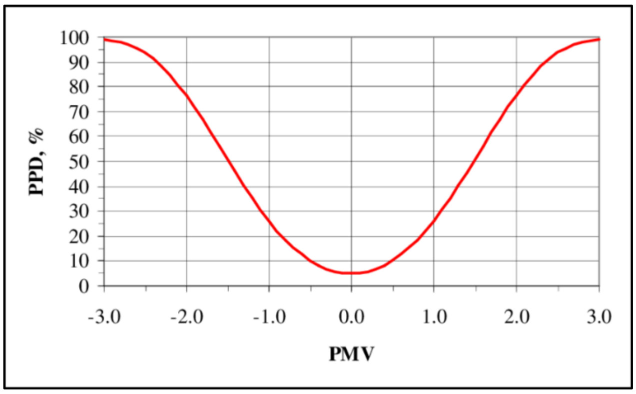


Figure 3.1: Relation between PPD and PMV. Adapted from Markov, 2022

The limitations of these indices stem from the fact that they were constructed based on votes from school-aged respondents who were highly habituated to air-conditioned environments and removed from their normal working environment (Rodrigues *et al.*, 2008). Consequently, a new methodology for calculating indices has emerged, developed through fieldwork that involved collecting responses from individuals exposed to their normal environment, whether air-conditioned or not, and wearing appropriate clothing (Rodrigues *et al.*, 2008). Termed the adaptive perspective (in contrast to Fanger's commonly referred to as rational perspective), these studies sought to demonstrate the significance of ecological adaptation and the impact of habituation to air-conditioned environments. Humphreys was a prominent proponent of this perspective, conducting fieldwork in various climates. The findings of these studies revealed that individuals adapt to environmental variations and, within a region, to seasonal variations (Rodrigues *et al.*, 2008).

There are several thermal comfort standards, including ISO 7730:2005 (international), EN 15251 (Europe), and ASHRAE 55 (American). ISO 7730:2005 and ASHRAE 55 are exclusively thermal comfort standards, while EN15251 provides guidelines for other environmental parameters. ISO 7730:2005 "Ergonomics of the thermal environment" provides guidelines for determining and interpreting thermal comfort parameters such as the PMV and PDD indices and local thermal comfort criteria (ISO, n.d.). The European standard EN 15251:2007 provides guidelines for designing and assessing energy performance in buildings, including indoor air quality, thermal environment, lighting, and acoustics (IEA, 2021). The ASHRAE 55 standard specifies conditions for acceptable thermal environments and is intended for use in the design, operation, and commissioning of buildings and other occupied spaces (ASHRAE, n.d.). Both the ISO and EN standards categorize buildings according to their level of expectation; classrooms fall into the second category with normal expectations (Zomorodian *et al*., 2016). These standards guide operative temperatures and comfort equations based on rational and adaptive models. Regarding PPD and PMV, both EN 15251 and ASHRAE 55 specify that -0.5 < PMV < +0.5 and PPD < 10 (Education and Skills Funding Agency, 2016).

3.2 Thermal Comfort Studies in Schools

Numerous studies have been conducted to assess the applicability of standard methodologies to school environments, namely in secondary education students (aged 11-18 years old). This age group is considered a reliable population for thermal comfort research due to their ability to provide accurate information about their thermal sensation and preferences and greater capacity for environmental adaptation through behavioral actions (Zomorodian *et al*., 2016).

In reviewing 48 articles on thermal comfort in schools, Zomorodian *et al*. (2016) compared common thermal comfort standards across different educational stages and climate zones. Their findings revealed that these standards are not suitable for assessing classroom thermal environments, with overestimation being observed in most secondary education levels. Additionally, studies conducted within the same climate zones found a disparity in thermal neutralities, highlighting the need for micro-level thermal comfort research. Both naturally ventilated and air-conditioned schools were examined, with results indicating that thermal comfort is often not achieved in naturally ventilated classrooms due to low air velocity. The reviewed studies also suggested that students prefer colder environments and are more sensitive to warm conditions.

Several studies have been assessed, with their results in Table 3.2. In a study conducted in Portugal, Pereira *et al*. (2014) found that students felt comfortable in temperatures outside the range established by the thermal comfort norms during mid-season. The study examined two secondary classrooms with temperatures of 22.1°C and 25.1°C, respectively, and employed a methodology that included calculating thermal comfort indices and subjective surveys. Most students reported feeling neutral (69% in the colder classroom and 58% in the warmer classroom). Most students indicated no desire for change when asked about their thermal preferences, despite 12% and 35% reporting feeling slightly warm. A comparison between the subjective responses and the calculated PMV votes revealed that students were comfortable within a wider range of temperatures than those prescribed by standards.

To define the students' preferred temperatures, neutral temperatures, and acceptable temperature ranges and compare them with adults', De Dear *et al*. (2015) conducted a study in both primary and secondary schools in Australia in a mixture of classrooms. 22.5°C was found to be the students' preferred temperature, 1.5°C cooler than the predicted by the thermal comfort standards for adults populations. 70.6% of students were satisfied with the classroom' thermal conditions. A later study by Kim and De Dear (2018) presented similar results, with students' preferred temperatures being 2-3°C lower than adults' neutral temperatures. It was also observed that primary students adjust their insulation level when the temperature drop while secondary students remain unresponsive. Students in the air-conditioned classroom were less likely to practice other adaptive methods such as windows, fans, blinds, or clothing adjustment.

Perceived control, defined as an individual's awareness of their ability to control their environmental surroundings, can influence both thermal comfort and thermal acceptability. In their study, Torriani *et al*. (2022) found that students were more likely to report satisfaction when they believed they had control over their indoor environment, regardless of the operative temperature they were experiencing. Students with perceived control exhibited a neutral temperature that was 0.3 °C lower than that of students without perceived control.

In their analysis of the thermal preferences and adaptive behaviors of children aged 9-11 in classroom environments, Korsavi & Montazami (2020) found results consistent with other studies. Their findings indicated that students have lower comfort temperatures than adults and exhibit greater sensitivity to temperature changes during heating seasons and, therefore, an overestimation of children's thermal needs by thermal comfort standards. Regarding adaptive behaviors, the study concluded that students tend to act as passive recipients of classroom conditions. During the non-heating and heating seasons, 12.4% and 39.4% of students reported having no adaptive behaviors in the classroom, and approximately 80% of window operations were performed by teachers. With approximately the same age group (7-11), Teli *et al*. (2012) took similar conclusions, as it was concluded that children were more sensitive to higher temperatures and tend to prefer lower temperatures than adults. The teachers generally control the classroom environment, and the only adaptation that children can take is the addition or removal of layers of clothing.

Gender may influence thermal comfort temperatures. In a study of thermal comfort temperatures and adaptive habits among female and male high school students, it was found that 56% of female students reported feeling thermally neutral, compared to nearly 20% of male students. Female students also exhibited lower temperature acceptability limits than their male counterparts. Gender differences were also observed regarding adaptive behaviors, with female students demonstrating greater knowledge of measures other than adjusting the air conditioning (Al-Khatri *et al*., 2020). In a tropical region, the thermal comfort temperatures of high school students seem to be much higher. Hamzah *et al*. (2018) carried out research on Indonesian high schools and concluded that these students were tolerant of the hot temperatures. The temperatures ranged the 28.2 °C to 33.6 °C, with most students saying they felt neutral (37%), slightly cool (20%), or slightly warm (30%), and more than 86% of respondents accepted these thermal conditions.

In Spain, Sánchez-Torija *et al*. (2022) measured the temperature in three schools for one year and compared these measures with the standards on Spain's thermal standards. The Regulation of Thermal Installations in Buildings in Spain defined that the thermal comfort range is in the temperature range of 21 °C to 23 °C in winter and 23 °C to 25 °C in summer. Still, those temperatures were only archived 30% of the time for one year. Classrooms may be excessively heated, as concluded by Mumovic *et al*. (2008). Some classrooms where classrooms were excessively heated according to the standards. The level of discomfort, calculated with PPD, varied and was associated with high classroom temperatures or the air draught caused by air conditioning or natural ventilation.

Thermal comfort in schools seems to be more than a preference; students' discomfort affects their academic performance. Wargocki & Wyon (2013) concluded that reducing the classroom temperature from 25°C to 20°C significantly improved students' performance on arithmetical and language-based tests. Goodman *et al*. (2019) found that analyzed exams results in American schools and concluded that hotter school days in years before the test reduce scores, with extreme heat being particularly damaging. Exams taken on hotter days also tend to be lower than the ones performed in colder days. Other factors related to air quality in classroom, such as low ventilation rates, significantly reduce pupils' attention and vigilance and negatively affect memory and concentration (Bakó-biró *et al*., 2013).

Table 3.2: Articles reviewed on thermal comfort in schools.

Author	Country	Educational stage	Season	Temperatures (°C)			The standards predicted the students' preferences correctly?
				Lower	Neutral	Higher	
Pereira *et al*. (2014)	Portugal	Secondary	Mid-season	22.1	-	25.2	No
De Dear *et al*. (2015)	Australia	Primary and secondary	Heating	19.5	22.5	26.6	No
Torriani *et al*. (2022)	Italy	Primary to university	Heating	-	21.7-22.2	-	No
Korsavi and Montazami (2020)	UK	Primary	Non-heating and Heating	-	20.9 (NH) 22.2 (H)	-	No
Al-Khatri *et al*. (2020)	Arabian Gulf region	Secondary	Non-heating	24 (F) 26 (M)	-	26 28	No, overestimates
Teli *et al*. (2012)	UK	Primary	Non-Heating	20.5	20.8	23	No, overestimates
Hamzah *et al*. (2018)	Indonesia	Secondary	Non-heating	-	29	-	No, underestimates
Kim and De Dear (2017)	Australia	Primary and secondary	Non-heating	-	-	-	No, overestimates
Sánchez-Torija *et al*. (2022)	Spain	-	One year	-	-	-	-
Mumovic *et al*. (2008)	UK	Secondary	Heating	-	-	-	-

Legend: -: not calculated/applicable; F: female, M: male; NH: non-heating season; H: heating season

4

Education in Portugal

4.1 Overview of the Portuguese Educational System

In 2021, the number of students enrolled in Portuguese schools reached approximately 1.6 million, with 80% attending public schools, as detailed in Figure 4.1 (PORDATA, 2023a; PORDATA, 2023b). The Portuguese government allocates an annual budget of around 10,000 million euros for education (PORDATA, 2022c), which represented 4.6% of Portugal's GDP in 2021 (PORDATA, 2022d). Class sizes play a crucial role in education as they determine the amount of time teachers can dedicate to each student. Normative order No. 10-A/2018 establishes guidelines for the composition of Portuguese classes, stipulating that the number of students per class in secondary education should range from 28 to 30, depending on the type of education. In 2020, the student-to-teacher ratio in secondary education was 8.9 in Portugal, while the European average stood at 11.2 (Eurostat, 2023a).

Portugal follows a 12-year compulsory education system, divided into three mandatory levels according to the International Standard Classification of Education (ISCED). Prior to mandatory education, there is preschool education for children aged three to six, corresponding to ISCED level 0 (Eurostat, 2023b). Mandatory education begins at the age of six with basic education, which includes the First Cycle (ages six to ten), the Second Cycle (ages ten to twelve) corresponding to ISCED level 1, and the Third Cycle (ages twelve to fifteen) corresponding to ISCED level 2 (Lower Secondary Education). After completing the third cycle, students proceed to upper secondary education (ISCED level 3) until the age of eighteen (Eurostat, 2023b). In secondary school, students have the option to choose between scientific and humanistic courses, specialized artistic courses, or vocational courses (Eurostat, 2023b).

There are a total of 8 241 educational establishments in Portugal, comprising 5 774 preschools, 4 057 first cycle schools, 1 180 second cycle schools, 1 440 third cycle schools, and 967 secondary schools (PORDATA, 2022e). Most of these educational establishments are public, as observed in Figure 4.2. The Portuguese Government spends 9.2% of their total government expenditures on education, which is slightly above the EU22 average (8.8%) (OECD, 2021). Portugal, the compulsory instruction time in primary education is 5 429.4 hours and 2 505 hours for lower secondary education, which is higher than the EU22 average (4 188.8 in primary education and 3 024.1 hours in lower secondary education) (OECD, 2021).

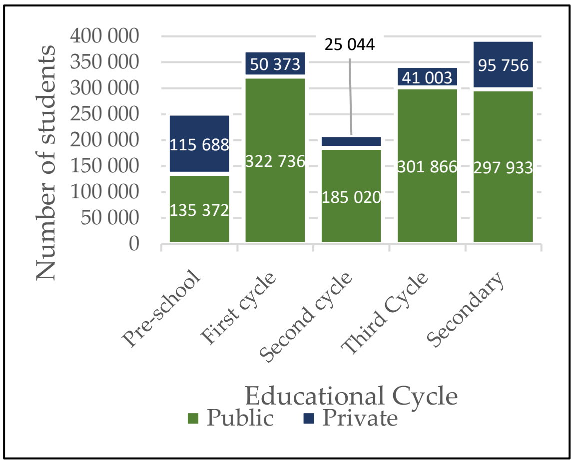


Figure 4.1: Number of students enrolled per education level and type of ownership. Adapted from PORDATA, 2023a and PORDATA, 2023b.

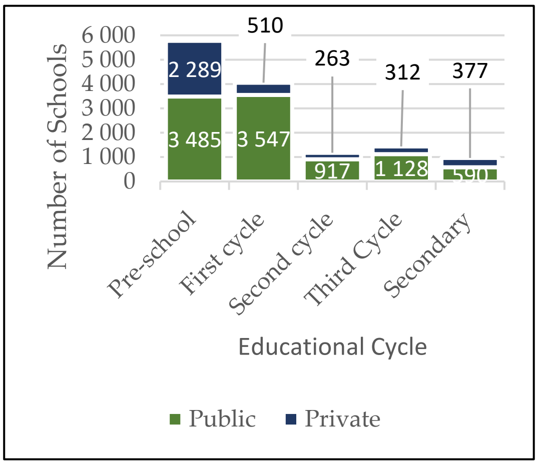


Figure 4.2: Number of schools per education level and type of ownership. Source: PORDATA, 2023e.

The public school has a fundamental role in the fight against the reduction of inequalities and social exclusion. Through support measures contemplated in the legislation and the additional support provided by some schools, it is possible to contribute to the eradication of poverty and equal conditions of education for all students. Decree-Law No. 55/2009 establishes the legal regime applicable to the attribution and functioning of support within the scope of school social support. There are three levels of school social support: level A, for students with annual income up to 3 071.67€, level B for families to annual income up to 6 143.34€ and level C, for families with income up to 9 215.01€. In alimentation matter, the school is obligated to provide a balanced and appropriate diet, that considers the dietary habits of the region in which the school is inserted. Students who benefit from school social support benefit from a 100% (students with level A) or 50% (students with level B) co-payment of these meals. The pre-school and 1st stage students also receive a package of milk daily and free of charge, throughout the school year. Pre-schoolers also receive fruit daily.

The support in terms of school supplies is also contemplated in Portugal. Since 2019, school textbooks are free for primary and secondary students, as established in law No.96/2019. The same law established that families in financial needs also benefit from support to buy school supplies and to pay for field trips. in the same year, the total expenditure in social action was 250 410 804 euros, where food (25%) and social-economic support (62%) represented the biggest share of it (PORDATA, 2023f).

4.2 Energy Consumption and Energy Efficiency in Schools

According to Observatório de Energia (2022), the services sectors account for 13.4% of final energy consumption. This group includes school buildings, which are classified as "commerce and services" under decree-law no. 101-D/20202. If their useful floor area exceeds 1000 m², they are further classified as "Large commercial and services buildings." Energy consumption in school buildings is primarily attributed to lighting, heating and cooling systems, water heating systems and other uses. The education sector's electricity consumption represents 1.07% of national consumption (DGEG, 2023c). Figure 4.3 shows the evolution of the educational sector electricity consumption between 2010 and 2022. Through the years, two major fluctuations were observed: a decrease during the 2010-2015 period, likely due to the financial crisis in Portugal, and again during the 2020-2021 period because of the COVID-19 pandemic. The education sector's share of national electricity consumption has decreased from 1.25% in 2010 to 0.89% in 2021. Natural gas consumption by school buildings is even less significant, representing an average of 0.25% of national consumption. Figure 4.4 shows an increase in natural gas consumption in the education sector from 2014 to 2015, followed by a decreasing trend until 2021.

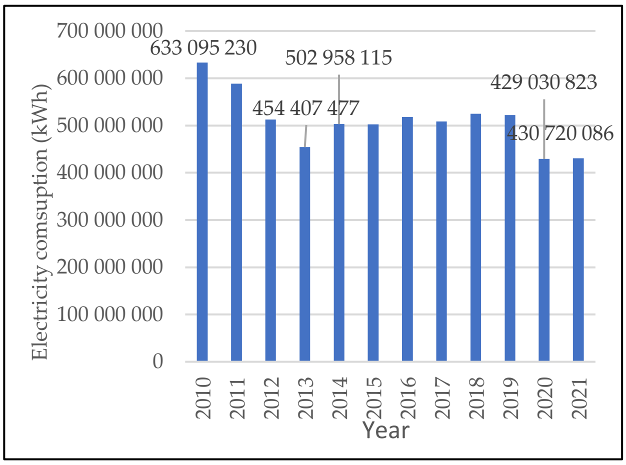


Figure 4.3: Electricity consumption in the education sector. Source: DGEG, 2023c.

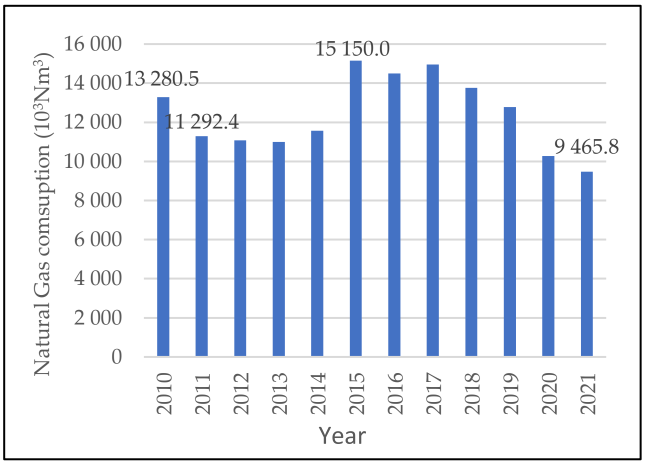


Figure 4.4: Natural Gas consumption in the education sector. Source: DGEG, 2023c.

In terms of energy certification of buildings, 212 423 certificates for services have been registered. However, this sector represents only 11% of the total number of certificates issued (Observatório de Energia *et al*., 2022). In 2022, 23 494 energy certificates were issued for services, with class C being the most common at 43.7% and class B- at 16.2% (SCE, 2023). Despite this, the energy class of new certificates has not evolved since 2014, with class C remaining the predominant class (Observatório de Energia, 2022). According to ADENE (2023), for secondary schools, there are 280 records of energy certificates. The predominant energy classes for these buildings are similar to those of other service buildings: class C accounts for 53% of certificates, and class B- for 23% (Figure 4.5). 61% of certificates have a classification of C or lower. The average energy consumption for registered buildings is 105 kWh/(m². year), with associated emissions averaging 1076 t/year of CO_2. Renewable energy use in these buildings' accounts for 11.2% An analysis of the indicators present in energy certificates reveals that lighting and uses classified as "others" on the energy performance certificates are responsible for the highest energy consumption in schools, as observed in Figure 4.6.

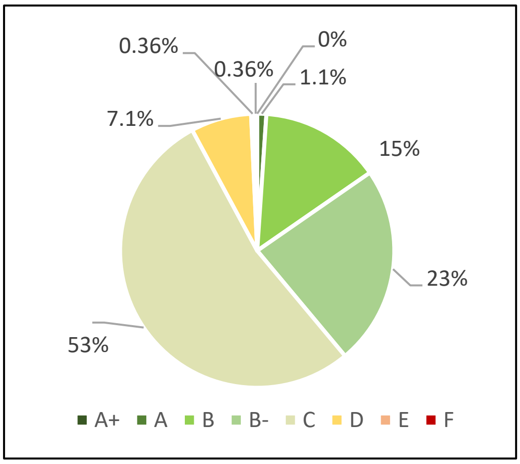


Figure 4.5: Energy performance Certificates by efficiency rating. Source: ADENE, 2023.

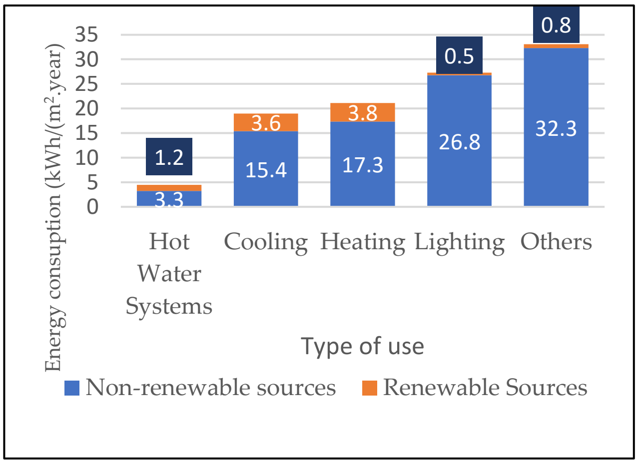


Figure 4.6: Energy consumption in school buildings by different types of uses and by renewable and non-renewable sources. Source: ADENE, 2023.

In terms of renewable energy use, space heating and cooling have the highest percentages. It is noteworthy that buildings with higher energy classes have lower energy consumption for lighting and other uses due to the presence of more efficient equipment (table 4.1). Conversely, there is a higher consumption of heating and cooling in buildings with higher energy classes, which can be attributed to the absence of such equipment in schools with lower energy classes.

Table 4.1: Energy Consumption by uses and energy classification. Source: ADENE, 2023.

	Hot Water Systems (kWh/m².yr)	Cooling (kWh/m².yr)	Heating (kWh/m².yr)	Lighting (kWh/m².yr)	Others (kWh/m².yr)	% of renewables	Total energy consumption (kWh/m².yr)
A+	-	-	-	-	-	-	-
A	6.0	27.4	6.1	9.4	25.8	37.2	74.7
B	7.0	21.0	20.2	13.4	32.2	19.4	93.8
B-	5.0	23.8	15.8	25.7	38.7	8.4	109.0
C	3.9	9.9	42.4	14.0	32.6	5.7	102.9
D	3.1	14.1	33.5	23.7	22.6	4.6	96.9
E	0.0	10.2	13.5	66.1	30.0	0.0	119.8
F	0.0	17.1	12.9	84.7	35.1	0.0	149.8

Legend: - : no data

Of the certificates analyzed, 254 included proposed improvement measures. Consistent with the most energy-intensive uses, the most frequently proposed measure was the replacement of lighting, followed by the replacement of other systems and the replacement of the roof (Figure 4.7). If these measures were implemented in all buildings, 88% would achieve a classification of B- or higher, and none would be classified as D, E, or F (Figure 4.8).

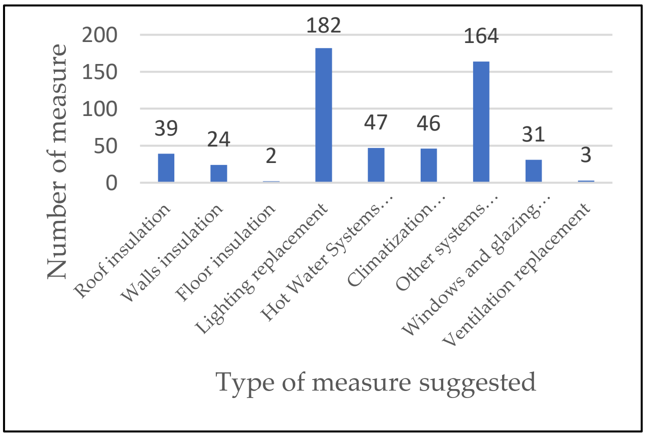


Figure 4.7: Improvements measures suggested on the Energy Performance Certificates by type of measures. Source: ADENE, 2023.

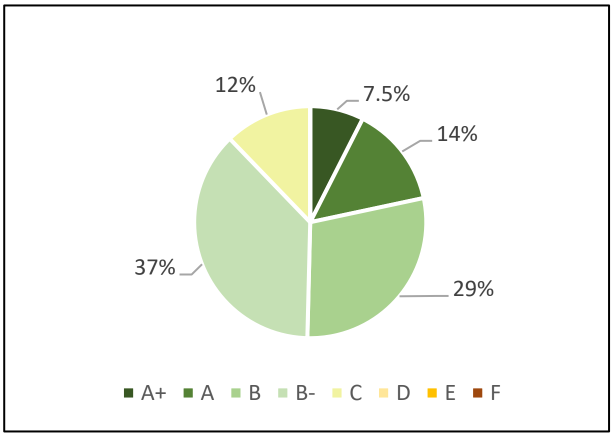


Figure 4.8: Energy performance Certificates classification after the Improvement measures, by efficiency rating. Source: ADENE, 2023.

4.2.1 Studies on Energy Efficiency in Secondary Schools

In the present subsection some energy audit studies carried out in Portuguese primary and secondary schools were analyzed and compared with the statistics mentioned in the previous subsections. The results of the studies are presented in Figure 4.9, where they were compared to other studies performed in European schools.

In a 2014 study, Lourenço *et al*. audited eight secondary schools in Lisbon that had undergone renovations. Despite the renovations, high energy consumption was observed, indicating a need for improved energy management and efficiency to reduce the schools' environmental impact. Before refurbishment, the average energy consumption of the schools was 35 kWh/(m^2.yr) for electricity and 6 kWh/(m^2.yr) for gas. After refurbishment, energy consumption in the schools increased by almost 65%, with an average consumption of 51 kWh/(m^2.yr) for electricity and 16 kWh/(m^2.yr) for gas. The authors reported significant differences in energy use before and after the modernization program.

Before the program, heating was provided by small portable electrical heating equipment located in classrooms and administrative offices (when available), while cooling was provided by natural ventilation. After the program, new integrated mechanical ventilation and air-conditioning systems were installed. These new systems were identified by school directors as major drawbacks, with many reporting that their management was challenging and stressful.

Another factor contributing to the increase in energy use was the loss of usability of windows. After the modernization program, factors such as sealed glazed areas, reduced window opening span, inaccessible window location, and enlarged window size and weight made it difficult to handle these facades. This was associated with thermal dissatisfaction and increased energy consumption for cooling during warm seasons. The increase in gas consumption was attributed to some schools introducing gas for space heating after refurbishment. After refurbishment, the three schools that introduced gas for space heating had the highest total variation in energy consumption patterns.

A 2017 study by Dias Pereira *et al*. analyzed energy consumption in six secondary schools and found an average yearly consumption of 53 kWh/(m^2.yr). Higher energy consumption was observed in inland and northern schools compared to coastal schools. In contrast, Bernardo *et al*. (2017) found lower energy consumption while analyzing a secondary school in central Portugal that had undergone modernization. The school featured external thermal insulation on the envelope, double-glazed windows, and heat pumps. Classrooms were identified as the end-use sector with the highest consumption, representing 45.4% of total energy use. Heating and cooling accounted for 10% of energy consumption, while ventilation represented 11.2%. In 2015, Brás *et al*. (2015) conducted energy audits on a group of buildings in a primary school in Moita. The audits included a detailed analysis of construction materials, energy consumption, and lighting, as well as interviews with pupils and teachers to understand occupant behavior. The school was found to be inefficient due to a lack of insulation on envelopes and roofs, single-glazed windows (sliding, fixed, and rotating), and climatization consisting of electric heaters and fans. The inefficiency of the climatization systems was reflected in the school's electricity consumption, with these systems representing 90% of the total installed power. Heating was identified as the most significant energy need (50 kWh/(m^2.yr)), while lighting and cooling needs were negligible. The highest energy consumption occurred during the coldest months, particularly between October 2013 and March 2014, when consumption exceeded 3 000 kWh.

The findings from these studies indicate that the values reported in energy performance certificates tend to be higher than those observed in the studies. This discrepancy may be attributed to the fact that energy performance certificates are calculated based on specific conditions that may not align with the typical usage of buildings. For example, energy performance certificates assume an indoor temperature range of 20 to 25 °C, which may not reflect the actual conditions in practice. Another conclusion that can be drawn is that looking into the results obtained in these studies, Portuguese schools consume less energy than almost all other schools across Europe. Several studies have identified typical values for benchmarking energy consumption in European secondary schools. For example, Jones *et al*. (2000) reported that typical values for electricity consumption in Irish secondary schools were 16 kWh/(m^2.yr) in schools with best practices and 22 kWh/(m^2.yr) in typical schools, while fossil fuel consumption was 101 kWh/(m^2.yr) in schools with best practices and 120 kWh/(m^2.yr) in typical schools. Santamouris *et al*. (2007) indicated that typical electricity consumption in Greek school buildings was 20 kWh/(m^2.yr), with best practices achieving 10 kWh/(m^2.yr). Brychkov *et al*. (2023) assessed energy consumption (electricity and heating) in several European countries and found consumption of 119.57 kWh/(m^2.yr) in France, 112.13 kWh/(m^2.yr) in The Netherlands, and 56.96 kWh/(m^2.yr) in Ireland. Zhang and Bluyssen (2020) reported average electricity consumption of 19.97 kWh/m^2.yr and gas consumption of 99.6 kWh/m^2.yr in Dutch schools. Beusker *et al*. (2012) reported an average energy consumption of 93 kWh/m^2.yr in German schools, a value also identified by Thewes *et al*. (2014) for schools in Luxembourg.

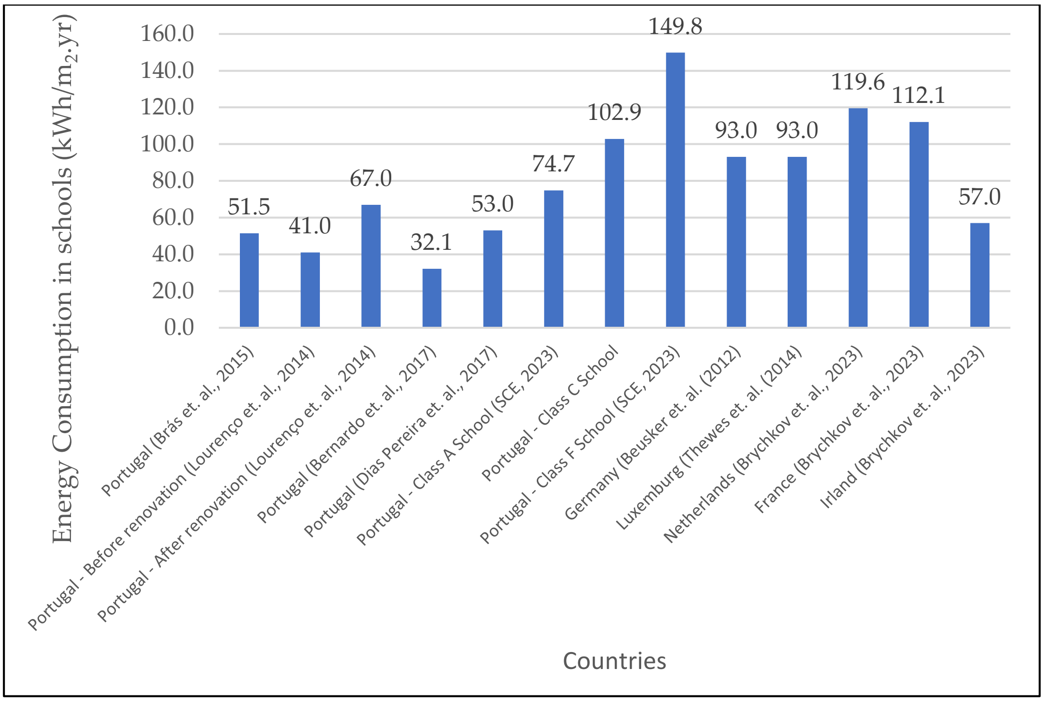


Figure 4.9: Energy consumption in schools across Europe.

4.3 Modernization Program of Portuguese Schools

The modernization program implemented in Portugal that focused on secondary schools was the "Secondary School Building Modernisation Programme". This initiative was launched in 2009 with the goal of renovating 332 secondary schools by 2015, with the first 166 to be renovated by 2011 (OECD, 2012). The schools under renovation were categorized according to their construction year into three phases: phase 1 included schools built until 1935 (2% of the schools under renovation), phase 2 included schools built between 1936 and 1968 (21% of the schools under renovation), and phase 3 included schools built from 1968 (77% of the schools under renovation) (PE, N.D.). At the start of this program, the school building stock physically deteriorated, had low energy performance, environmental comfort, and sanitary standards, and was functionally inadequate for teaching and learning (OECD, 2012). The physical disqualification was concentrated in four aspects: the school grounds, the buildings' cladding inside the building, and infrastructure. In functional terms, the disqualification resulted from developments in the educational model and teaching-learning processes, which led to the need for requalified working spaces adapted to contemporary teaching realities (OECD, 2012). Finally, most schools lacked environmental conditions, resulting from the absence of appropriate environmental and comfort parameters and sanitary requirements during construction.

The program had three main areas of intervention: modernizing the physical infrastructure and creating spaces suitable for educational needs, opening up schools to the local community, and maintaining and managing the buildings after modernization (OECD, 2012). It aimed to provide attractive spaces that promote well-being, allow good teaching practice, provide access to information, and support teachers' work outside the classroom (OECD, 2012). The program also aimed to create flexible, multifunctional, safe, and accessible spaces for all students that could adapt quickly and inexpensively to changes in the curriculum, provide a healthy environment, and support people with restricted mobility and special educational needs. Furthermore, the program focused on increasing energy efficiency by implementing durable and environmentally efficient solutions to reduce energy consumption, management, and maintenance costs (OECD, 2012). The Portuguese government allocated 2450 million euros to this renovation program, divided into renovation phases (OECD, 2012). The attribution of each school to their respective phase was based on the school's age, characteristics, condition of the stock, and the vision of regional education authorities, with a fair regional distribution considered in the process. The first four phases of this program are detailed in Figure 4.10.

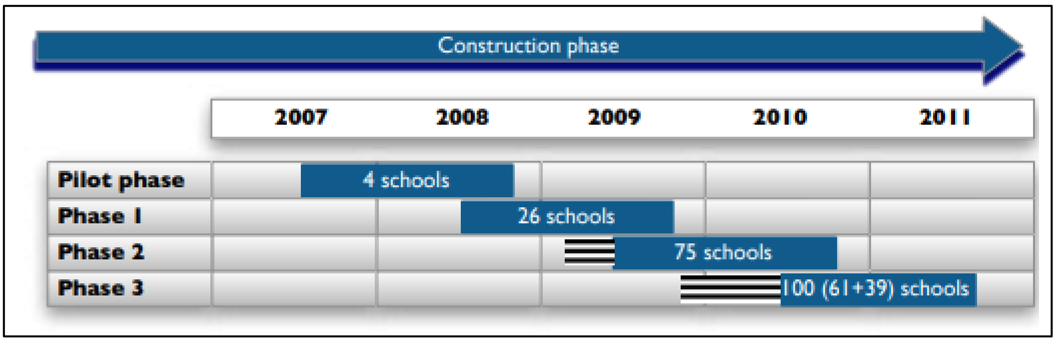


Figure 4.10: Timeline of the renovation of secondary schools. Adapted from OECD, 2012.

The renovation of the secondary schools was conducted by Parque Escolar, an autonomous organization established by the Portuguese government to oversee the renovations. The Secondary School Building Modernization Program was designed to create a school building model that catered to each school's specific educational project, requirements, objectives, and features (PE, 2011). This approach aimed to ensure the longevity and sustainability of school buildings, considering the adaptability required to restructure spaces considering changes in educational strategies and the natural wear and tear resulting from their use. A diverse range of activities, such as collaborative, exploratory, and experimental activities, were incorporated into the student's curriculum. As such, the renovated schools needed to meet the requirements of these activities by providing well-equipped learning spaces. Therefore, the renovation included classrooms with access to information technology equipment, laboratories for conducting experimental work, studios/workshops, rooms for individual or group study, spaces conducive to teaching and informal learning, areas for extra-curricular activities (clubs, school radio), and spaces for disseminating schoolwork and educational content. The program emphasized the interaction between students and teachers; therefore, the cafeterias and dining halls, lobbies and circulation spaces, common rooms, stairwells, and outdoor areas were designed to be interactive spaces for transmitting and acquiring knowledge. To me*et al*l the requirements, the conceptual model of the school was based on three basic principles: integration between various functional areas (teaching and non-teaching areas), guaranteed conditions for their integrated operation, and the possibility of opening some sectors for use by the wider community during after-school periods. The model used in the requalification of schools is illustrated in Figure 4.11. Additionally, each school has a maintenance plan for the next thirty years after the renovation.

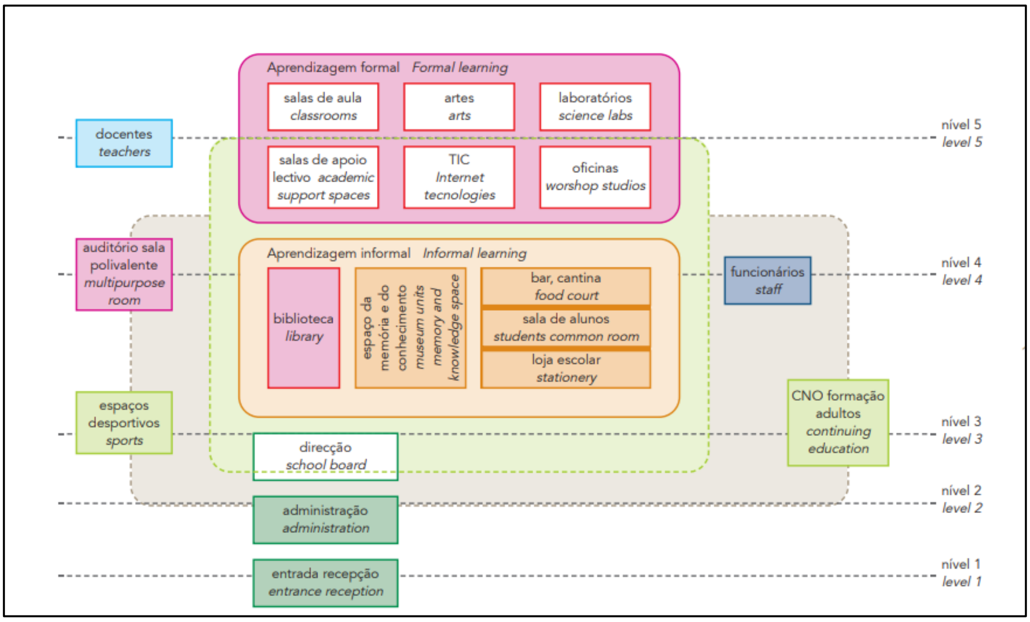


Figure 4.11: Projected layout of the secondary schools. Adapted from Parque Escolar, 2011.

The European Commission has recognized the Parque Escolar renovation program as an exemplary case of smart, effective, and inclusive investment in education infrastructure. The Commission's study noted the program's cost-saving solutions, long-term performance guarantees, maintenance system, design standards, and stakeholder involvement (EC, 2022).

4.4 Schools on Portuguese Thermal Comfort Regulation

Before 1990, Portugal lacked thermal comfort or climate control regulations within residential, commercial, or services buildings. The first legal framework was implemented in 1991 through Decree-Law No. 40/90 of February 6th 1990. This legislation outlines the thermal performance of buildings by providing guidelines for calculating various indices and parameters. These include the energy required for heating and cooling according to the season, the thermal transmission coefficients of the building's envelope elements, the thermal inertia class of the building, and the solar factor of glazing. In addition to regulating the envelope parameters, it is also important to control the heating and cooling equipment used within buildings. Consequently, Decree-Law No. 156/92 of July 29th aimed to regulate the conditions under which the dimensions and conditions of use of equipment and systems in buildings with heating and/or cooling energy systems, without or with dehumidification, are defined to ensure the quality of the respective performances, concerning the rational use of energy, for the environment, and the safety of the installations. Characterizing an energy system for air conditioning is defined by quantifying the maximum heating and/or cooling output. Other parameters were also considered to ensure good energy efficiency. This legislation was subsequently repealed in 1998 by Decree-law No. 118/98, which approved the regulation on the quality of Energy Systems for climatization in Buildings. The objective of this regulation was to ensure that the thermal comfort and environmental quality requirements imposed inside buildings could be met under conditions of energy efficiency, guarantee the quality and safety of installations, and safeguard respect for the environment.

The transposition of Directive 2002/91/EC resulted in the revocation of a previously mentioned decree-law. This Directive aimed to promote the improvement of energy performance in buildings by considering various factors such as outdoor climatic conditions, local requirements, indoor climate requirements, and cost-effectiveness. The Directive established requirements for a methodology of calculation of the integrated energy performance of buildings, minimum requirements for energy performance in new and large existing buildings, energy certification of buildings, and promotion of the inspection of boilers and air-conditioning systems, as well as assessment of the heating installation in buildings where the boilers are over 15 years old. In Portugal, the transposition of this Directive was implemented through three decree-laws:

- Decree-law No. 78/2006 from 4th April: Approved the National System for Energy and Indoor Air Quality Certification of Buildings. The main objectives of this legislation were to ensure regulatory application, namely, regarding the conditions for energy efficiency, the use of renewable energy systems, and the conditions for guaranteeing the quality of indoor air in accordance with the requirements and provisions contained in the Regulation of Thermal Behavior Characteristics of Buildings and in the Regulation of Energy and Air-Conditioning Systems of Buildings; to certify energy performance and the quality of indoor air in buildings and to identify corrective or performance improvement measures applicable to buildings and their energy systems, namely boilers and air conditioning equipment, both in terms of energy performance and indoor air quality.
- Decree-Law No. 79/2006 from 4th April: Approves the Regulation on Energy Systems for Air-Conditioning in Buildings. This regulation defined the conditions to be observed in new climatization systems, namely in terms of thermal comfort and indoor air quality requirements; the maximum limits for energy consumption in large existing services buildings; the maximum limits for energy consumption for the whole building and, in particular, for the climatization, foreseeable under nominal operating conditions for new buildings or for large interventions for the rehabilitation of existing buildings that will have new climatization systems covered by this Regulation, as well as the power limits applicable to the climatization systems to be installed in these buildings; the conditions for monitoring and auditing the operation of buildings in terms of energy consumption and indoor air quality, and the training requirements for technicians responsible for designing, installing and maintaining air-conditioning systems, in terms of both energy efficiency and indoor air quality.
- Decree-Law No. 80/2006: Approved the Regulation of Thermal Performance of Buildings that defined the thermal comfort requirements, whether for heating or cooling, and ventilation to ensure the quality of the air inside the buildings, as well as the domestic hot water requirements, may be met without excessive energy consumption and the requirements to prevent pathological situations in the construction elements caused by surface or internal condensation, with potential negative impact on the durability of the construction elements and the quality of the air inside, are minimized.

In 2010, the Directive was recast through Directive 2010/31/EU, leading to the transposition and update in a single piece of legislation: Decree-Law No. 118/2013 of 20 August, which approved the System for Energy Certification of Buildings, the Regulation of Energy

Performance of Residential Buildings, and the Regulation of Energy Performance of Buildings for Commerce and Services. The separation of these last regulations facilitated the technical treatment and administrative management of the processes, while recognizing the technical specificities of each building type in what is most relevant for the characterization and improvement of energy performance.

The regulation regarding thermal comfort and energy efficiency currently in force in Portugal is the Decree-Law No. 101-D/2020. This regulation transposes Directive 2018/844 and partially transposes Directive 2019/994 and highlights the regulation of mandatory periodic inspections of technical ventilation, cooling, and heating systems and the installation of automation and control systems in buildings with higher energy consumption, to rationalize their consumption and enable greater monitoring, recording, and continuous and comparative analysis of energy consumption and energy efficiency of buildings, with a view to collecting information on their actual or potential energy performance. Changes were also made in the normative and regulatory frameworks of the energy performance of buildings based on the experiences obtained with the remaining regulations. The decree-law is supported by other administrative regulations, and the most important regulations currently in force for school buildings are summarized in Table 4.2.

Table 4.2: Regulation applicable to school buildings currently in force.

Legislation	**Requirements appliable for educational buildings**
Normative order no. 6476-D/2021	Approves the requirements for the development of the Plan for Energy performance Improvement in Buildings. This plan is mandatory for all Large Commercial and Services Buildings with an Energy performance classification below C or that have an energy consumption equal or higher than 5.5 GWh in the previous year. The targets of this plan include the increase of the energy performance raking to C or above, reduction of at least 4% of primary energy consumption and maintenance or reduction of greenhouse gas emissions.
Normative order no. 6476-E/2021, July 1st 2021	Approves the minimum requirements for thermal comfort and energy performance, namely on the indicators of

	primary energy, renewable primary energy, and Fossil primary energy. New service buildings are obligated to have a B or above energy performance classification and renovated service buildings to have a C or above classification.
Ordinance No. 138-G/2021, July 1st 2021	Establishes the requirements for the assessment of indoor air quality in commercial and service buildings, including protection thresholds, reference conditions and conformity criteria, and the respective methodology for measuring pollutants and monitoring compliance with the approved standards.
Normative order no. 6476-H/2021, July 1st 2021	Approves the "Manual SCE", which contains the set of rules and guidelines for the instruction, conduct and conclusion of the processes of assessment of the energy performance of buildings, considering the specificities of the buildings covered. In commercial and service buildings, energy balances are determined under nominal conditions, considering an indoor temperature in the range of 20 to 25 °C.
Ordinance No. 138-I/2021, July 1st 2021	Regulates minimum energy performance requirements for building envelope and technical systems and their application according to the type of use and specific technical characteristics.
Normative order no. 6476-B/2021, July 1st 2021	Approves the selection criteria and the methodologies applicable to the verification processes of the quality of the information produced within the scope of the Energy Certification System for Buildings, namely the acceptable deviation levels for the several indicators.

5

METHODOLOGY

The principal aim of this study was to examine the perception of individuals aged 15-18 years old to energy poverty and inadequate thermal comfort within schools and to identify the vulnerability to both situations. To achieve this objective, the methodology illustrated in Figure 5.1 was employed.

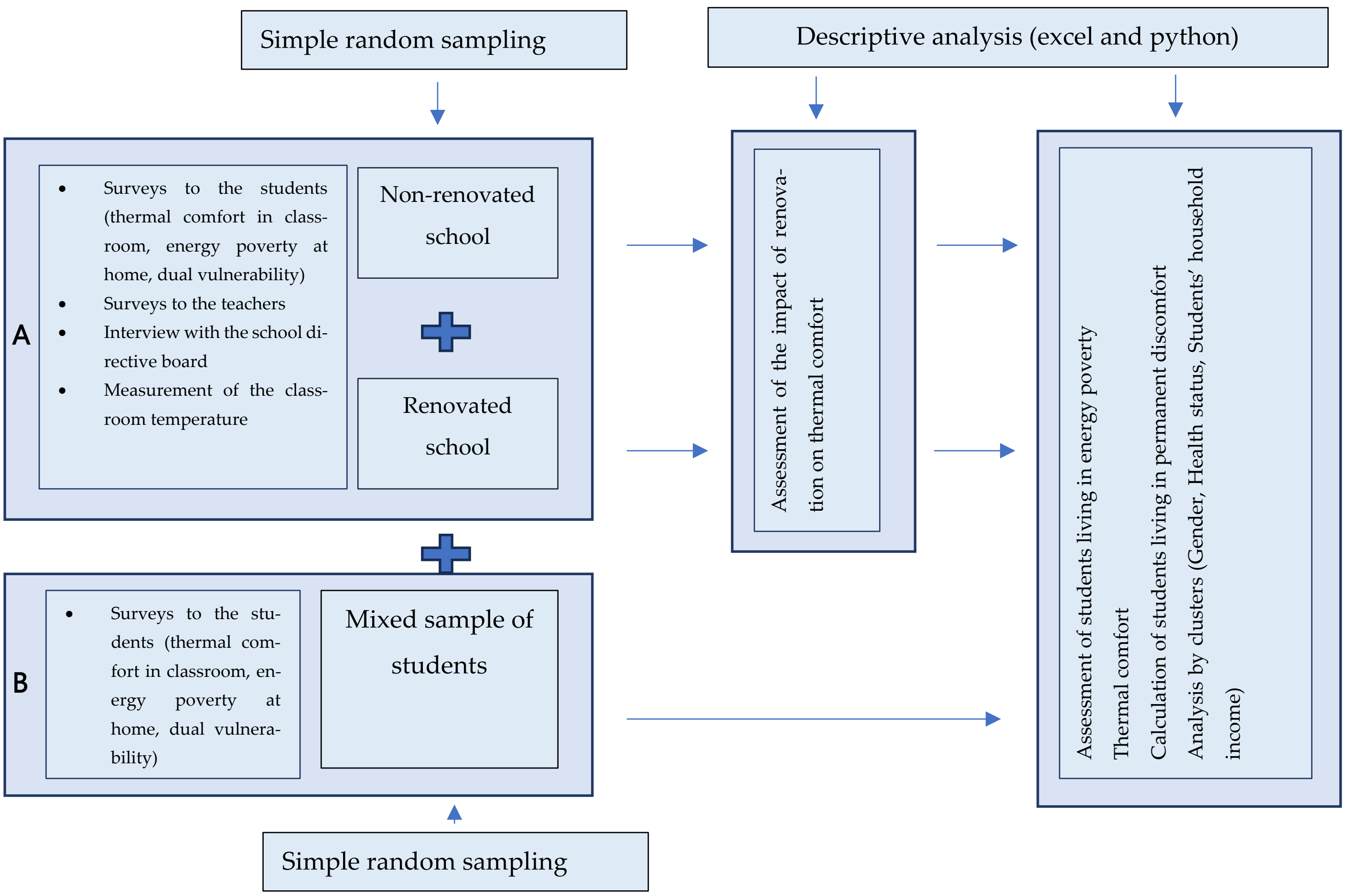


Figure 5.1: Overall methodological process applied in this work.

Two distinct and complementary methodologies were employed to achieve this study's objectives. The first, designated as segment A in Figure 5.1, was initiated by randomly selecting thirty secondary schools comprising renovated and non-renovated buildings. These schools were subsequently contacted via electronic mail, inviting them to participate. This phase aimed to obtain a focused perspective on the problem, where other important variables were collected, and the views of other stakeholders were considered. The data collection in each school consisted of student surveys, teacher surveys, interviews with the school's directive board, temperature measurements of classrooms. The measurement of the temperature consisted of the collection of the outside temperature and temperature inside classroom using a digital temperature sensor. Only two schools consented to participate in the study, which are characterized in the following section subsection. The student surveys were divided into five sections, addressing various aspects related to the research objectives. The survey administered to students was composed of 22 questions divided into five sections:

- Characterization section: where the students were asked about their age, gender, preexistent health conditions, and their school social support level to better understand their financial conditions;
- Section regarding dwelling conditions: in this section, the students were asked If their dwellings had a comfortable temperature during winter and summer, the type of cooling and heating equipment present in their homes, and whether they had experienced problems with dampness or mold in their dwellings;
- Section regarding thermal comfort in classrooms: the students were asked to rate the thermal comfort Inside their classrooms during winter and summer using a thermal comfort scale (Figure 3.1). The percentage of discomfort was calculated by summing the percentage of students who rated their comfort as "hot", "warm", "cool" or "cold". They were also asked about their perception of the impact the classroom temperature on their attention during classes and their academic performance, as well as the actions they took when they felt uncomfortable (e.g., asking the teacher to open the windows or adapting their level of clothing) Additionally, students were asked if they frequently brought garments such as blankets, coats, scarves or folding fans to the classroom;
- Section assessing the presence of a double vulnerability: in this section, the comfort at home and at school was compared, and students were asked to indicate which location was more comfortable during summer and winter;

- Open-ended section: an optional section where students could share any additional thought or experience regarding thermal comfort or energy poverty at home or at school.

A full version of the survey is available in Appendix A1. Before conducting the surveys in schools, a pretest was conducted with five students to determine the time required to complete the survey and identify any questions that needed to be revised. The pretest resulted in a clarification of the school social support level question, specifically the "Level C" option, as students without any benefits were unsure of which school social support level they belonged to. Additionally, a picture of a wall with mold was added to provide a visual representation of the mold/damp issue. The surveys were disseminated to the student population by electronic mail, and answers were collected through random sampling until the sample size achieved statistical significance in representing the number of students in each school. The sample size was calculated with equation 1, with a 95% confidence and 5% margin of error.

Equation 1: Modified Cochran's sample size formula. $N = population\ size$; $e = margin\ of\ error$; $Z = z - score$; $p = population\ porportion = 0{,}5$

$$Sample\ size = \frac{\frac{Z^2 * p(1-p)}{e^2}}{1+(\frac{Z^2 * p(1-p)}{e^2 * N})}$$

The teachers' surveys included 14 questions (Appendix A2). The questions covered the teachers' perception of the classroom's temperature, the type of equipment in classroom, and their perception of the impact of temperature on their performance as teachers and of students' attention during class and tests. Teachers were also asked if the students had permission to open windows or turn on/off the heating and cooling devices and about the frequency that students bring garments to class. The survey was pretested with four teachers, and no modifications were necessary. The school board was also interviewed (Appendix A3). The questions regard the school's energy consumption, their perception of consumption compared to other schools, and the presence of HVAC systems. Questions about thermal comfort included the perceptions of student comfort in classrooms, whether the temperature was adjusted according to student or teacher preferences, and factors that may prevent classrooms from being comfortable (e.g., high energy prices or lack of equipment). If the school had undergone renovations, the impact of it on student comfort was also addressed. Regarding energy poverty, the school board was asked about the number of students experiencing financial difficulties and their awareness of energy poverty among students. They were also asked if any campaigns had been undertaken to raise awareness about this issue.

After collecting the results, the next step in the methodology entailed an analysis and interpretation of the data to answer the objectives proposed. The impact of the renovation was assessed by calculating prevalence ratios and corresponding confidence intervals (with a 95% confidence level) to specific questions that gave the students' perceptions regarding the discomfort. The prevalence ratios and intervals were computed using Python.

The second part of the methodology, denoted as segment B in Figure 5.1, involved gathering surveys from students across different schools and regions of Portugal. This segment aimed to obtain a more comprehensive understanding of the problem by exploring discomfort levels irrespective of school type (public or private) and geographical location. The data collection materials included student surveys (the sample applied the segment A of the methodology) collected during the university's open day that welcomed students from secondary schools from all over the country and through energy efficiency initiatives conducted in schools.

Following data collection, the surveys collected in this phase were combined with those obtained from the two schools in part of the methodology A. A descriptive analysis was conducted, which involved examining clusters based on gender, students' household Income, and health factors. It was denominated as a "mixed students' sample." Prevalence ratios and confidence intervals were calculated to further analyze the data and draw conclusions.

5.1 Case-study

5.1.1 Gago Coutinho's Secondary School (Renovated School)

The Gago Coutinho Secondary School (GCSS) is in the Alverca do Ribatejo and Sobralinho Civil Parish, inserted in the municipality of Vila Franca De Xira. This civil parish has 36 465 habitants, with a population density of 1 525 inhabitants per km^2 (INE, 2023a). Most of the population is between 40 and 49 years old, and the ageing index (ratio between the number of people older than 65 years and the number of people younger than 14 years) is 134.19 (INE, 2023b). Looking Into other socioeconomic indicators from the Vila De Franca De Xira municipality, the unemployment rate is 7.8%, the average monthly base salary in 2019 was 1 036.8€ and the difference between the national minimum wage and the average monthly in the same year was -437€ (PORDATA, 2023g; PORDATA, 2023h; PORDATA, 2023i).

Regarding the building stock, most of the buildings were built between 1961 and 1980 (Figure 5.2), and the proportion of buildings in need of repair is 29.1 (INE, 2023c). In the Vila Franca de Xira municipality, 79% of buildings have a C or below classification on the energy performance certificate, as observed in Figure 5.3 (SCE, 2023). According to the EPVI, the Vila Franca de Xira Municipality has a value of 5.9 on the Heating EPVI and 6.9 on the cooling EPVI (Gouveia *et al*., 2019). Regarding climate characterization, the peak levels are recorded in August, with a daily average high of 31 ºC and a daily average low of 18 ºC (Weather Spark, 2023). On the other hand, the lowest temperatures occur in January, with a daily average high of 15 ºC and a daily average low of 7 ºC. Throughout the school year, from September to June, the highest temperatures are observed in June and September, reaching 28 ºC. Conversely, the lowest temperatures are experienced in January and February, with average highs of 7 ºC and 8 ºC, respectively. Vila Franca de Xira is in the winter climatic zone I_1, summer climatic zone V_3 and the heating season lasts 5.3 months.

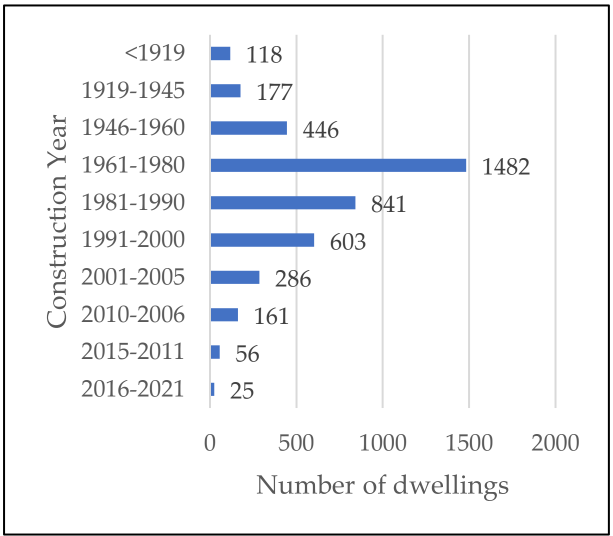


Figure 5.2: Number of dwellings by construction year in Alverca do Ribatejo and Sobralinho civil parish. Adapted from INE, 2023c

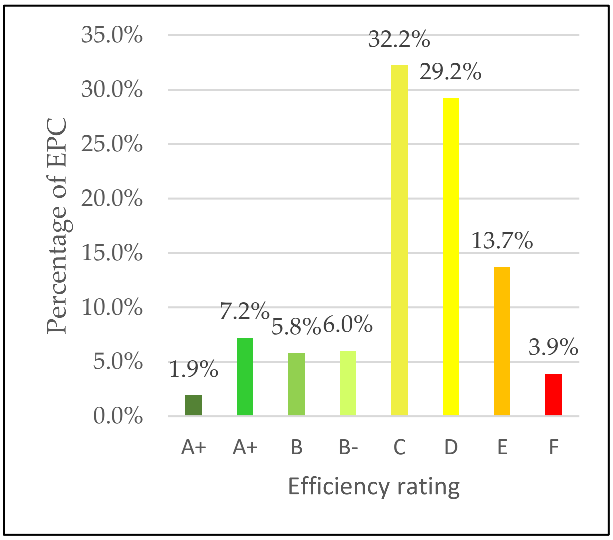


Figure 5.3: Energy performance certificates by efficiency rate in Vila Franca de Xira Municipality. Adapted from ADENE, 2023

The Gago Coutinho secondary school (Figure 5.4) is located near the industrial area of the civil parish. It was constructed in 1984 and was included in the modernization program. Despite

Figure 5.4: Pictures from the school façade, classrooms, and Indoor spaces of Gago Coutinho Secondary School.

the initiation of requalification efforts in 2011, these were suspended in 2012. However, in 2018, the requalification process resumed and was completed in 2021. The school has nearly 1400 students, of whom 124 receive social support level A and 133 receive social support level B. Regarding energy consumption, the school relies on electricity and gas and is equipped with HVAC systems in classrooms and common areas. The surveys were collected between 10/03/2023 and 27/03/2023.

5.1.2 Damião de Goes Secondary School (Non-renovated school)

Damião de Goes secondary school is in the Union of Civil Parish of Alenquer, located in the municipality of Alenquer. It is the only secondary school in the whole municipality. This municipality has 44 442 habitants and a population density of 146.09 inhabitants per km^2. In demographic terms, this municipality follows a similar trend to the Alverca and Sobralinho Civil parish since most of the population is Alenquer Civil Parish, with the biggest share of the population having between 40 and 49 years old and an aging Index of 134.89 (INE, 2023b). Considering additional socioeconomic indicators from the Alenquer municipality, the unemployment rate is 7.2%. In 2019, the average monthly base salary was 965.8€, and there was a discrepancy of -366€ between the national minimum wage and the average monthly salary in the same year (PORDATA, 2023g; PORDATA, 2023h; PORDATA, 2023i). The building stock in Alenquer was mainly built between 1961 and 1980 (Figure 5.5), and the proportion of buildings needing repair is 32.5 (INE, 2023c). The residential stock is equally Inefficient, with only 1.7% of dwellings having an A+ energy performance certificate, as observed in Figure 5.6 (SCE, 2023). According to the EPVI, the Alenquer Municipality has a value of 9.5 on the Heating EPVI and 11 on the cooling EPVI (Gouveia *et al.*, 2019). The highest recorded temperatures occur in August, with a daily average high of 30 ºC and a daily average low of 18 ºC. Conversely, the lowest temperatures are observed in January, with a daily average high of 15 ºC and a daily average low of 7 ºC. During the school year, the highest temperatures are typically experienced in June and September, reaching around 27 ºC and 28 ºC, respectively. On the other hand, the lowest temperatures are observed in January and February, averaging around 7 ºC and 8 ºC, respectively. Alenquer is located in the winter climatic zone I_1, summer climatic zone V_2 and the heating season lasts 5.7 months.

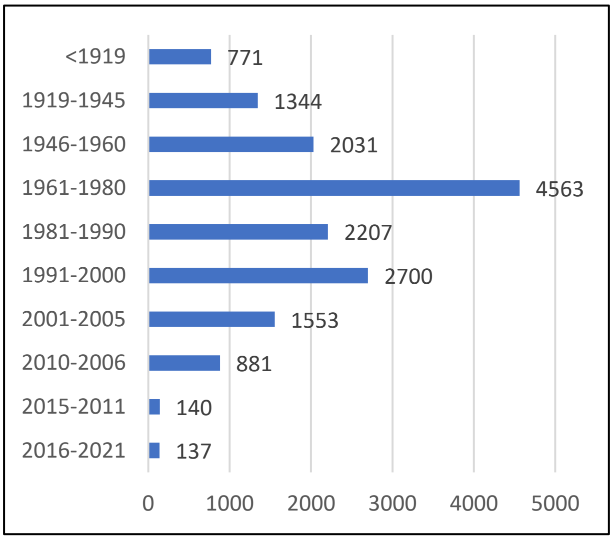


Figure 5.6: Number of dwellings by construction year in Alenquer Municipality. Adapted from INE, 2023c

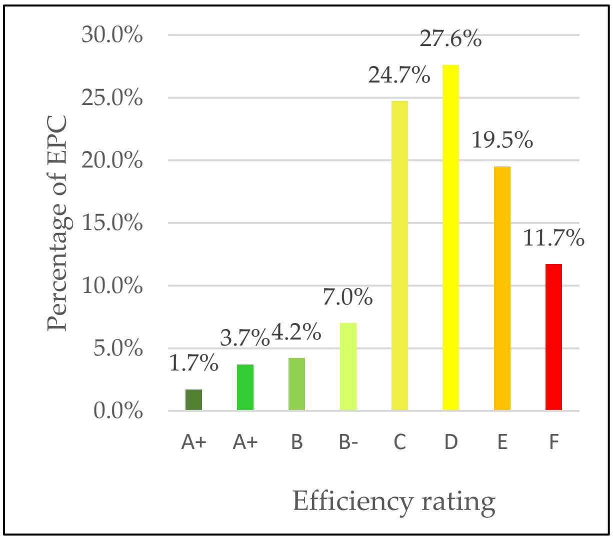


Figure 5.5: Energy performance certificates by efficiency rate in Alenquer Municipality. Adapted from ADENE, 2023

Located in a residential area, this school was built in 1970 and currently has around 948 students, and it has not been renovated. The school's heating system consists solely of electric heaters, which are only present in some rooms, as presented in Figure 5.7, and the classrooms are not equipped with cooling systems. The surveys were collected between 12/04/2023 and 22/05/2023.

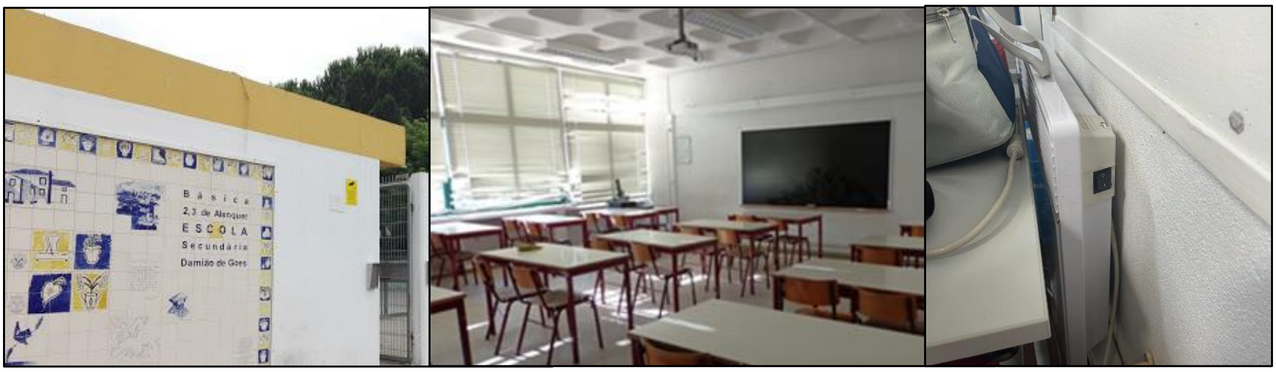


Figure 5.7: Pictures from the Damião de Goes secondary School' façade, classrooms, and heating equipment

6

RESULTS

6.1.1 Gago Coutinho Secondary School

6.1.1.1 Classrooms' Temperature, Interview with the School Directive Board

The outside temperature was 18 ºC, and the temperature recorded in two classrooms was 22 ºC and 21.6 ºC. The interview with the school directive board provided valuable insights into the school's functioning and its relationship with thermal comfort. They informed us that the school primarily relies on gas and electricity for energy consumption, and the city council oversees the management of energy consumption and billing. According to their perception, the school's electricity usage reduced after renovation and is now lower than that of other schools. They believe that students feel comfortable in the classrooms, although there are no specific guidelines on regulating classroom temperature, leaving them unaware of the temperature adjustments made. The school renovation had a positive impact on students' thermal comfort. It was mentioned that the school has some autonomy to carry out activities, such as changing lights, depending on the situation. However, no sensibilization actions have been undertaken to raise awareness about thermal comfort or energy poverty.

6.1.1.2 Students' Surveys

The students sample in this school was characterized according to their age, gender, school year, school social support level, and by pre-existing conditions. 360 students answered the survey, where 92 (26%) were in 10th grade, 161 (45%) in 11th grade, and 106 (29%) in 12th grade. Most of the students were 16 years old (n=129, 36%) and 17 years old (n=122, 34%) and identified as female (n=217, 60%) or male (n=135, 38%). Regarding the self-reported health status, most students reported having no chronic or disabling disease (n=280, 78%), and the most reported condition was respiratory (n=31, 9%). Regarding financial conditions, most students reported belonging to level C of school social support, which corresponds to not having any support. All the detailed answers are in Figure 6.1.

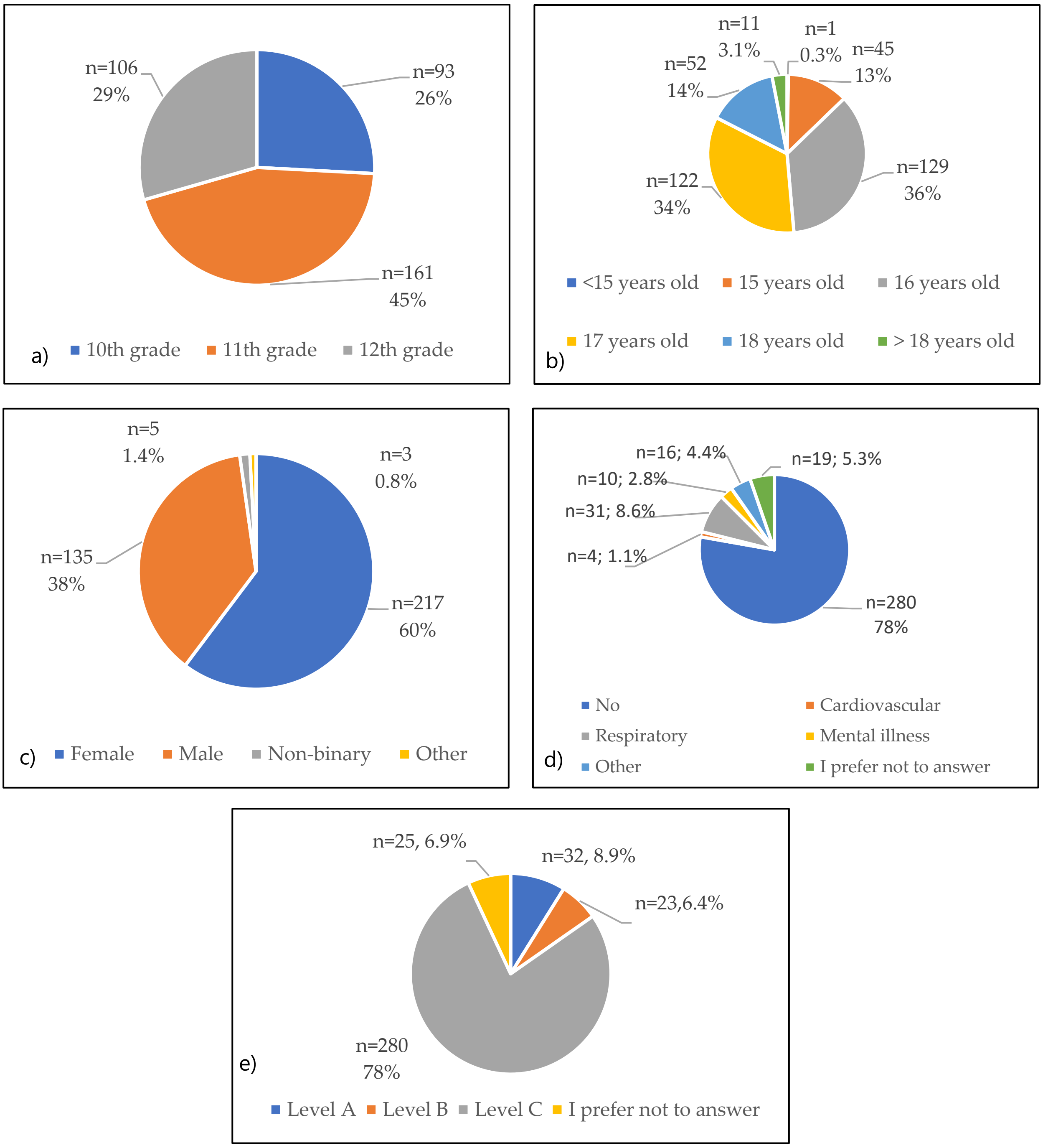


Figure 6.1: Sample Size from the RS distributed by School grade (a), Age (b), Gender (c), Existence of health conditions (d) and School Social support level (e).

Regarding the temperature of their house, 79% (n=286) of students declared that it was a comfortable temperature during summer and 81% (n=293) affirmed that has a comfortable temperature during winter (Figure 6.2). Among the students that declared not to be comfortable in their house during summer, 48 (65%) identified as female, 24 (32%) as male, and 2 (2.7%) as non-binary. 23% (n=17) of these students also declared to have level A or B of school social support.

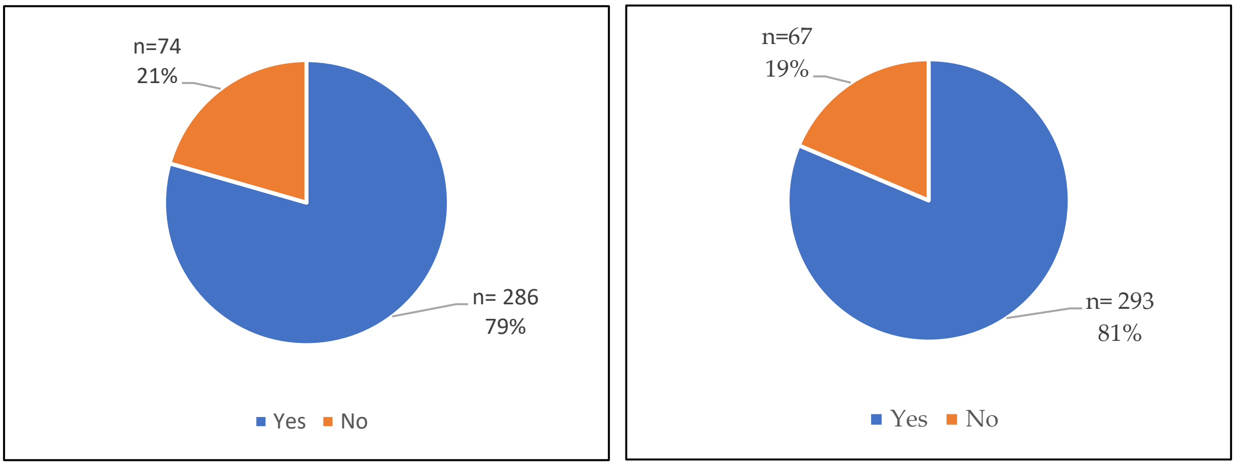


Figure 6.2: Answers from the RS students to the question "Is the temperature of your home comfortable during summer?" (left) and "Is the temperature of your home comfortable during winter?"

When comparing the number of students that reported not to feel comfortable in their house during winter with their self-reported health status, 2 (2.7%) affirmed having cardiovascular conditions, 8 (11%) having respiratory conditions, 5 (6.8%) reported mental Illness and 6 (8.1%) admitted having other chronic or disabling conditions. Likewise, most of the students who reported not having a comfortable temperature indoors during winter were mainly females (n=47, 70%), followed by males (n=15, 22%), non-binary (n=3, 4.5%) and other (n=1, 1,5%). 10% (n=7) of students who reported thermal discomfort at home during winter benefited from school social support level A or B and, in terms of their self-reported health conditions, the most reported one was respiratory conditions (n=5, 7.5%), followed by mental Illness or other conditions (both with n=4, 6%). Additionally, 31 students (8.6%) do not feel comfortable at home during summer and winter.

When confronted with the presence of mold or damp in their dwellings, 152 (42%) students answered having problems with mold or damp in their dwellings, while 208 (58%) reported not having them. When asked about the equipment used in their houses, 36 (10%) students acknowledged not using heating equipment, while 52 (14%) reported not using cooling equipment. 14 (3.9%) students reported not using any equipment. The type of equipment reported by students is present in Figure 6.3. 11 students reported not feeling comfortable at home during summer and not using any cooling equipment, and 18 students reported not feeling comfortable during winter and not using any space heating equipment.

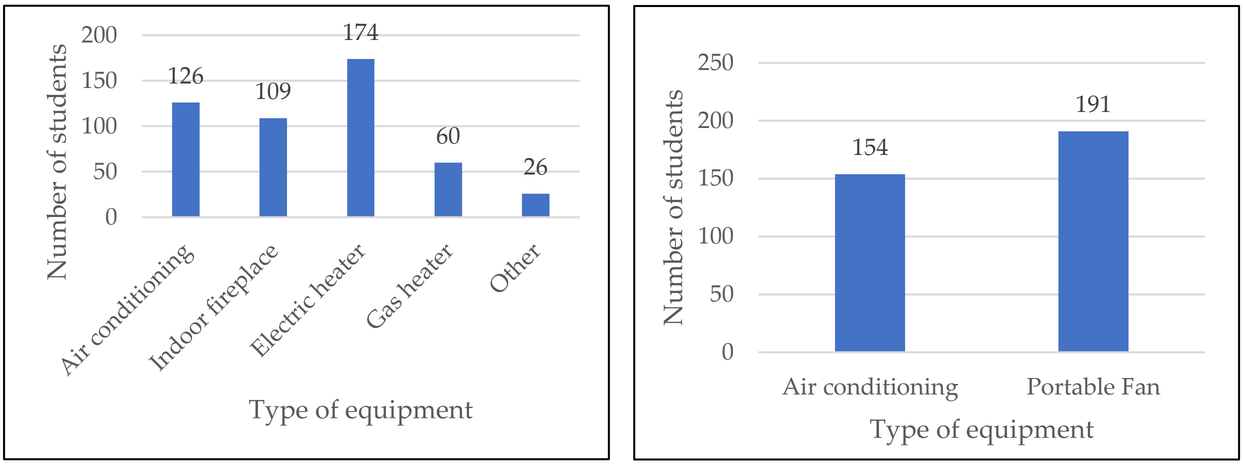


Figure 6.3: Type of space heating (Left) and space cooling (right) equipment used in the dwelling from the RS students.

The students voted on the thermal sensation scale regarding their thermal comfort inside the classroom are, presented in Figure 6.4. During summer, 52% (n=187) of students feel thermal discomfort, where 51 (14%) students stated the classroom felt Hot, 135 (38%) warm, and 1 (0.3%) cold. Disparities were observed in thermal sensation votes regarding thermal comfort in classroom during winter: while 7.2% (n=26) voted for "Cold" and 27% (n=98) for "Cool", 4% (n=13) voted for "Warm" and 0.8% (n=3) for "Hot", which results in an accumulated percentage of discomfort of 39%.

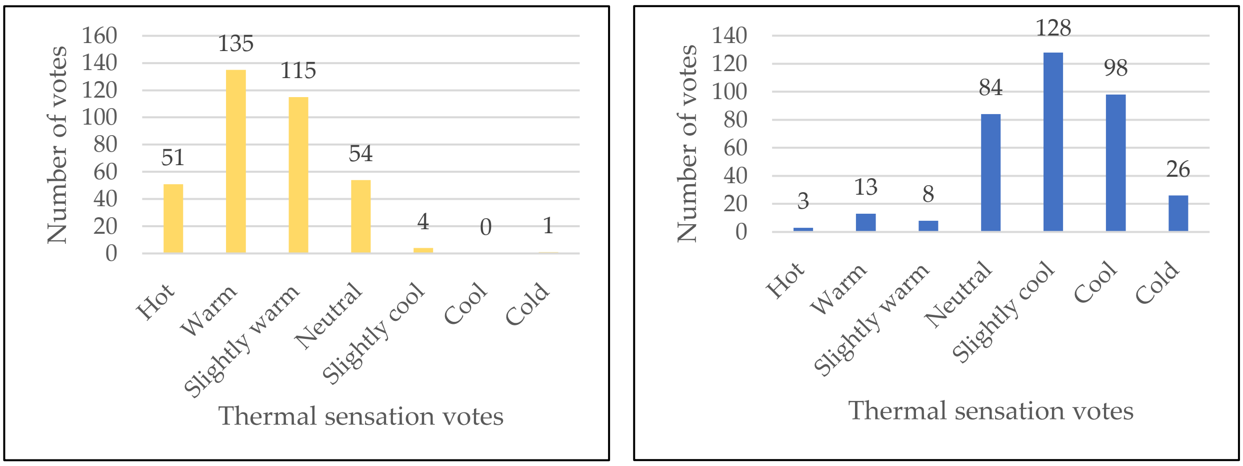


Figure 6.4: Thermal sensation voted during summer (left) and winter (right) from students from RS.

When asked about the impact of the temperature in classroom, 244 (n=68%) of students perceived that the temperature affects their attention, while 233 (n=62%) students stated that the classrooms' temperature impact their academic performance. In terms of the garment that students use in class to face themal discomfort, the most frequent used were jackets, with 163 (45%) students saying the use it frequently and 139 (39%) saying it use is very frequent. The other garment, such as scarfs and blankets, or paper fans were pointed to be use mainly never or rarely, as pictured in Figure 6.5.

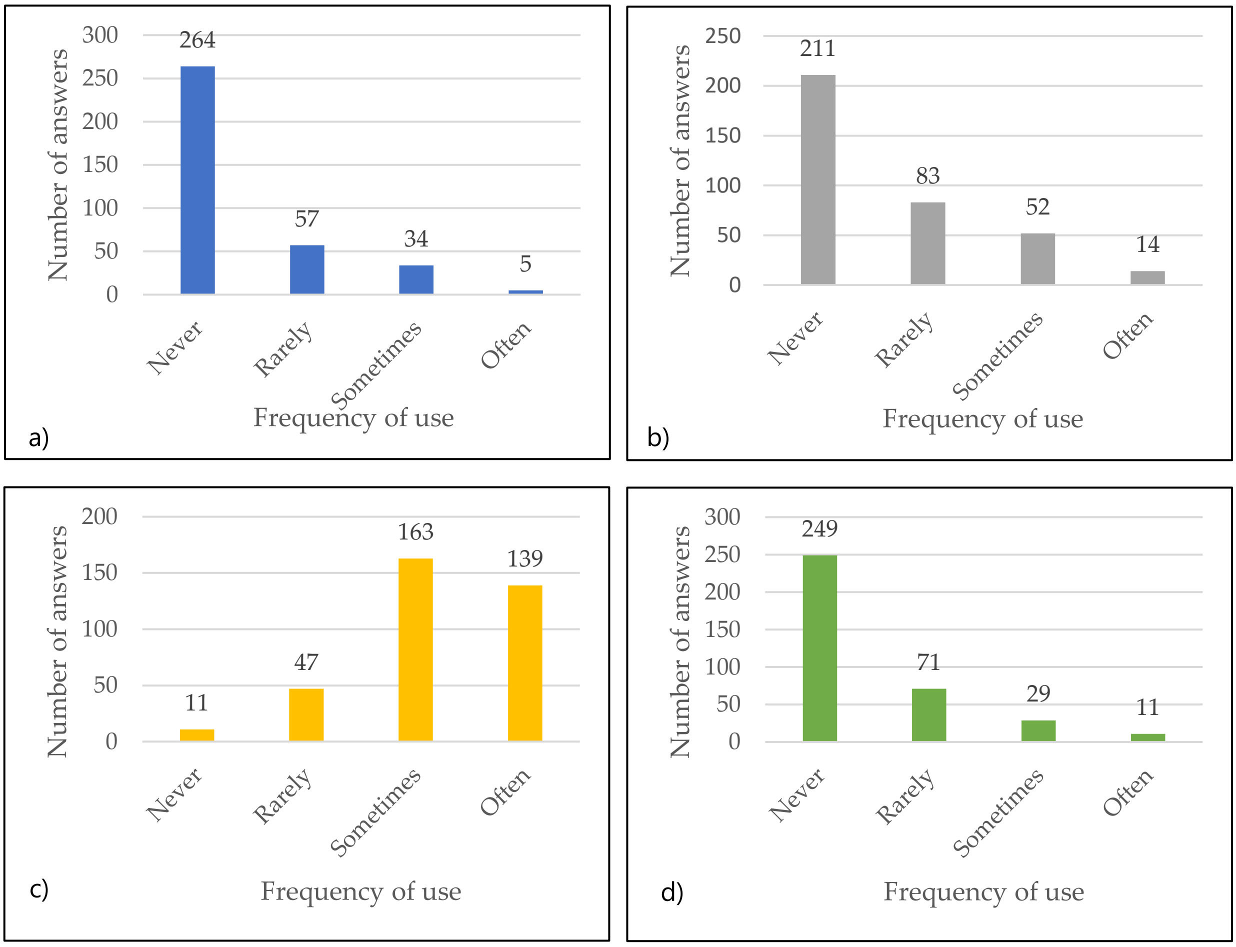


Figure 6.5: Frequency of use of blankets (a), scarfs (b), jackets (c), and paper fans (d) in the classroom by students from the RS.

The actions took by students when they feel uncomfortable were divided by behaviour actions (when students reported that they use the windows, ajust the blinds or ajust their level of clothing), active actions (using equipments or asking the teachers to use them) or if they took no action. Students were allowed to vote for more than one option. The facing thermal discomfort, students mainly reported to inform the teacher and ask for a change in the temperature of the classroom (n=234) or ajust their level of clothing by putting a jacket on or taking it off (n=213) (Figure 6.6). Nevertheless, 36 students admited not doing anything when the temperature of the classroom was not comfortable.

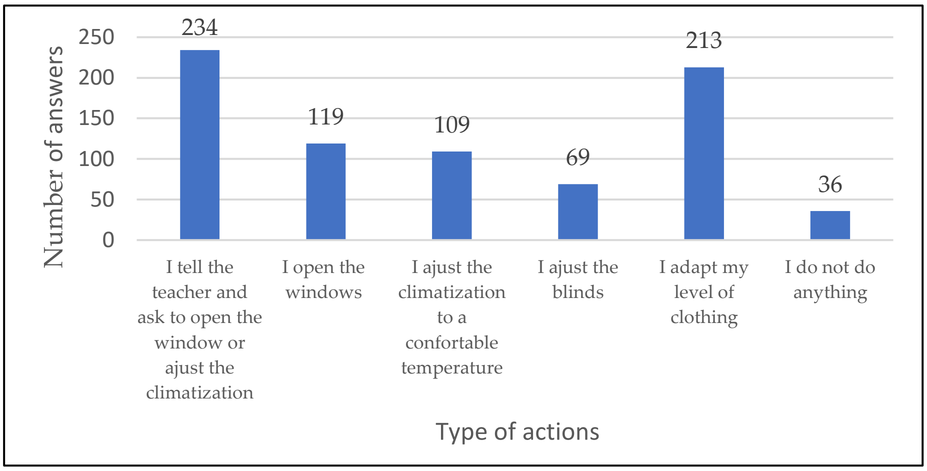
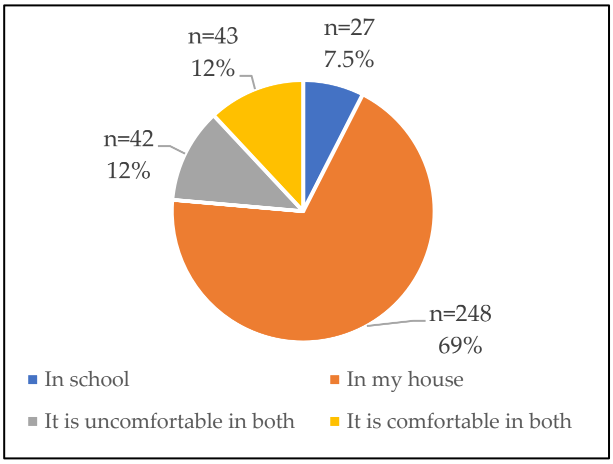


Figure 6.6: RS students' answers to the question "When the temperature in classroom is not comfortable, I..."

In the section that compared the thermal comfort in school and at home, most students reported that they found the temperature at home to be more comfortable at home than at school, both during summer (n=248, 69%) and winter (n=274, 76%). However, 8% (n=27) of students admitted that the temperature was more comfortable at school during summer and 6% (n=23) during winter. As detailed in Figure 6.7, it was also evidenced that 12% (n=42) students are not comfortable either at home and at school during summer and 4% (n=15) during winter. The results in this section were compared with the number of voted simultaneously that they were not comfortable at home and at school in other sections of the survey and a slight variation was observed: 47 (13%) students voted simultaneously for these two options for summer and 35 (11%) for winter. One of the ways to assess the impact of the renovation was by comparing the number of students who voted "It is comfortable at both" and "In school" and 70 (19%) students did so in summer and 71 (20%) during winter.

In the open-ended question, nineteen students gave their opinion regarding energy poverty and thermal comfort in schools. Ten of the statements pertained to issues with the air conditioning, including Instances where teachers did not turn on the air conditioning upon request and classrooms that either lacked air conditioning or had non-functional units. One student provided her personal experience about the impact of thermal discomfort in school: *"During winter, the temperature in the classroom can be so cold that it becomes difficult to write. During summer, considering that we are a class of twenty-four students, the heat can be overwhelming, even with windows open or with the blinds down. In contrast, I feel very comfortable at home, whether it is hot or cold"* (Female, 18 years old, 12th grade). Despite their young age, some students demonstrated their developing literacy on the topic of energy poverty by contributing with opinions on this issue, such as: *"In Portugal, the lack of thermal insulation in dwellings and educational buildings makes it difficult to achieve thermal comfort."* (Male, 18 years Old, 12th grade);*"Some dwellings in Portugal lack of winter adaptations, which led to many people experiencing extreme cold conditions"* (Female, 16 years old, 10th grade).



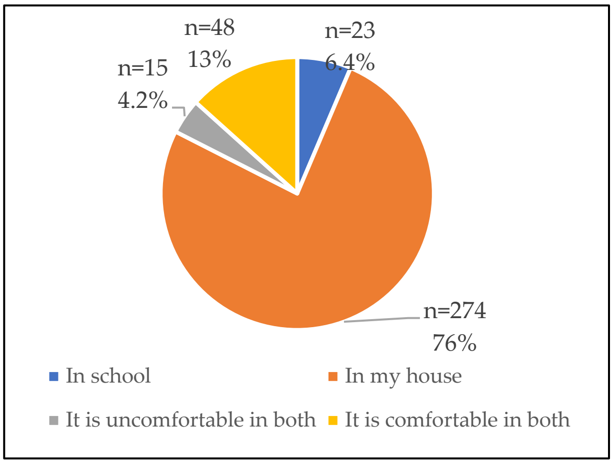


Figure 6.7: Students from the RS answers to the question "In the warmer months, the temperature is more comfortable: " (left) and "In the colder months, the temperature is more comfortable:" (right)

6.1.1.3 Teachers' Surveys

20 teachers contributed with their perception on thermal comfort inside classrooms. They were also asked to vote on their thermal sensation during summer and winter. Six teachers voted on option outside the thermal sensation range during summer, indicating a 30% of discomfort during summer. During winter, the percentage of discomfort as 35%. The teachers' thermal sensation votes are expressed on Figure 6.8. Inquiries regarding the impact of inadequate thermal comfort within a classroom were presented to a sample of participants, whereupon 95% (n=19) acknowledged perceiving that thermal discomfort adversely affected students' concentration during lectures, and 90% (n=18) opined that such discomfort impairs student performance during assessments. Additionally, 15 teachers reported that thermal discomfort hinders their ability to effectively educate their students. With regards to the freedom of students to regulate the thermal conditions within the classroom, 85% of the surveyed teachers affirmed that students are authorized to manipulate the windows' openings and closings, while only 35% confirmed that students are permitted to operate the air conditioning system.

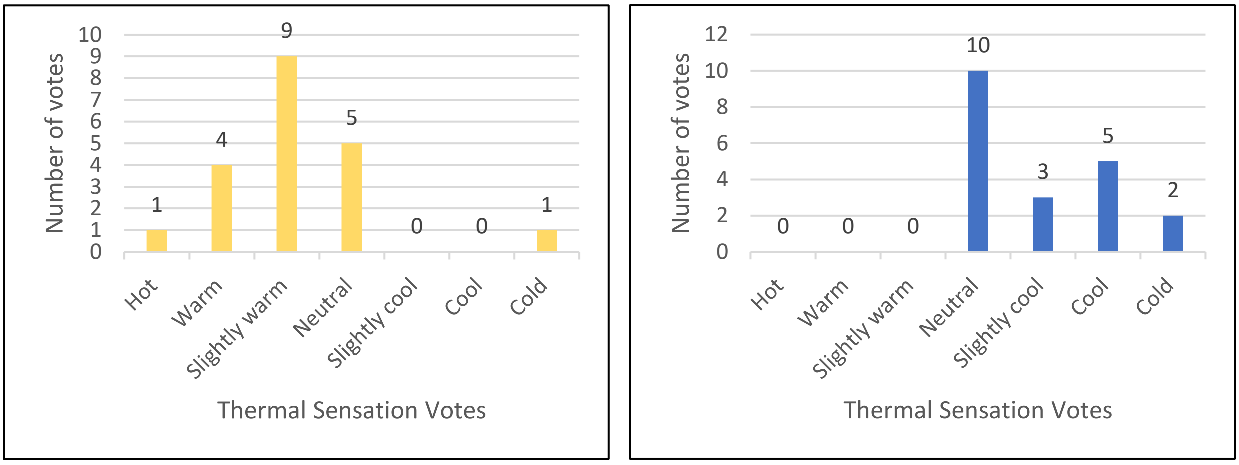


Figure 6.8: Thermal sensation voted during summer (left) and winter (right) from teachers from RS.

6.1.2 Damião de Goes' Secondary School

6.1.2.1 Classrooms' Temperature and Interview with the School Directive Board

The outside temperature recorded was 24.2 ºC and the temperature measure in two classrooms was 25.5 ºC and 26 ºC. Regarding energy consumption, the school directive board acknowledges that their consumption level exceeds that of other schools since they are a conglomerate of schools encompassing various educational levels in the same location. Consequently, their energy consumption is higher compared to schools with only secondary education. Concerning the climatization system, each classroom is equipped with a small electric heater. However, when queried about the thermal comfort experienced inside the classrooms, the directive board stated that the classrooms fail to provide adequate comfort for students, as they become excessively hot during summer and excessively cold during winter. As a result, certain classrooms are avoided during national exams due to unbearable temperatures. Furthermore, it was mentioned that some classroom blinds are damaged, but efforts are being made to replace non-operational blinds in specific classrooms. The sole improvement carried out in the school involved the removal of asbestos from the roof. Despite having the autonomy to implement energy efficiency measures, the school faces challenges due to insufficient funding for such initiatives. Notably, no initiatives have been undertaken to raise awareness about energy poverty or thermal comfort within the school environment.

6.1.2.2 Students' Surveys

At the Damião de Goes secondary school, the sample of students answering the survey was 291 students. Looking into the socio-demographic aspects of this population (Figure 6.9), most of the students were frequenting 11th grade (n=132, 45%), had 16 years old (n=84, 29%) or 17 years old (n=111, 38%) and identified as female (n=159, 55%) or male (n=126, 43%). In terms of their self-reported health conditions, most of the students reported having no chronic or disabling disease (n=237, 81%). Among the students who reported having a chronic or disabling conditions, the most reported one was respiratory (n=26, 8.9%).

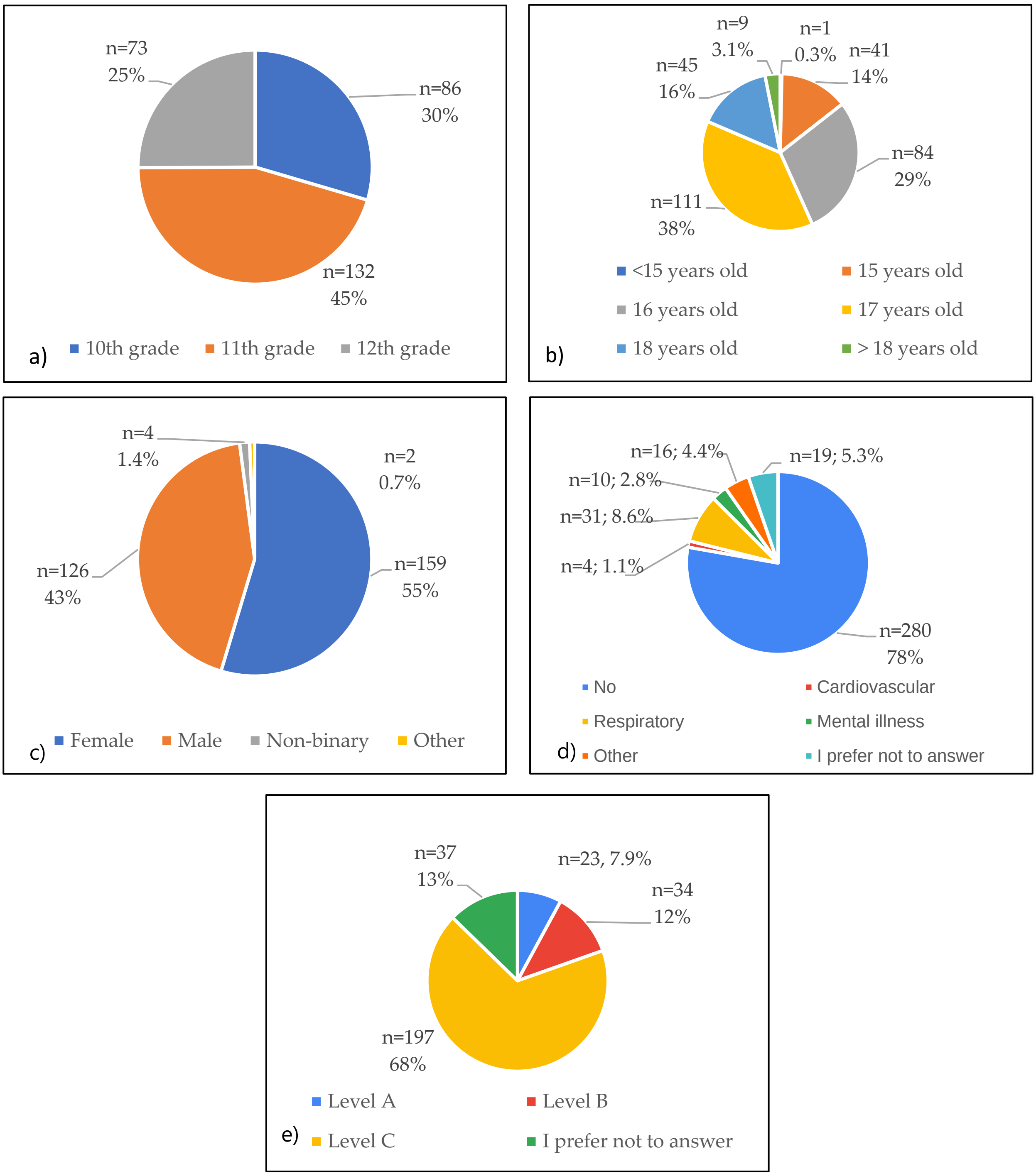


Figure 6.9: Sample Size from NRS distributed by School grade (a), Age (b), Gender (c), Existence of health conditions (d) and School Social support level (e).

Looking into the students' financial conditions, most students reported belonging to level of school social support that does not have any support, level C (n=197, 68%) which corresponds to not having any support. The section regarding the students' dwellings conditions exposed that most of the students feel comfortable at home, and the results for heating and cooling season were similar: during summer, 17% of students (n=50) reported that the temperature was not comfortable at home and 15% of students (n=44) reported the same for winter, as observed in Figure 6.10.

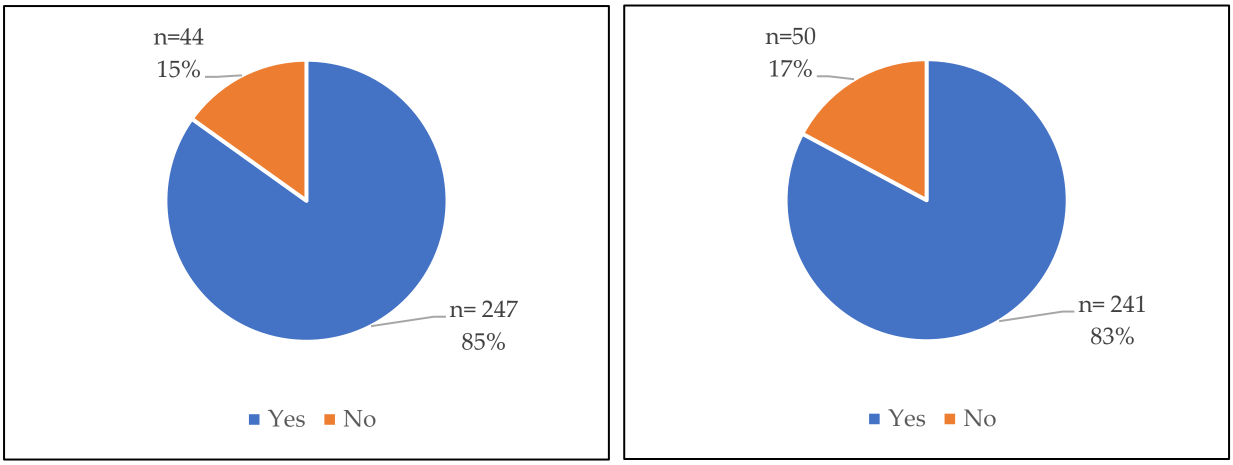


Figure 6.10: Answers from the NRS students to the question "Is the temperature of your home comfortable during summer?" (left) and "Is the temperature of your home comfortable during winter?"

17 students (5.8%) feel uncomfortable during both seasons. Among the 44 students who reported discomfort during summer, most of them identified as female. 10 benefited from school social support level B or C and, despite most of them reported having no chronic or disabling conditions, 6 of them reported having respiratory conditions and 2 of them mental Illness conditions. During the heating season, the sample of students that reported feeling discomfortable at home were mainly female (n=31), had no chronic or disabling conditions (only three of them reported having respiratory conditions and 3 reported having mental Illness) and did not have any school social support (7 students reported benefiting from school social support level A or B). 41% of students (n=119) reported having problems with mold or dampness in their dwellings. Looking into the students' equipment at home, 8% of students (n=23) reported using no heating equipment while 18% (n=53) reported using no cooling equipment. 10 students (3.4%) indicated using no equipment. The most frequent heating equipment has the electric heater (n=142) and the indoor fireplace (n=120). For cooling purposes, most of the students use

portable fans (n=191) (Figure 6.11). Additionally, 7 students reported not feeling comfortable at home and not having any equipment, both during summer and winter.

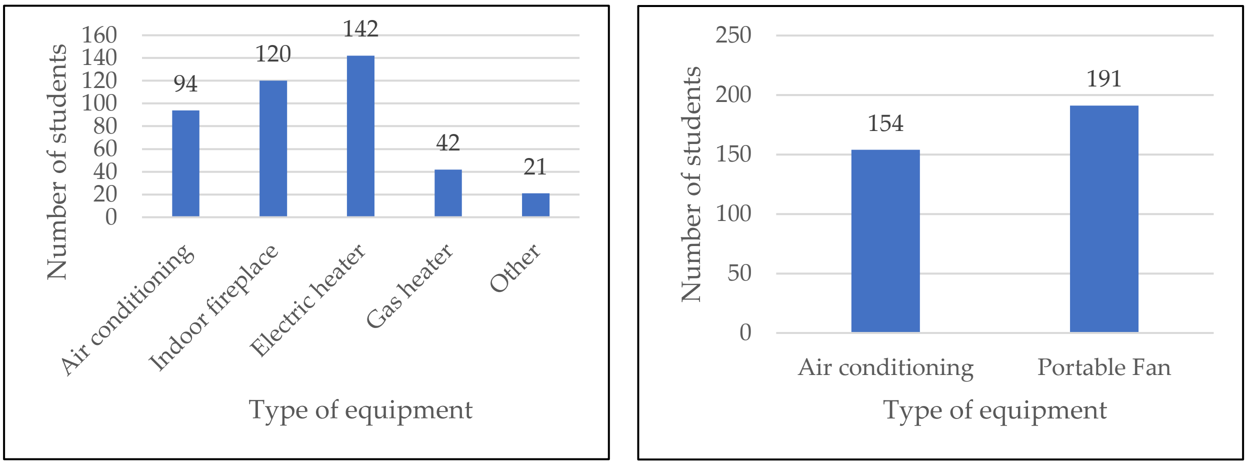


Figure 6.11: Type of space heating and space cooling equipment present in dwelling from the NRS students.

In the section regarding the thermal comfort inside classroom, the levels of discomfort in this school were higher than the ones observed in the renovated school, as indicated in Figure 6.12. During summer, 84% of students were discomfort, as 122 students (41.9%) rated the classroom temperature as "Hot" and 123 students (42.3%) rated as "Warm". Lower levels of discomfort were observed during winter but still more than half of the students fell discomfort: the percentage of students uncomfortable was 61% with 57 students (20%) of students rating the classroom temperature as "Cold", 118 students (41%) rating it as "Cool" and 2 rating it as "Warm" (0.69%).

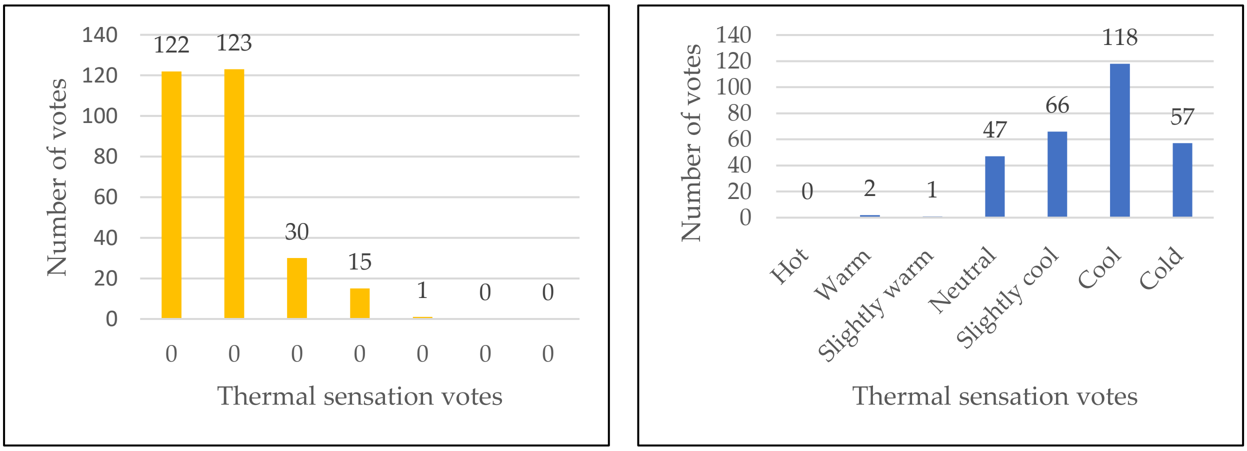


Figure 6.12: Thermal sensation voted during summer (left) and winter (right) from students from NRS.

Students perceive the classrooms' temperature as an important factor for their well-being in school: 76% of students indicated that the classroom temperature affects their attention in class and 70% of students indicated that the classroom temperature affects their performance during exams. Considering the type of garments usually used by students in class (Figure 6.13), the garment with more frequency was jackets (with 171 students (59%) reporting using them often and 109 students (37%) reporting using them sometimes).

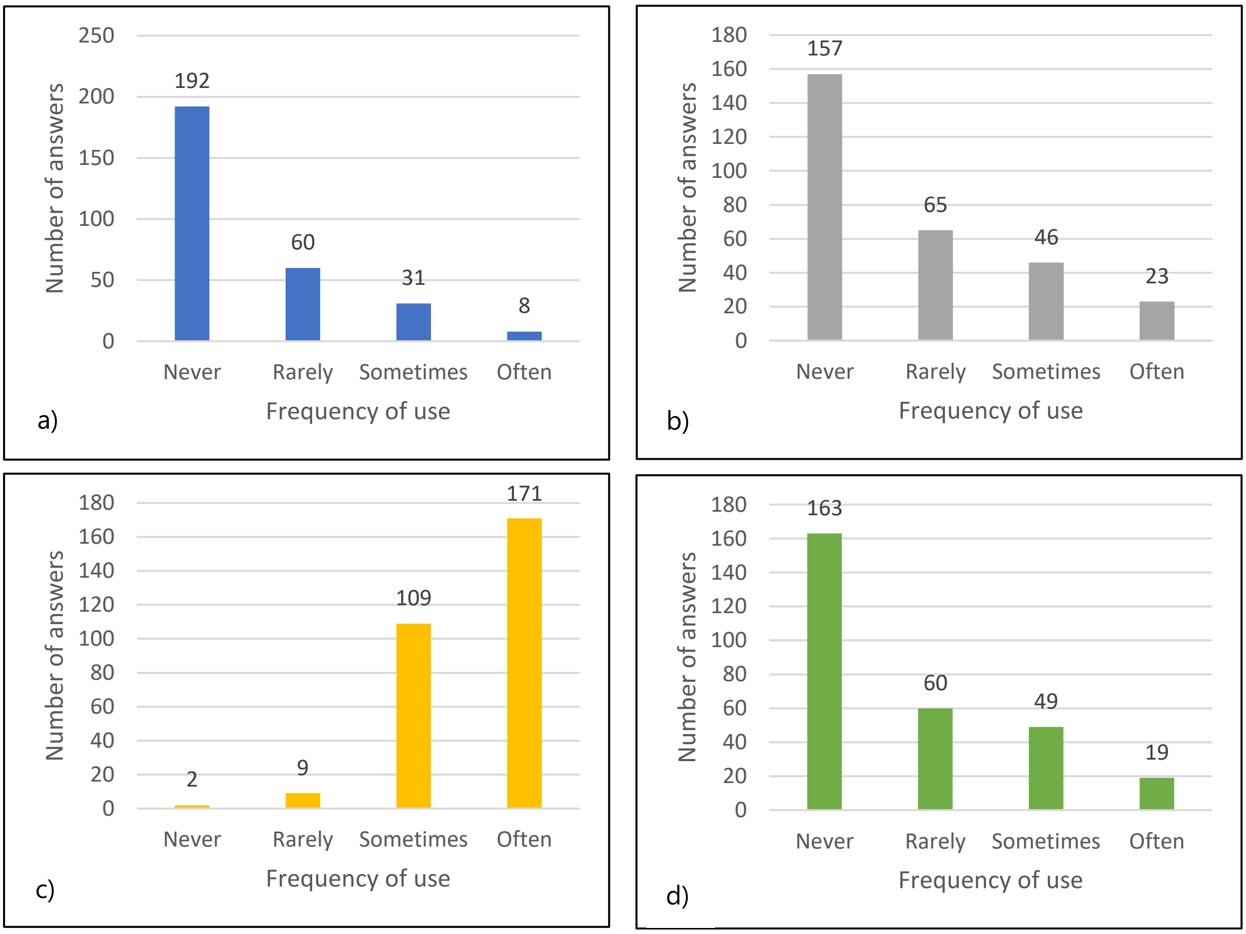


Figure 6.13: Frequency of use of blankets (a), scarfs (b), jackets (c), and paper fans (d) in classroom by students from NRS.

In the last questions of this section, students were asked about their actions when facing thermal discomfort, where they could vote for more than one action. The most voted behavior was to adapt their level of clothing, with 209 students admitting doing it (Figure 6.14). 22 students (8%) of the students Indicate to take no action when they feel uncomfortable. When asked to compare the thermal comfort in school and in their houses (Figure 6.15), most students indicated that their houses were more comfortable: 93% (n=272) stated that it was more comfortable during summer and 88% (n=257) during winter.

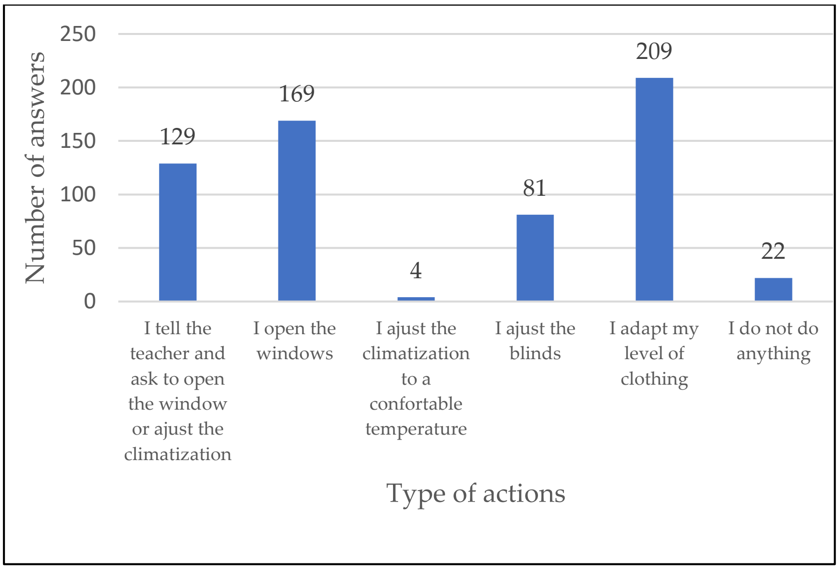


Figure 6.14: NRS students' answers to the question "When the temperature in classroom is not comfortable, I…"

The second most frequent answer was students expressing that there were not comfortable either at school or at home, with 4.1% (n=12) answering it during summer and 5.2% (n=15) during winter. Nevertheless, and as observed in the sample of students from the renovated school, when the number of students who indicated feeling uncomfortable at home and uncomfortable at school, the numbers were slightly higher: 40 (14%) students were uncomfortable in both places during summer and 41 during winter (14%).

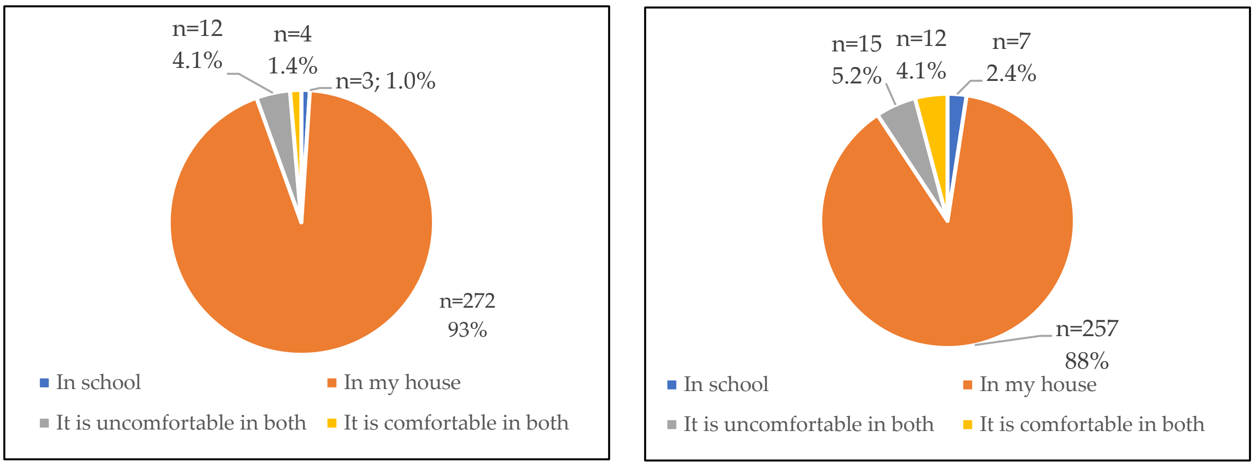


Figure 6.15: Students from NRS answers to the question "In the warmer months, the temperature is more comfortable: " (left) and "In the colder months, the temperature is more comfortable:" (right)

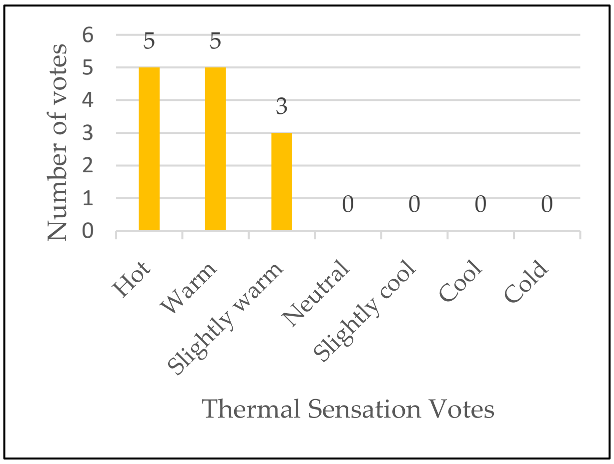
In the open-ended question, 44 students gave their opinion regarding energy poverty and thermal comfort in schools. Among these, 20 opinions were regarding the climatization systems and the lack of them, six opinions expressed and reinforced the students' discomfort in school, and 18 opinions were on the impact of the classroom's temperature. In the comments regarding the climatization systems, the students expressed how they like the classrooms to have air conditioning and how they thought that equipment would Improve their comfort. Some students also described problems with the blinds, windows, or with heaters presented in some classrooms, for example: *"The blinds in our school let a lot of light through, and with that light and heat it fills the room, and sometimes some teachers don't let or don't want to open windows or doors because of noise and in the winter when some rooms (I don't know if they all have them) have heaters I don't know why they don't turn on, I don't know if it's my teachers or if it has already happened, heaters don't work, but sometimes we are all cold in the room, and they can't heat it."* (Other, 15 years Old, 10th grade).

On the comments reinforcing the classroom conditions, the students comment on how their classroom is too hot during summer and/or cold during winter. Some students commented on how some classrooms or spaces are particularly discomfortable, for example: *"I just wanted to mention that in laboratories the temperature of the rooms is unbearable in winter. You can't stay warm and consequently the absorption of information is very low, if not null."* (Male, 17 years Old, 11th grade). The students also detailed how the classrooms' temperature affects their health or their well-being and performance in school, for example: *"Last winter, I had "chilblains" on my fingers due to the very low temperatures in the classroom."* (Female, 17 years old, 12th grade);*" I can't breathe in classrooms during the summer"* (Male, 16 years old, 11th grade); "*The fact that the classrooms were very hot led to me having an atonic seizure*" (Female, 16 years old, 11th grade).

Only a student directly mentioned the impact of her home's conditioning on her comfort levels, indicating discomfort at home and school. This statement suggests that some students may experience a persistent lack of thermal comfort:*" It's terrible to be in the winter at school in a horrible freeze, and the heater either does not turn on or, if it does, it does not reach everyone, only those who are near it! At home, the nights are the most complicated and often prevent me from sleeping because it's either very cold and I can't even keep warm with many blankets and several layers on, or it's so hot that even leaving the window half open to receive the night air does not help me from sweating."* (Female, 18 years Old, 12th grade).

6.1.2.3 Teachers' Surveys

The teachers' survey obtained 13 answers, expressing their perception on the thermal comfort inside classroom, its impact and if they led students. Regarding the thermal sensation in classroom (Figure 6.16), the results for summer indicated that 76% of the respondents feel discomfort, where 5 (38%) rated their thermal sensation as "Hot" and 5 (38%) rated their it as "warm". A similar trend was observed during winter, where 6 teachers rated their thermal sensation as "Cold" and 5 (38%) as "cool", resulting in a level of discomfort of 85%. All the teachers agreed that the temperature in classroom is a factor that may Impar students' attention in class and their performance during tests. 9 teachers (70%) indicated that the thermal discomfort is detrimental to their performance as teachers. Most teachers (n=12, 92%) indicated that they allow their students to operate the windows.



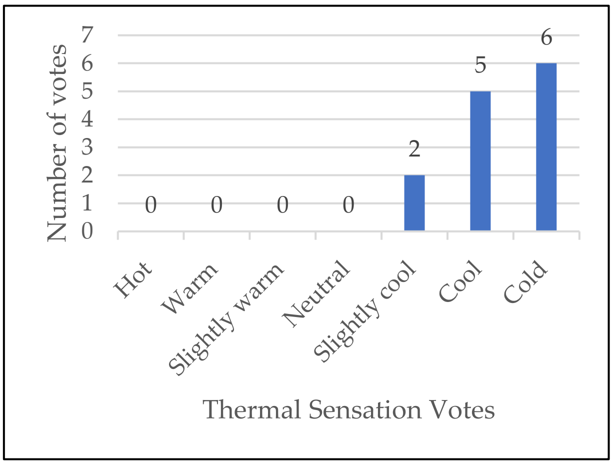


Figure 6.16: Thermal sensation voted during summer (left) and winter (right) from teachers from NRS.

Four teachers gave their opinion on the open-ended section of the survey and all the comments were related with the lack of thermal comfort lived inside classroom. For example, one of the teachers stated: "*It has been my experience, over 40 years of teaching, that when the temperatures are either too hot or too cold, the teaching-learning process does not achieve a third of the proposed objectives. We could think about equipping classrooms with hybrid equipment, or ending the annual timetable earlier, for example in May, and having a week's break in January or February, as in France."*. Other teachers indicated the impact of the lack of thermal comfort on health: *"It is a struggle to teach classes, mostly lectures lasting 90 minutes each, in an environment that is "hostile" to teaching practice. Throughout the year, I face health problems with my airways, as well as hoarseness and sore throats/ears, which have an impact on my attendance."*

6.1.3 Mixed Students Sample

As mentioned in the methodology section, the sample of students collected in the two schools was merged with surveys collected in the university open day and in energy efficiency initiatives in secondary schools. This sample includes responses from 808 students, described in figure 6.17.

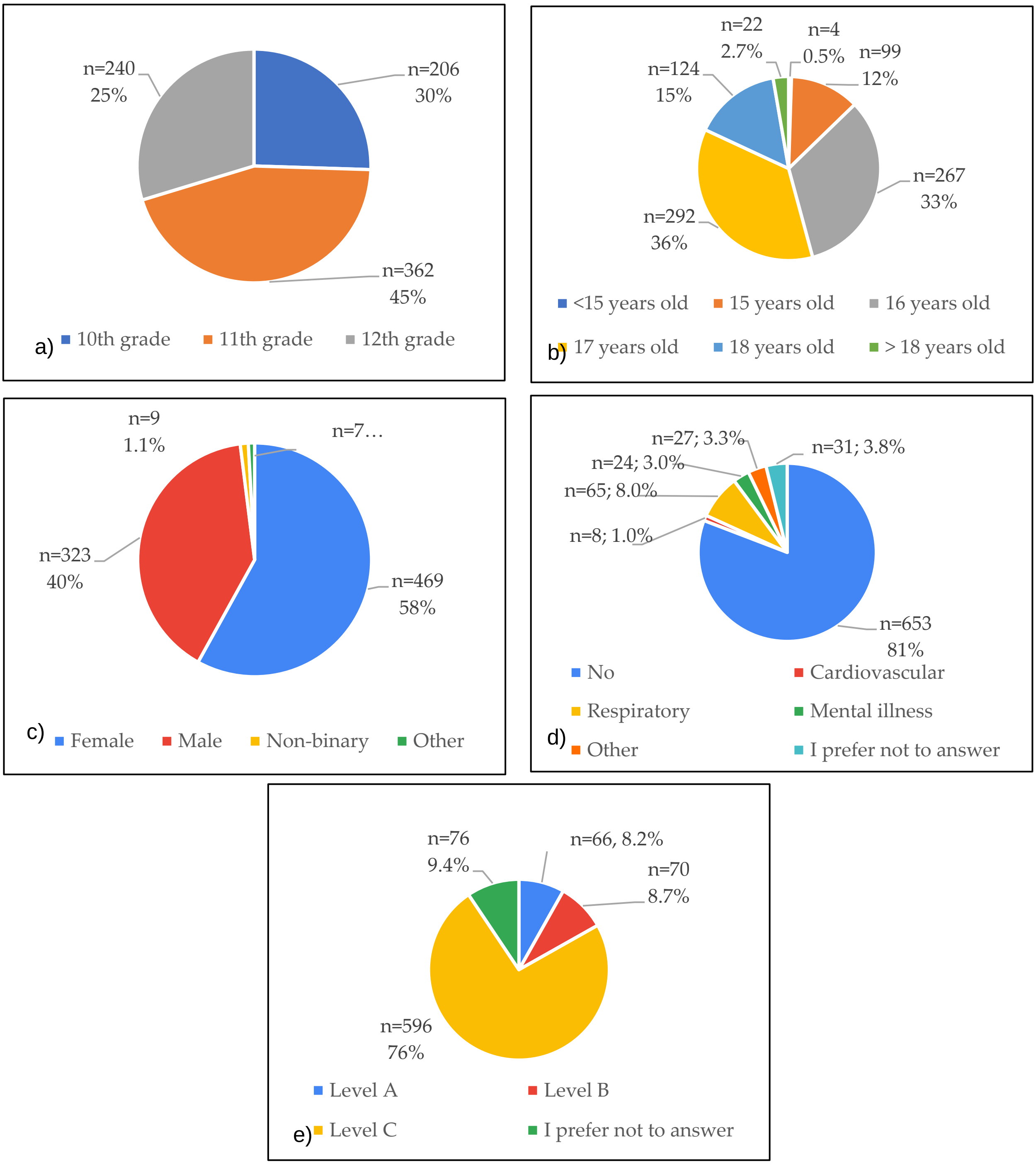


Figure 6.17: Sample Size from the mixed sample of students distributed by School grade (a), Age (b), Gender (c), Existence of health conditions (d) and School Social support level (e).

Most of the students were in 11th grade (n=240, 30%) and were 16 years old (n=267, 33%) and 17 years old (n=292, 36%). Regarding the gender, most of the students reported Identifying as female (n=469, 58%) and male (n=323, 40%). Most students had no chronic or disabling conditions (n=653, 81%) and were in level C of the school social support (n=596, 74%). Considering the students' perception of their comfort at home, curiously aproximatly the same amout of students reported discomfort during winter and summer: 147 students (18.2%) students reported feeling uncomfortable at home during summer and 148 students (18.3%) reported the same for the heating season, as indicated in Figure 6.18. 64 (7.9%) students reported feeling uncomfortable at home in both seasons.

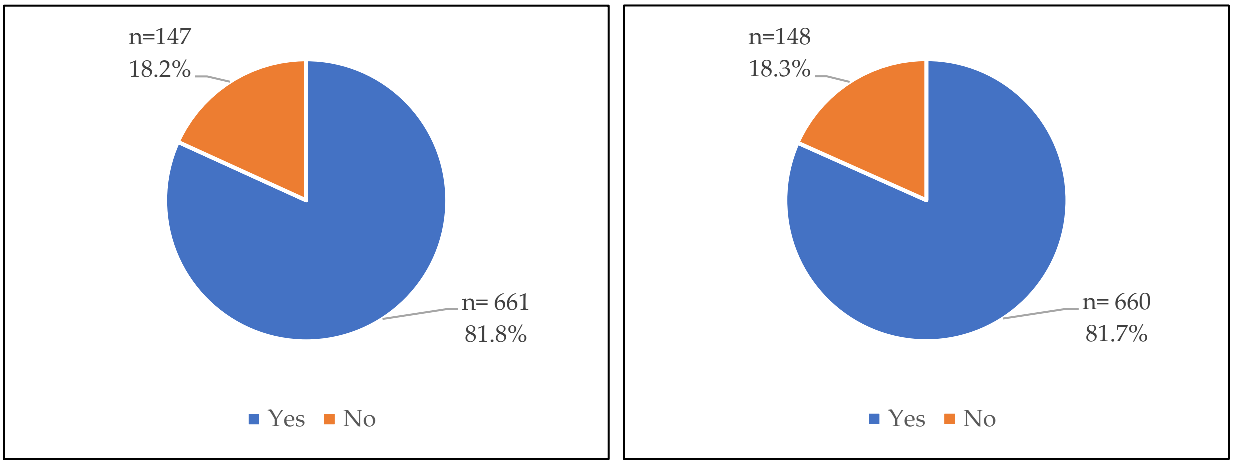


Figure 6.18: Answers from the mixed sample of students to the question "Is the temperature of your home comfortable during summer?" (left) and "Is the temperature of your home comfortable during winter?"

Looking into the students who reported feeling uncomfortable, it is possible to observe that students who identify as female and with certain conditions are more likely to report discomfort (table 6.1). In fact, girls were 1.3 times (CI 95%: 0.93-1.7) more likely to report discomfort during summer and 1.6 (CI 95%: 1.1-2.2) times more likely to report discomfort during winter. During summer, students with respiratory diseases are 1.8 time (CI 95%: 1.2-2.7) more likely to report discomfort and students with mental illness are 2.0 times (CI 95%: 1.1-3.6) more likely to report It. During winter, this trend is not observed as the number of students who reported feeling uncomfortable and reported having any chronic or disabling conditions and the ones who did not were close. However, students who reported having mental illnesses were 1.6 times (CI 95%: 0.83-3.0) more likely to report discomfort. Students who benefit from school social support were also more likely to report discomfort at home than the ones who do not: 1.64 times (CI 95%: 1.2-2.3) during summer and 1.46 times (CI 95%: 1.0-2.1) during winter.

Table 6.1: Prevalence of gender, self-reported health status, and School Social Support Level among students who reported discomfort at home.

Variable	Category	Discomfort summer			Discomfort winter		
		%	PR	CI (95%)	%	PR	CI (95%)
Gender	Female	20%	1.3	0.93-1.7	21%	1.6	1.1-2.2
	Male	15%	1	-	13%	1	-
Self-reported Health	Cardiovascu-lar	25%	1.5	0.45-5.0	13%	0.67	0.11-4.3
	Respiratory	29%	1.8	1.2-2.6	18%	1	0.58-1.7
	Mental	33%	2.0	1.1-3.6	29%	1.6	0.83-3.0
	No diseases	17%	1	-	19%	1	-
School social support level	A and B	26%	1.7	1.2-2.3	24%	1.5	1.0-2.1
	C	16%	1	-	17%	1	-

Legend: %: percentage face to the total; PR: prevalence ratio; CI (95%): confidence Interval with 95% confidence; -: not applicable

Looking into the students' use of equipment at home, 10% (n=78) reported using heating equipment, 17% (n=141) reported using no cooling equipment, and 3.8% (n=31) reported having either. The electric heater and the indoor fireplace were the most used equipment while, for cooling, most students reported having portable fans (Figure 6.19). 33 students reported not feeling comfortable at home during summer and not using any cooling equipment; 24 students reported not using comfortable during winter and not having any space heating equipment. Regarding the students' house conditions, 42% of students (n=336) reported having problems with mold or dampness in their dwellings.

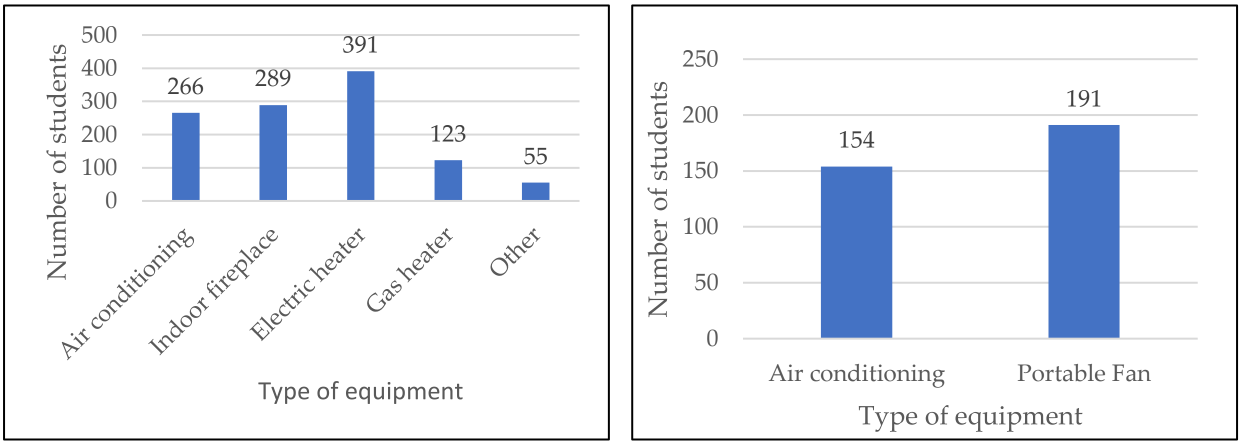
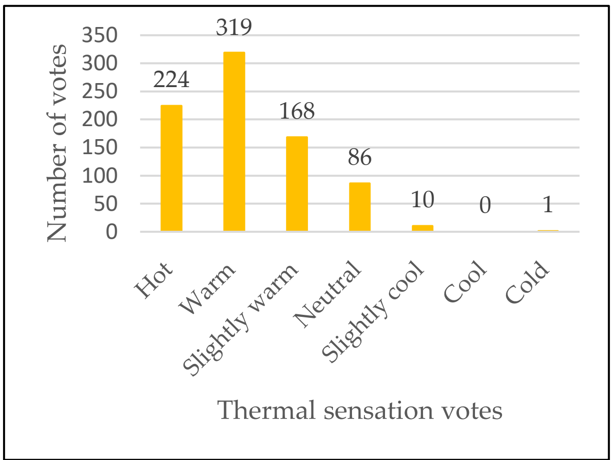


Figure 6.19: Type of space heating and space cooling equipment present in dwelling from the mixed sample students.

Looking into the students' comfort at school, the percentage of students who voted their comfort as "Hot", "Warm", "Cool" or "Cold" was 67% (n=544) during summer and 51% (n=409) during winter (Figure 6.20). During winter, 3% of students rated their thermal sensation as "Hot" or "Warm". The classroom's temperature is considered for 72% (n=580) an important factor for their attention in class and 66% (n= 530) as a factor that influences their academic achievement.



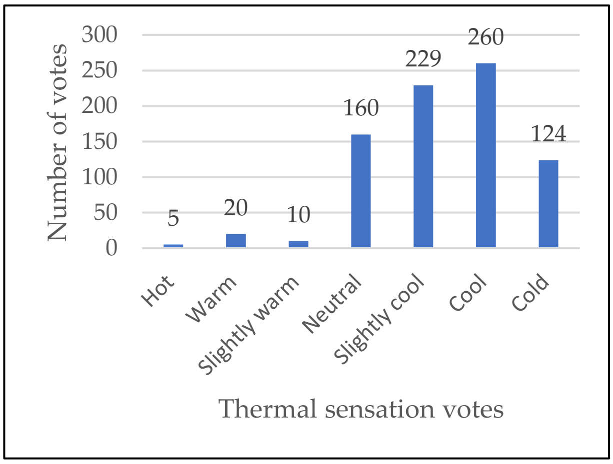


Figure 6.20: Thermal sensation votes during summer (left) and winter (right) from students by the mixed sample.

Analyzing the gender and self-reported mental state of students who reported feeling uncomfortable in the classroom, it is possible to identify certain patterns. Looking into gender, during summer, boys and girls reported approximately the same discomfort. Still, during winter boys reported feeling less discomfort than girls, as it was 1.4 times (CI 95%: 1.2-1.6) more likely for girls to report discomfort. Comparing the students who reported discomfort and had a chronic condition with the ones who did not, 79% of students who had mental Illness and 100% of students who had cardiovascular diseases reported discomfortable during summer, while 70% of students who did not have any diseases reported discomfort during summer. For winter, students with chronic conditions and healthy students reported approximately the same level of discomfort. All these results are described in Table 6.2. When asked about the frequency of use of certain types of garments in the classroom, expressed in Figure 6.21, students indicated that blankets and paper fans were the garments with less frequency, with only 11% and 13% of students indicating using it sometimes, respectively. Conversely, scarfs and jackets were indicated by students as garments with higher frequency of use as, for example, 43% of students indicating that they use jackets sometimes, and 47% indicating to use them often. The last question of the section regarding comfort at school asked students about their action when they feel uncomfortable (Figure 6.22). The results indicate that students act when they feel uncomfortable, as 430 students said they tell their teachers to open the window or ajust the climatization, and 369 indicated that they open the windows by themselves.

Table 6.2: Prevalence of gender and self-reported health status among students who reported discomfort in school.

Variable	Category	Discomfort summer			Discomfort winter		
		%	PR	CI (95%)	%	PR	CI (95%)
Gender	Female	69%	1.1	0.97-1.2	57%	1.4	1.2-1.6
	Male	64%	1	-	40%	1	-
Self-reported Health	Cardiovascular	100%	1.4	1.4-1.2	57%	0.72	0.29-1.8
	Respiratory	65%	0.93	0.77-1.1	52%	1.1	0.87-1.4
	Mental	79%	1.1	0.92-1.4	38%	0.93	0.64-1.4
	No diseases	70%	1	-	48%	1	-

Legend: %: percentage face to the total; PR: prevalence ratio; CI (95%): confidence Interval with 95% confidence; -: not applicable

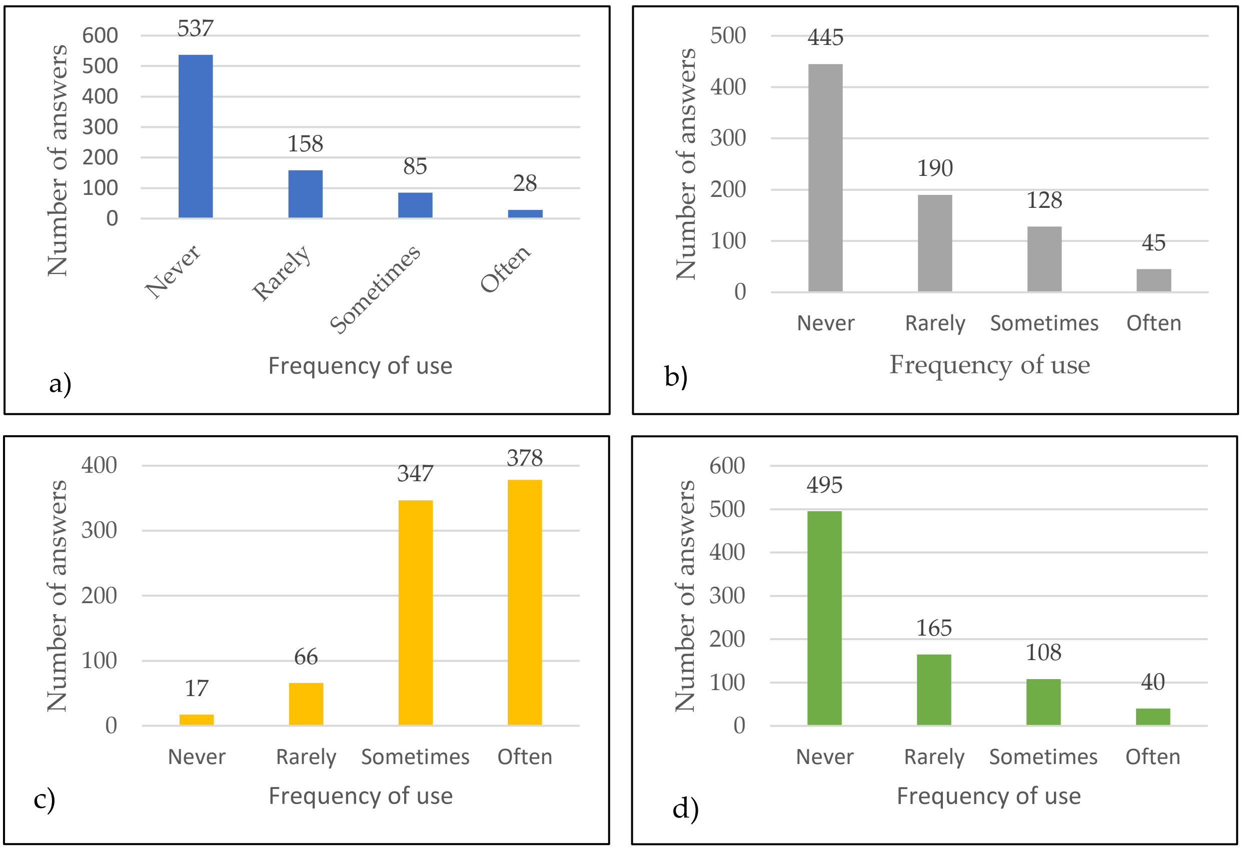


Figure 6.21: Frequency of use of blankets (a), scarfs (b), jackets (c), and paper fans (d) in classroom by students from the mixed sample.

the most selected action was to adjust the level of clothing, with 502 students indicating to take this action. Nevertheless, 10% of the students act passive when uncomfortable, since that percentage indicated not doing anything.

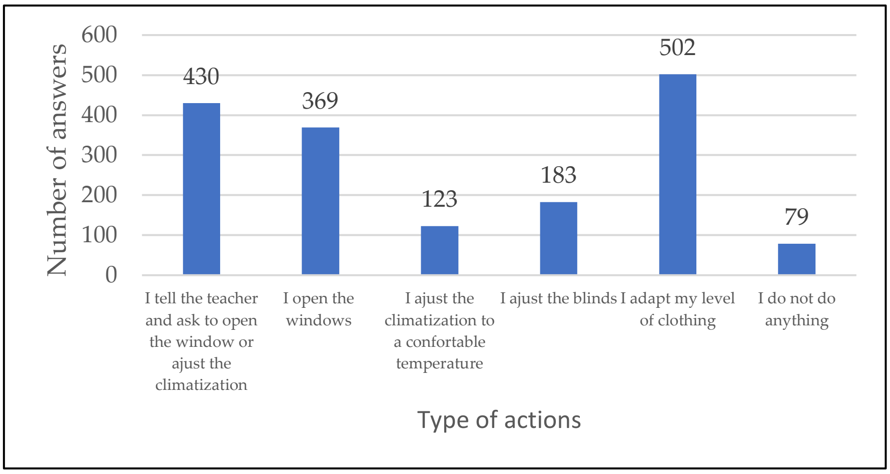
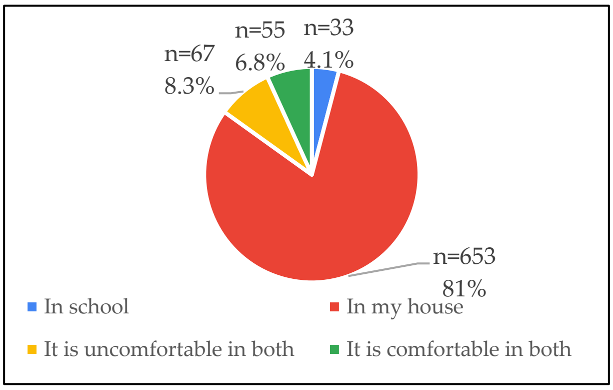


Figure 6.22: Students' answers to the question "When the temperature in classroom is not comfortable, I…"

The results from the last section of the survey (figure 6.23), comparing the thermal comfort at home with the one at school, unveil that some students are being exposed to permanent thermal discomfort: 8.3% of students (n=67) indicated that they were uncomfortable at both places during summer and 5% (n=40) reported the same for winter. However, a similar share of students reported feeling more comfortable at school than home, namely 4.1% (n=33) during summer and 4.5% (n=36) during winter. As indicated in the other subsections, the percentage of students in permanent discomfort was also calculated by couting the number of students who reported feeling uncomfortable at home in the energy poverty section and uncomfortable at school in the thermal comfort section. The results indicated higher percentages than those initially observed: 112 students (14%) reported experiencing discomfort in both sections during the summer, while 97 students (12%) reported similar discomfort during the winter.



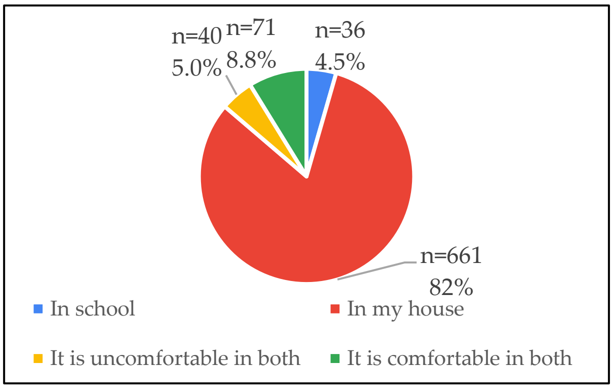


Figure 6.23: Students' answers to the question "In the warmer months, the temperature is more comfortable: " (left) and "In the colder months, the temperature is more comfortable:" (right)

Among the students who voted "It is uncomfortable in both places", no gender pattern was found, since the similar percentage of girls and boys reported it. However, among the students who reported discomfort, students with respiratory and mental illnesses were more likely to report it than the ones who self reported as healthy. All the results are presented in table 6.3.

Table 6.3: Prevalence of gender, self-reported health status and School Social Support Level among students who reported feeling uncomfortable in school and at home.

Variable	Category	Discomfort summer			Discomfort winter		
		%	PR	CI (95%)	%	PR	CI (95%)
Gender	Female	9%	1.0	0.64-1.6	5%	1.0	0.56-1.9
	Male	8%	1	-	5%	1	-
Self-reported Health	Cardiovascu-lar	0%	0.0	-	0%	0.00	-
	Respiratory	18%	2.4	1.4-4.3	6%	1.2	0.45-3.3
	Mental	13%	1.7	0.65-4.4	6%	1.3	0.32-5.1
	No diseases	8%	1	-	5%	1	-
School social support level	A and B	11%	1.4	0.79-2.4	8%	1.7	0.85-3.2
	C	8%	1	-	5%	1	-

Legend: %: percentage face to the total; PR: prevalence ratio; CI (95%): confidence Interval with 95% confidence; -: not applicable

The students left 84 comments in the open-ended section of the survey, where 47 were about the lack of climatization in their school or restriction in its use, 7 were about the impact of the thermal discomfort in their life, and 30 were statements reinforcing the lack of thermal comfort in their school. Most of the comments were already detailed In the other sections of the results and the comments added by the remaining sample of students pointed out malfunctioning climatization systems or the complete absence of such systems. Furthermore, two students reported that, other than not being allowed to utilize the climatization in the classroom, they could not bring blankets to cope with the thermal discomfort.

7
DISCUSSION

7.1 Comparison Between the Two Schools

In this subsection, the results obtained for both schools (renovated and non-renovated) are compared in terms of differences in terms of energy poverty, thermal comfort in the school, and the impact of renovation on students' comfort.

7.1.1 Energy Poverty

The two schools reported similar levels on the questions from the energy poverty section. During summer, 15% (NRS) and 21% (RS) considered that their house was not comfortable during summer, and 17% (NRS) and 19% (RS) during winter. The heating equipment use was higher in students from the NRS, but these students used less equipment for cooling than the students from the RS. These differences highlight the importance of studying energy poverty at the local level, even in seemingly similar regions. Nevertheless, it was not straightforward why students from the renovated school reported more discomfort, as it was initially expected that the opposite would be true. In Alenquer, the population had a lower salary, the buildings had a lower energy performance, and Alenquer has a higher vulnerability to energy poverty in the EPVI (Gouveia *et al.*, 2019).

Nevertheless, the Vila Franca de Xira municipality has a higher employment rate, and the temperatures are slightly higher, which may explain why these students reported more discomfort at home. The fact that the heating season has a longer duration in the non-renovated school may be related to the fact that these students reported more discomfort at home during winter. On the opposite, the renovated school is in the V_3 summer climatic zone, a region with higher temperatures, which explains why these students reported more discomfort at home during summer.

7.1.2 Thermal Comfort at School

The students from the two schools exhibited disparate levels of discomfort, as expected, given the variations in the construction characteristics of the respective buildings. The school that had not undergone renovation, characterized by the prevalent use of simple-glazed windows and malfunctioning blinds, reported higher levels of discomfort compared to the renovated school. However, even in the renovated school, the observed level of discomfort exceeded expectations. It was anticipated that after renovation, the level of discomfort would align closely with the thermal comfort standards, with an anticipated value of around 10%. However, higher values were observed, with 52% of students reporting discomfort during summer and 39% during winter. This high level of discomfort can be attributed to multiple factors, and it is challenging to attribute it to a single explanation. One contributing factor may be the malfunctioning climatization equipment in some classrooms. As per the renovation process by Parque Escolar, the responsibility for repairing the climatization systems lies with the organization itself, limiting the schools' independence in addressing these issues. The bureaucratic nature of this process may result in delays, thereby causing discomfort among students. Another factor is the potential restriction on using climatization systems or inadequate knowledge of their proper operation by teachers. This assumption is supported by the finding that 4.8% of students classified the temperature as "hot" or "warm" during winter. Variations in the location of classrooms may also contribute to differential levels of discomfort, as specific classrooms receive varying degrees of sunlight exposure.

Additionally, the size and weight of the windows can influence discomfort levels. In the classrooms under consideration, the windows are large. Still, only a small portion is operable, leading to limited natural ventilation and accumulated stagnant classroom air, thereby contributing to discomfort. It is also important to emphasize that the discomfort experienced by the non-renovated school students is more severe than that felt by the renovated school students. Among the students who reported discomfort, most of them rated their thermal sensation on the extreme end of the scale.

The disparities in comfort levels between the two schools were further evident through the frequency of garment usage. Students attending the non-renovated school reported a higher frequency of utilizing blankets, jackets, scarves, and paper fans. This indicates their need for additional external measures to address the discomfort they experience. In contrast, students from the renovated school relied less on such garments. The observed differences in comfort levels between the two schools also translated into variations in behavioral responses among the students. Those attending the non-renovated school reported engaging in more behavior-related actions compared to active actions. One common detail about the two schools was that the level of discomfort was higher during summer than in winter. 8% of the surveyed students from the NRS and 10% from the RS reported not doing anything when they feel uncomfortable, which was lower than the ones obtained in other studies. De Dear *et al*. (2018) reported that 30% of students do not act when they feel uncomfortable.

7.1.3 Impact of Renovation in Thermal Comfort

Analyzing the results from the final section of the survey reveals several noteworthy observations. Students from the non-renovated school experienced more discomfort during winter. In contrast, students from the renovated school faced more discomfort during summer, a trend also observed in the energy poverty section. The key distinction between these two groups of students appears to be related to those who reported feeling more comfortable at school, at home, or in both places, as the percentage of students indicating discomfort in both locations was relatively similar. In fact, the renovation of the school provides another vision for this Issue. Looking into the students who reported feeling uncomfortable during summer, the students from the NRS were 1.6 times (CI 95%: 1.5-1.8) more likely to report being uncomfortable at school than the ones from the renovated school. During winter, this frequency was 1.6 times higher (CI 95%: 1.3-1.8). Other than that, the number of students who indicated feeling more comfortable at school summed with the number of students who indicated feeling comfortable in both places was three times higher (CI 95%: 1.8-4.9) in the renovated school during winter and almost eight times higher (CI 95%: 3.8-17) during summer.

One of the potential implications of this study is that schools that provide thermal comfort conditions may serve as a refuge for students experiencing energy poverty at home, thereby mitigating its negative impacts. Energy poverty can have significant adverse effects on students, including feelings of stigma and isolation. These feelings may arise from a reluctance to invite friends to their homes due to shame about their living conditions. This can lead to increased isolation and negative mental health outcomes. Additionally, poor dwelling conditions can negatively impact students' productivity and academic performance. By providing a comfortable environment where students can socialize and study outside of regular school hours, schools can offer an alternative to spending time at home until conditions improve. Nevertheless, it is noteworthy that the provision of a conducive environment in which students can experience comfort has the potential to alleviate pre-existing health conditions. In accordance with this perspective, a school that ensures thermal comfort for teachers and students is highly likely to instill motivation among students from disadvantaged backgrounds and offer them stimulation and opportunities that may be lacking in their home environments. This, in turn, presents a potential avenue for escaping from cycle of energy poverty vulnerability.

7.1.4 Teachers' Surveys Results

The findings from the teachers' surveys complement the students' responses and provide valuable insights into their relationship with the classroom environment. Notable differences emerged between the two schools: in the renovated school, teachers reported significantly lower levels of discomfort compared to the students, whereas in the non-renovated school, the results were more closely aligned. This discrepancy may be attributed to the fact that classroom temperatures in the renovated school might be tailored to the teachers' preferences rather than the students', resulting in discomfort for the latter. Teachers face the dilemma of trying to regulate the temperature to suit every student's needs, often leading them to maintain a temperature they find comfortable. However, this approach might not align with the students' thermal preferences due to age and thermal sensitivity differences.

Interestingly, the students appear to have the liberty to operate the windows in the classroom, with a significant percentage (ranging from 85% to 92%) of teachers reporting that they allow the students to control the windows. Moreover, the teachers from the non-renovated school permit students to operate the climate control system more frequently than those from the renovated school. This is likely due to the renovated school's newer and more complex climate control system, while the non-renovated school relies mainly on electric heaters. Nonetheless, it is crucial to interpret the results from the teachers' surveys cautiously, as the number of responses might not be statistically significant compared to the total number of teachers in each school.

7.2 Results from the Mixed Sample of Students

In this sub-section, the results obtained for the sample of students at the national level are discussed. They are divided in terms of energy poverty, thermal comfort at school, and students' double vulnerability.

7.2.1 Energy poverty

Three indicators can be used to assess these students' vulnerability to energy poverty: the percentage of students reporting discomfort, the percentage of students indicating they have mold or dampness in their dwellings and the equipment ownership. On average, 18% of students do not feel comfortable at home during summer and during winter. Comparing to the fact that, in 2021, the number of households that in Portugal cannot keep their houses adequately warm was 16.4% (EPAH, 2023a), which was slightly lower than the ones obtained in this study. Nevertheless, the results were much lower than the ones obtain for Lisbon municipality by Lisboa e-nova (42% of respondents could not keep their home warm during summer and 32% during winter) (Lisboa E-Nova & AdE-PORTO, 2022). They were also lower than the ones obtained by Castro & Gouveia (2023) on a study on university studentsin a research involving university students. In this study, it was revealed that 66% of local Portuguese students and 77% of exchange students studying in Portugal experienced discomfort during the winter season. Similarly, 51% of local Portuguese students and 54% of exchange students studying in Portugal expressed discomfort during the summer months. Comparing directly with the indicator "Population Living in dwelling with presence of leak, damp and rot" with the percentage of students reporting having problems with dampness and mold in their dwellings, the results were higher since, in 2020, 25.2% of the Portuguese population were reporting it (EPAH, 2023a). The were lower than the ones obtained by Castro & Gouveia (2023), where 51-52% of the students in Portugal reported having this issue in their dwellings. Looking Into the ownership of equipment in the students' homes, 10% of students reported not having heating equipment, 17% reported having no cooling equipment and 3.8% of students don't have any equipment. These numbers differ from the ones obtained at the Survey on Energy Consumption in Households (DGEG & INE, 2020) (18.4% don't have for heating and 67,3% don't have for cooling) but the trend observed of lower cooling equipment ownership is still observed. The type of equipment reported is also consistent with the results obtained from other studies (DGEG & INE, 2020; Castro & Gouveia, 2023), since the main reported equipment were electric heater for heating and portable fan for cooling. Indoor fireplaces were also frequent, related to the fact that the population obtains biomass for free or at a lower price (Palma *et al*., 2022; Stojilovska *et al.*, 2023). It is also important to note that 22% of students who reported not feeling comfortable at home during summer have equipment at home and 16% for winter. Several explanations can be provided to this fact: it may be a matter of income where, since the reported equipment are inefficient, aligned with a low energy efficiency of the dwelling, the households may not keep the equipment turned on long enough to obtain significant thermal comfort. Another plausible explanation is the fact that the existence of the equipment does not mean that it is being used, this is especially true for air conditioning systems, as also reported by Gouveia *et al*. (2018).

The income question is supported by the fact that students with school social support level A or B were 1.6 (CI 95%: 1.2-2.3) times more likely to report discomfort during summer and 1.5 (CI 95%: 1.0-2.1) times more likely to report discomfort during winter. Hence, students have shown us that energy poverty is an issue related to gender and health issues, as also demonstrated in studies performed with younger and older populations: looking at the thermal comfort at home, the students that identified as female had a 1.3 or 1.6 higher chances of reporting discomfort at home than the ones who identified as male, depending on the season. Despite the higher values of discomfort reported by girls, this percentage was not as high as observed in other studies in older populations, suggesting that the difference between genders is only notable in older ages. The same phenomenon was observed in students who reported any chronic or disabling health condition: students who reported having mental illness had a higher chance of reporting discomfort at school.

7.2.2 Thermal comfort at school

Regardless of the school, students reported feelings uncomfortable during both summer and winter: 67% during summer and 51% during winter. The percentage of students who reported feeling uncomfortable were higher than the ones obtained in the others studies that evaluated the student's perception in Portugal: In a different methodology, Pereira *et al*. (2014) studied the thermal comfort on a Portuguese secondary school in Beja during mid-season and performed a survey regarding the thermal sensation in that day (T= 22.1 ºC and 25.2ºC) and two classrooms were assessed. Most of the students stated their comfort around the three central answers (slightly cold, neutral, and cold), where only in one of the classrooms showed discomfort (5% of the students reported feeling warm). Nevertheless, these studies can now be directly compared since they asked for the students' thermal sensation on one specific day and the results presented here concerned the whole year. Using a different thermal comfort scale (raging from comfortable to very uncomfortable), students from a secondary school in Guimarães rated mainly their thermal comfort as comfortable (61%) or slightly uncomfortable (23%) (Saraiva *et al*., 2018).

Looking into other thermal comfort studies in schools in other Mediterranean countries, the report of discomfort was, on average, lower than the one observed in this study. In Italy, in four secondary schools, the level of discomfort during winter varied from 10% to 62% (Corgnati *et al*., 2007). In a secondary school in Cyprus, when asked about how they feel in school during winter, 43,35% of students reported feeling uncomfortable, and 43,34% felt uncomfortable during summer (Katafygiotou and Serghides, 2014). In Greece, a study in a secondary school during winter reported a level of discomfort of 15.8% (Papazoglou *et al*., 2019).

Students from this sample were from different locations of the country and different schools, so it is difficult to provide one explanation to this discomfort. Schools that have not been renovated are old and have problems with the blinds of the doors, which prevents the use of natural systems. In renovated schools, the discomfort may be associated with the lack or impediment of the use of equipment. The renovation of the school was also associated with the enlargement of the size of windows and area of glazed windows, reduction of the windows opening span and the placement of windows in inaccessible locations, which was observed in this study (Figure 5.4) and pointed by Lourenço *et al*. (2014).

One of them might be the fact that the classrooms' temperature is being mold by the teachers' preferences and not the students' one. Children and young people have more sensibility to temperatures, so molding the temperature to the teachers' preferences interfere with the students' well-being. This was also observed in other studies in younger populations (Teli *et al*., 2012). The fact that students reporting less discomfort in classroom during winter may be related with the fact that students prefer cooler environments and report more discomfort in warmer conditions, which was also reported by several thermal comfort studies in schools (Zomorodian *et al*., 2014).

Looking into trends for reporting discomfort at schools, girls reported more discomfort than boys namely 1.05 more during summer and 1.04 during winter, meaning that the gender difference was not so evidence as it was at home. The same phenomenon was observed when crossing the reported health condition with the thermal discomfort: the difference between students who reported being healthy and reported having any chronic or disabling condition was closer. Analyzing the action when uncomfortable, students seem to not act as passive when they feel uncomfortable: the most reported action was to ask the teacher to open the window or adjust the climatization. Nevertheless, 9% of the surveyed students reported not doing anything when they feel uncomfortable, which is a number that should be considered. This number was lower than the ones obtained in other studies, for example, De Dear *et al*. (2018) reported that 30% of students do not act when they feel uncomfortable.

7.2.3 Double vulnerability

Aligned with the objectives of this study, it can be asserted that, for a portion of the secondary education students population surveyed, enduring thermal discomfort is a prevailing reality.

Within the survey section evaluating double vulnerability, 8.3% of students indicated discomfort both in school and at home during summer and 5% during winter. However, it is plausible that the actual number of students experiencing perpetual discomfort may be higher. This assumption is based on the intersection of different survey sections, where the percentage of students reporting discomfort at home and school amounts to 14% during summer and 12% during winter. No discernible gender patterns were identified among students reporting discomfort. Nevertheless, correlations emerged between reporting discomfort and the presence of chronic or disabling conditions, specifically among students reporting respiratory or mental conditions. The frequency of such reports was higher during summer. Additionally, students benefiting from school social support reported higher levels of discomfort compared to those who did not, with ratios of 1.4 in summer and 1.7 in winter. These findings correspond with prior research on the relationship between health and discomfort reporting while shedding new light on the issue. Considering the exacerbating effects of poor housing conditions on pre-existing health conditions, it can be extrapolated that if a school building fails to provide thermal comfort, such exacerbation will likely manifest. Moreover, young individuals from disadvantaged backgrounds often encounter reduced levels of stimulation and lower academic expectations (Cassio *et al.*, 2021). Consequently, if a school fails to provide an environment that fosters stimulation and motivation, these aspects can be further exacerbated.

8

CONCLUSION, LIMITATIONS AND FURTHER WORK

This dissertation aimed to investigate how young people aged 15 to 18 perceive energy poverty in their homes and thermal comfort at school. Over recent years, energy poverty has gained prominence on the political agenda, and Portugal, being one of the European countries with the highest energy poverty rates, assumes a critical role in tackling this issue. The significance of Portugal's involvement in this matter is further underscored by the vulnerability of young people to energy poverty and by considering that this age group individuals spend a substantial amount of time in school buildings, many of which have inadequate energy performance due to their age and limited renovations. Considering this study's objectives, it was concluded that 18% of young people experience a lack of thermal comfort in their homes, while over half face discomfort in the classroom, and 7 to 14% endure permanent discomfort.

Renovating schools (and homes) is a solution to alleviate this situation, as, in this study, students in the renovated schools reported less discomfort. Examining the perspective of other school stakeholders reveals that addressing this issue still has a long way to go. However, the process should consider the unique characteristics of each school and region, as diverse situations were observed across different educational institutions. This emphasizes the importance of involving all stakeholders in the discussion and formulating tailored, localized regulations for each school to ensure the comfort of both teachers and students in these environments. Another significant finding from this study is that, even within an already vulnerable group, specific student characteristics contribute to varying levels of discomfort. Particularly, students with chronic or debilitating diseases and those from less favorable socioeconomic backgrounds reported experiencing more discomfort compared to others. The conditions in which a child lives and grows up play a crucial role in shaping their success in adulthood. It is crucial to consider that growing up in conditions where they are never comfortable could have lasting impacts on future generations. Thus, this highlights the urgency of addressing these disparities and creating environments where all young individuals can thrive and find comfort.

The upcoming years will play a crucial role in addressing this problem, and several proposed measures aim to mitigate its impact. Firstly, at the energy poverty level, it is imperative to target these younger age groups in energy poverty policies. Presently, policies often overlook specific vulnerable groups (e.g., elderly, children, disabled, etc.) and their specific needs and none of the existing energy poverty proxy indicators accounts for young people. To rectify this, indicators such as "% of households with young people aged 18 and under" and "Poverty risk rate by age group (under 18)" should be incorporated into energy poverty risk mapping. Future nationwide studies must consider the perspectives of young people, creating indicators that capture their views on energy poverty and energy literacy. Engaging young individuals in policy-making processes is equally vital, especially at the local level. This can be achieved by empowering them to lead youth-driven projects within their communities, attentively listening to their experiences and insights, and encouraging them to become proactive agents of change. By involving young people in these efforts, we can make significant progress towards effectively addressing energy poverty.

Regarding thermal comfort in schools, a clear and effective solution to this issue involves renovating and closely monitoring the condition and maintenance of all school buildings. Priority should be given to renovating the oldest and most poorly maintained schools. In any new renovation project, particular emphasis should be placed on thermal comfort as a key consideration. The schools design should prioritize the use of passive strategies Instead of depending on climatization. To achieve that, the design of windows and glazed areas should be tailored to the needs of the school's occupants, ensuring that students and staff can easily handle them. To achieve this, construction designs that hinder operation, such as very heavy windows or non-opening glazed openings, should be avoided. It is also essential to implement the monitoring program contemplated in the modernization program to ensure the proper functioning of air conditioning systems and maintain the comfort of the students without compromise. Other than the renovation, behavioral measures can also be considered. For instance, adapting school timetables to the seasons, like starting classes earlier during the summer period to avoid peak temperatures and starting later during winter, can be a practical approach to improve indoor thermal comfort,

Changing the way we perceive school buildings could also be a way of tackling energy poverty. For instance, one of the objectives of Parque Escolar in the renovation program was to make school buildings accessible to the community during non-school periods. Implementing this plan and opening schools to communities can help alleviate the inadequate conditions experienced by some at home. This highlights the vital role of schools in the fight against energy poverty and offers a fresh approach to the issue. By providing spaces where students can socialize and study outside of school hours, the impact of their living conditions on their growth can be diminished. By capitalizing on schools' openness to the community, they can also operate as local energy poverty alleviation office, working as one-stop-shops where families can get guidance on addressing energy poverty. Furthermore, school spaces can act as transition points for decarbonization efforts. Leveraging the ample unused roof space, schools can install solar photovoltaic panels and take part on neighborhood energy communities.

This study has its inherent limitations. Firstly, the surveys were conducted during mid-season when temperatures were moderate and not at extremes—neither too hot nor too cold. This thermal comfort level might have influenced the students' responses, potentially impacting the survey results. Secondly, the surveys received a higher number of responses from the Lisbon region, where the climate is less extreme compared to other regions in Portugal. As a result, this work paves the way for further research in this area. Future work should include school studies with representative samples across different regions and various types of schools (public, private, traditional, and vocational education).

Moreover, conducting surveys throughout the heating, cooling, and mid-season would provide a more comprehensive analysis of young people's context regarding energy poverty and thermal comfort at school (and at home). Supplementing these surveys with interviews would offer a qualitative perspective of young people's experiences. Furthermore, future research opportunities could involve expanding similar studies to other educational levels since the challenges of infrastructure renewal extend beyond the secondary educational level under consideration. Further work should also include more detailed measurement of the classrooms' temperature and outside temperature in several days, as in this study the measurements were took only in one day and using a digital thermometer. By addressing these limitations and exploring new avenues of research, we can gain a more comprehensive understanding of the complexities of energy poverty and its impact on young individuals.

Based on the findings of this study, it is important to emphasize that climate change and its extreme events will further intensify indoor thermal discomfort. Considering the discomfort observed during summer, climate change will exacerbate the heat island effect, and students are at risk of being more uncomfortable, impacting their health and academic performance. Consequently, taking decisive action to mitigate these effects is imperative, as it is key to ensuring comfort in residential and educational settings. Looking into the future, children and young people will bear with the climate change long-term impacts. By investing today in resilient infrastructure, we are creating a safe and sustainable future where every young individual can thrive, regardless of the challenges brought by climate change.

This work was partly presented at the 8th Meeting on Energy and Environmental Economics (Valente & Gouveia, 2023a) and the 29th International Sustainable Development Research Society Conference (Valente & Gouveia, 2023b).

9

REFERENCES

ADENE. (2023). *Estatística do Sistema de Certificação Energética dos Edifícios.* Agência para a Energia. https://www.sce.pt/estatisticas/. Accessed January 15, 2023.

Al-Khatri, H., Alwetaishi, M., & Gadi, M. B. (2020). Exploring thermal comfort experience and adaptive opportunities of female and male high school students. *Journal of Building Engineering, 31, 101365*. https://doi.org/10.1016/j.jobe.2020.101365

Antova, A. T., Pattenden, S., Brunekreef, B., Heinrich, J., Rudnai, P., Forastiere, F., Luttmann-Gibson H., Grize L., Katsnelson B., Moshammer H., Nikiforov B., Slachtova, H., Slotova, K., Zlotkowska, R., Fletcher, T. & Nikiforov, B. (2008). Exposure to indoor mould and children's respiratory health in the PATY study. *J Epidemiol Community Health, 62 (8), 708–715*. doi: 10.1136/jech.2007.065896.

ASHRAE. (2010). *Thermal Environmental Conditions for Human Occupancy.* American Society of Heating, Refrigerating and Air-Conditioning Engineers. http://arco-hvac.ir/wp-content/uploads/2015/11/ASHRAE-55-2010.pdf

ASHRAE. (No Data). *Standard 55 – Thermal Environmental Conditions For Human Occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers. https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy. Accessed February 20 2023.

Auffhammer, M., & Mansur, E. T. (2014). Measuring climatic impacts on energy consumption: A review of the empirical literature. *Energy Economics, 46, 522–530.* https://doi.org/10.1016/j.eneco.2014.04.017

Bakó-biró, Z., Clements-croome, D. J., Kochhar, N., Awbi, H. B., & Williams, M. J. (2012). Ventilation rates in schools and pupils ' performance. *Building and Environment*, *48*, 215–223. https://doi.org/10.1016/j.buildenv.2011.08.018

Bartiaux, F., Day, R., & Lahaye, W. (2021). Energy poverty as a restriction of multiple capabilities: A systemic approach for Belgium. *Journal of Human Development and Capabilities, 22, 1–22.* https://doi.org/10.1080/19452829.2021.1887107

Bartiaux, F., Vandeschrick, C., Moezzi, M., & Frogneux, N. (2018). Energy justice, unequal access to affordable warmth, and capability deprivation: A quantitative analysis for Belgium. *Applied Energy, 225, 1219–1233.* https://doi.org/10.1016/j.apenergy.2018.04.113

Bernardo, H., Antunes, C. H., Gaspar, A., Pereira, L. D., & da Silva, M. G. (2017). An approach for energy performance and indoor climate assessment in a Portuguese school building. *Sustainable Cities and Society, 30, 184–194.* https://doi.org/10.1016/J.SCS.2016.12.014

Beusker, E., Stoy, C., & Pollalis, S. N. (2012). Estimation model and benchmarks for heating energy consumption of schools and sport facilities in Germany. *Building and Environment, 49(1), 324–335.* https://doi.org/10.1016/j.buildenv.2011.08.006

Bhattacharya, J., DeLeire, T., Haider, S. & Currie, J. (2003). Heat or Eat? Cold-Weather Shocks and Nutrition in Poor American Families. *Am. J. Public Health 93, 1149–1154.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447925/

Boardman, B. (2009). Fixing Fuel Poverty: Challenges and Solutions (1st ed.). Routledge. https://doi.org/10.4324/9781849774482

Bouzarovski, S. (2018). Energy Poverty Revisited. In: Energy Poverty. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-69299-9_1

Bouzarovski, S., & Petrova, S. (2015). Energy Research & Social Science A global perspective on domestic energy deprivation : Overcoming the energy poverty – fuel poverty binary. *Chemical Physics Letters*, *10*, 31–40. https://doi.org/10.1016/j.erss.2015.06.007

Brás, A., Rocha, A., & Faustino, P. (2015). Integrated approach for school buildings rehabilitation in a Portuguese city and analysis of suitable third party financing solutions in EU. *Journal of Building Engineering, 3, 79–93.* https://doi.org/10.1016/j.jobe.2015.05.003

Bridge, B. A., Adhikari, D., & Fontenla, M. (2016). Electricity, income, and quality of life. *Social Science Journal, 53(1), 33–39.* https://doi.org/10.1016/j.soscij.2014.12.009

Brown, H., & Vera-Toscano, E. (2021). Energy poverty and its relationship with health: empirical evidence on the dynamics of energy poverty and poor health in Australia. SN Business & Economics, 1(10). https://doi.org/10.1007/s43546-021-00149-3

Brychkov, D., Goggins, G., Doherty, E., Romero, N., Roudil, N., di Trani, A., Singh, A., Smit, S., McLoughlin, E., de Castro Rodrigues Lima, R., Günbay, S. M., Delmonte, B. A., Hill, A., Domegan, C., & Clifford, E. (2023). A systemic framework of energy efficiency in schools: experiences from six European countries. *Energy Efficiency, 16(4).* https://doi.org/10.1007/s12053-023-10099-4

Cassio, L., Blasko, Z., Szczepanikova, A., (2021). *Poverty and mindsets — How poverty and exclusion over generations affect aspirations, hope and decisions, and how to address it.* Publications Office of the European Union. doi:10.2760/453340, JRC124759

Castaño-rosa, R., Solís-guzmán, J., Rubio-Bellido, C., & Marrero, M. (2019). Towards a multiple-indicator approach to energy poverty in the European Union : A review. *Energy and Buildings, 193, 36–48.* https://doi.org/10.1016/j.enbuild.2019.03.039

Castro, C. C., & Gouveia, J. P. (2023). Students' perception of energy poverty—A comparative analysis between local and exchange university students from Montevideo, Lisbon, and Padua. *Frontiers in Sustainable Cities, 5.* https://doi.org/10.3389/frsc.2023.1114540

Charles, K.E. (2003). *Fanger's thermal comfort and draught models*. Publication from the National research Council Canada. https://doi.org/10.4224/20378865

Clark, I. K. H., Chun, S., O'sullivan, K. C., & Pierse, N. (2022). Energy poverty among tertiary students in aotearoa New Zealand. *Energies, 15(1).* https://doi.org/10.3390/en15010076

Commission Recommendation (EU) 2020/1563 of 14 October 2020 on energy poverty. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020H1563

Cook, P. (2011). Infrastructure, rural electrification and development. *Energy for Sustainable Development, 15(3), 304–313.* https://doi.org/10.1016/j.esd.2011.07.008

Corgnati, S. P., Filippi, M., & Viazzo, S. (2007). Perception of the thermal environment in high school and university classrooms: Subjective preferences and thermal comfort. *Building and Environment, 42(2), 951–959.* https://doi.org/10.1016/j.buildenv.2005.10.027

Daka, K. R., & Ballet, J. (2011). Children's education and home electrification: A case study in northwestern Madagascar. *Energy Policy, 39(5), 2866–2874.* https://doi.org/10.1016/j.enpol.2011.02.060

Day, R., & Hitchings, R. (2011). "Only old ladies would do that": Age stigma and older people's strategies for dealing with winter cold. *Health and Place, 17(4), 885–894.* https://doi.org/10.1016/j.healthplace.2011.04.011

De Dear, R., Kim, J., Candido, C., & Deuble, M. (2015). Adaptive thermal comfort in australian school classrooms. *Building Research and Information, 43(3), 383–398.* https://doi.org/10.1080/09613218.2015.991627

Decree-Law No. 101-D/2020, Dezember 7th 2020. Establishes requirements for buildings to improve their energy performance and regulates the Energy Certification System for

Buildings, transposing Directive (EU) 2018/844 and partially transposing Directive (EU) 2019/944.

Decree-Law No. 118/2013, August 20th 2013. Approves the Energy Certification System for Buildings, the Energy Performance Regulation for Residential Buildings and the Energy Performance Regulation for Commercial and Service Buildings, and transposes Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.

Decree-law No. 118/98, May 7th 1998. Regulates energy-saving air-conditioning systems in buildings.

Decree-Law No. 156/92, July 29th 1992. Approves the Regulation on the Quality of Energy Systems for Air Conditioning in Buildings

Decree-Law No. 40/90, February 6th 1990. Approves the Regulation on the Thermal Characteristics and Behaviour of Buildings.

Decree-Law No. 55/2009. Establishes the legal regime applicable to the allocation and operation of support within the scope of school social support.

Decree-law No. 78/2006, 4th April 2006. Approves the National System for Energy Certification and Indoor Air Quality in Buildings and partially transposes into national law Directive 2002/91/EC of the European Parliament and of the Council of 16 December on the energy performance of buildings.

Decree-Law No. 79/2006, 4th April. Approves the Regulation on Energy Systems for Air Conditioning in Buildings

Decree-Law No. 80/2006, April 4th 2006. Approves the Regulation of the Thermal Behaviour Characteristics of Buildings (RCCTE).

DGEG & INE. (2020). *Inquérito ao Consumo de Energia no Sector Doméstico – 2020.* Direção-Geral de Energia e Geologia & Instituto Nacional de Estatística. https://www.dgeg.gov.pt/media/jvfgkejh/dgeg-aou-icesd-2020.pdf

DGEG. (2023a). *Planos Nacionais para o Setor Energético: Plano Nacional de Energia e Clima 2030 (PNEC 2030).* https://www.dgeg.gov.pt/pt/areas-transversais/relacoes-internacionais/politica-energetica/planos-nacionais-para-o-setor-energetico/ Accessed March, 19, 2023

DGEG. (2023b). *Estratégia de Longo Prazo para a Renovação dos Edifícios de Portugal (ELPRE PT).* https://www.dgeg.gov.pt/pt/areas-transversais/relacoes-internacionais/politica-energetica/estrategia-de-longo-prazo-para-a-renovacao-dos-edificios-de-portugal-elpre-pt/. Accessed March, 19, 2023

DGEG. (2023c). *Consumo por município e setor de atividade.* Direção-Geral de Energia e Geologia https://www.dgeg.gov.pt/pt/estatistica/energia/eletricidade/consumo-por-municipio-e-setor-de-atividade/. Accessed February, 27, 2023

Dias Pereira, L., Neto, L., Bernardo, H., & Gameiro da Silva, M. (2017). An integrated approach on energy consumption and indoor environmental quality performance in six Portuguese secondary schools. *Energy Research and Social Science, 32, 23–43.* https://doi.org/10.1016/j.erss.2017.02.004

DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019L0944

DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU

DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU

Directive 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002 on the energy performance of buildings.

Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0072

Directive 2010/31/EU Of The European Parliament And Of The Council Of 19 May 2010 On The Energy Performance Of Buildings.

Directive 2018/844 Of The European Parliament And Of The Council Of 30 May 2018 Amending Directive 2010/31/EU On The Energy Performance Of Buildings And Directive 2012/27/EU On Energy Efficiency.

Djongyang, N., Tchinda, R., & Njomo, D. (2010). Thermal comfort: A review paper. *Renewable and Sustainable Energy Reviews 14 (9).* https://doi.org/10.1016/j.rser.2010.07.040

Dominianni, C., Lane, K., Johnson, S., Ito, K., & Matte, T. (2018). Health impacts of citywide and localized power outages in New York City. *Environmental Health Perspectives, 126(6).* https://doi.org/10.1289/EHP2154

Dorizas, P. V., Assimakopoulos, M. N., & Santamouris, M. (2015). A holistic approach for the assessment of the indoor environmental quality, student productivity, and energy consumption in primary schools. *Environmental Monitoring and Assessment, 187(5), 1–18.* https://doi.org/10.1007/s10661-015-4503-9

E.C. (2023). *Portugal: Organization and Governance-Organization of the education system and Its structure.* European Commission. https://eurydice.eacea.ec.europa.eu/national-education-systems/portugal/organisation-education-system-and-its-structure. Accessed May,19, 2023.

EC. (2022). *A study on smart, effective, and inclusive investment in education infrastructure.* European Comission https://parque-escolar.pt/docs/site/pt/empresa/Estudo%20Comiss%C3%A3o%20Europeia%20-%20Study-smart%20effective%20an%20inclusive%20investment%20in%20education%20infrastructure-final%20report.pdf

EC. (2023a). Energy poverty in the EU. European Commission. https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumer-rights/energy-poverty-eu_en. Accessed In March, 14, 2023

EC. (2023b). Renovation Wave. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en. Accessed In March, 17, 2023

Education And Skills Funding Agency (2016). *Guidelines on ventilation, thermal comfort and indoor air quality in schools.* https://consult.education.gov.uk/capital/bb101-school-design-iaq-comfort-and-ventilation/supporting_documents/DfE%20Ventilation%20guide%20consultation%20draft%2029%2006%202016.pdf

EPAH. (2022). *Introduction to the Energy Poverty Advisory Hub (EPAH) Handbooks: A Guide to Understanding and Addressing Energy Poverty. Energy Poverty Advisory Hub* https://energy-poverty.ec.europa.eu/system/files/2022-06/EPAH%20handbook_introduction.pdf

EPAH. (2023a). *National indicators. Energy Poverty Advisory Hub.* https://energy-poverty.ec.europa.eu/observing-energy-poverty/national-indicators_en. Accessed June, 26, 2023

EPAH. (2023b). Our vision in a nutshell. Energy Poverty Advisory Hub. https://energy-poverty.ec.europa.eu/about-us/vision-and-mission_en. Accessed March 17, 2023

ERSE. (2020). *Estudo de literacia dos consumidores na área da energia.* https://www.erse.pt/media/y23jkwk5/estudo-literacia-consumidores-energia.pdf

Ervin, J., Taouk, Y., Alfonzo, L. F., Hewitt, B., & King, T. (2022). Gender differences in the association between unpaid labour and mental health in employed adults: a systematic review. *The Lancet Public Health 7 (9) 775–786.* https://doi.org/10.1016/S2468-2667(22)00160-8

Estiri, H., & Zagheni, E. (2019). Age matters: Ageing and household energy demand in the United States. *Energy Research and Social Science, 55, 62–70.* https://doi.org/10.1016/j.erss.2019.05.006

European Parliament resolution of 17 December 2020 on the EU Security Union Strategy (2020/2791(RSP)). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020IP0378

Eurostat. (2023a). Ratio of pupils and students to teachers and academic staff by education level and programme orientation. https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_PERP04__custom_4874634/default/table?lang=en. Retrieved in February 2023.

Eurostat. (2023b). International Standard Classification of Education (ISCED). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_Standard_Classification_of_Education_(ISCED)#Implementation_of_ISCED_2011_.28levels_of_education.29. Retrieved in May 2023.

Eurydice. (2022). Compulsory education in Europe 2022/2023. European Union Publications. doi:10.2797/235076

Evans, J., Hyndman, S., Stewart-Brown, S., Smith, D., Petersen, S. (2000). An epidemiological study of the relative importance of damp housing in relation to adult health. *Journal of Epidemiology & Community Health 54(9). 677–686.* doi: 10.1136/jech.54.9.677

FA. (2023). *Apoio ao Programa "Vale Eficiência".* Fundo Ambiental https://www.fundoambiental.pt/plataforma-vales-de-eficiencia/documentacao/regulamento-pdf.aspx. Accessed March, 19, 2023

Farbotko, C. and Waitt, G. (2011), Residential air-conditioning and climate change: voices of the vulnerable. *Health Promotion Journal of Australia, 22: 13-15.* https://doi.org/10.1071/HE11413

Fato, I., Martellotta, F., & Chiancarella, C. (2004). Thermal comfort in the climatic conditions of southern Italy. *ASHRAE Transactions, 110 (2), 578–593.*

Gayoso Heredia, M., Sánchez-Guevara Sánchez, C., Núñez Peiró, M., Sanz Fernández, A., López-Bueno, J. A., & Muñoz Gómez, G. (2022). Mainstreaming a gender perspective into the study of energy poverty in the city of Madrid. *Energy for Sustainable Development, 70, 290–300.* https://doi.org/10.1016/J.ESD.2022.08.007

Gilbertson, J., Stevens, M., Stiell, B., & Thorogood, N. (2006). Home is where the hearth is: Grant recipients' views of England's Home Energy Efficiency Scheme (Warm Front). *Social Science and Medicine, 63(4), 946–956.* https://doi.org/10.1016/j.socscimed.2006.02.021

Gilbertson, J.; Grimsley, M. & Green, G. (2012). Psychosocial routes from housing investment to health: Evidence from England's home energy efficiency scheme. *Energy Policy 49, 122–133.* https://doi.org/10.1016/j.enpol.2012.01.053

Goodman, J., Hurwitz, M, Jisung, P., Smith, J. (2018). Heating and Learning. *American Economic Journal: Economic Policy, American Economic Association, 12(2) 306-339.* https://www.nber.org/papers/w24639

Gouveia, J. P., Palma, P., & Simoes, S. G. (2019). Energy poverty vulnerability index: A multi-dimensional tool to identify hotspots for local action. *Energy Reports, 5, 187–201.* https://doi.org/10.1016/j.egyr.2018.12.004

Gouveia, J. P., Seixas, J., & Long, G. (2018). Mining households' energy data to disclose fuel poverty: Lessons for Southern Europe. *Journal of Cleaner Production, 178, 534–550.* https://doi.org/10.1016/j.jclepro.2018.01.021

Harker, L. (2006). *Chance of a Lifetime: The Impact of Bad Housing on Children's Lives;* Shelter: London, UK. https://england.shelter.org.uk/professional_resources/policy_and_research/policy_library/chance_of_a_lifetime_-_the_impact_of_bad_housing_on_childrens_lives

Hensen, J. L. M. (1991*). On the thermal interaction of building structure and heating and ventilating system.* Phd thesis. Technische Universiteit Eindhoven. https://doi.org/10.6100/IR353263

Hinson, S. & Bolton, P. (2023) *Fuel Poverty*. Commons Library Research Briefing https://researchbriefings.files.parliament.uk/documents/CBP-8730/CBP-8730.pdf

Howden-Chapman P., Viggers H., Chapman R., O'Sullivan K., Telfar B. L. & Lloyd B. (2012). Tackling cold housing and fuel poverty in New Zealand: a review of policies, research, and health impacts. *Energy Policy, 49, 134–42.* https://doi.org/10.1016/j.enpol.2011.09.044

Howden-Chapman, P.; Matheson, A.; Crane, J.; Viggers, H.; Cunningham, M.; Blakely, T.; Cunningham, C.; Woodward, A.; Saville-Smith, K.; O'Dea, D.; Kennedy, M.; Baker, M.; Waipara, N.; Chapman, R. & Davie, G. (2007). Effect of insulating existing houses on health inequality: cluster randomised study in the community. *BMJ, 334(7591), 460–460.* https://doi.org/10.1136/bmj.39070.573032.80

Howieson, S.G., & Hogan, M. (2005). Multiple deprivation and excess winter deaths in Scotland. Journal of the Royal Society for the Promotion of Health125 (1) 2-48. https://doi.org/10.1177/146642400512500110

Howieson, S.G., & Hogan, M. (2005). Multiple deprivation and excess winter deaths in Scotland. *Journal of the Royal Society for the Promotion of Health, 125 (1) 2-48.* https://doi.org/10.1177/146642400512500110

IEA. (2021). *EN 15251:2007*. https://www.iea.org/policies/7029-en-152512007. Accessed February 19, 2023

IEA. 2018. *The future of cooling: opportunities for energy-efficient air conditioning.* International Energy Agency. https://iea.blob.core.windows.net/assets/0bb45525-277f-4c9c-8d0c-9c0cb5e7d525/The_Future_of_Cooling.pdf

IEA. 2023. CO2 emissions in 2022. International Energy Agency. https://iea.blob.core.windows.net/assets/3c8fa115-35c4-4474-b237-1b00424c8844/CO2Emissionsin2022.pdf

INE. (2023_a). *Base de dados*. Instituto Nacional de Estatística. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0011758&contexto=bd&selTab=tab2. Accessed April 20, 2023

INE. (2023_b). *Censos 2021 - Demografia*. Instituto Nacional de Estatística. https://censos.ine.pt/xportal/xmain?xpgid=censos21_populacao&xpid=CENSOS21. Accessed April 20, 2023

INE. (2023_c). *Censos 2021-Habitação.* Instituto Nacional de Estatística. https://censos.ine.pt/xportal/xmain?xpgid=censos21_habitacao&xpid=CENSOS21

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

ISO. (No Data). *ISO 7730:2005. Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.* https://www.iso.org/standard/39155.html. Accessed February, 20 2023.

Ivanova, D., & Middlemiss, L. (2021). Characterizing the energy use of disabled people in the European Union towards inclusion in the energy transition. *Nature Energy, 6(12), 1188–1197.* https://doi.org/10.1038/s41560-021-00932-4

Jessel, S., Sawyer, S., & Hernández, D. (2019). Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature. *Frontiers in Public Health 7.* https://doi.org/10.3389/fpubh.2019.00357

Jiglau, G., Bouzarovski, S., Dubois, U., Feenstra, M., Gouveia, J. P., Grossmann, K., Guyet, R., Herrero, S.T., Hesselman, M., Robic, S., Sareen, S., Sinea, A. & Thomson, H. (2023). Looking back to look forward: Reflections from networked research on energy poverty. *IScience, 26(3), 106083*. https://doi.org/10.1016/j.isci.2023.106083

Joint Research Center. (2003). *Indoor air pollution: new EU research reveals higher risks than previously thought.* https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_03_1278/IP_03_1278_EN.pdf

Jones, P.G., Turner, R.N., Browne, D.W.J. & Illingworth, P.J. (2000). *Energy Consumption for public sector buildings in northen Irland.* https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=be0a7cbe2c39b41433f67a3f068c534bd900e9cb

Kamp Dush, C. M., Yavorsky, J. E., & Schoppe-sullivan, S. J. (2018). What Are Men Doing While Women Perform Extra Unpaid Labor? Leisure and Specialization at the Transition to Parenthood. *Sex Roles, 78(11–12), 715–730.* https://doi.org/10.1007/s11199-017-0841-0

Katafygiotou, M. C., & Serghides, D. K. (2014). Thermal comfort of a typical secondary school building in Cyprus. *Sustainable Cities and Society, 13, 303–312.* https://doi.org/10.1016/j.scs.2014.03.004

Kim, J., & de Dear, R. (2018). Thermal comfort expectations and adaptive behavioural characteristics of primary and secondary school students. *Building and Environment, 127, 13–22.* https://doi.org/10.1016/j.buildenv.2017.10.031

Korsavi, S. S., & Montazami, A. (2020). Children's thermal comfort and adaptive behaviours; UK primary schools during non-heating and heating seasons. *Energy and Buildings, 214.* https://doi.org/10.1016/j.enbuild.2020.109857

Kose, T. (2019). Energy poverty and health: the Turkish case. *Energy Sources, Part B: Economics, Planning, and Policy, 1–13.* https://doi.org/10.1080/15567249.2019.1653406

Lan, L., Lian, Z., & Pan, L. (2010). The effects of air temperature on office workers' well-being, workload and productivity-evaluated with subjective ratings. *Applied Ergonomics, 42(1), 29–36.* https://doi.org/10.1016/j.apergo.2010.04.003

Law No. 96/2019, of 4 September. Establishes the free of charge of school textbooks in compulsory education in the public network of the Ministry of Education, making the second amendment to Law No. 47/2006, of 28 August, which defines the evaluation, certification and adoption regime applicable to school textbooks and other didactic-pedagogical resources of basic education and secondary education, as well as the principles and objectives to which socio-educational support must comply in relation to the acquisition and loan of school textbooks.

Li, K., Lloyd, B., Liang, X. J., & Wei, Y. M. (2014). Energy poor or fuel poor: What are the differences? Energy Policy, 68, 476–481.

Liddell C & Guiney C. (2015). Living in a cold and damp home: frameworks for understanding impacts on mental well-being. *Public Health 129(3):191–9.* https://doi.org/10.1016/j.puhe.2014.11.007

Liddell, C. & Morris, C. (2010). Fuel poverty and human health: A review of recent evidence. *Energy Policy, 38(6), 2987–2997.* https://doi.org/10.1016/j.enpol.2010.01.037

Liddell, C., Morris, C., Thomson, H., & Guiney, C. (2016). Excess winter deaths in 30 European countries 1980–2013: A critical review of methods. *Journal of Public Health, 38(4), 806–814*. https://doi.org/10.1093/pubmed/fdv184

Lin, Z., & Deng, S. (2008). A study on the thermal comfort in sleeping environments in the subtropics-Developing a thermal comfort model for sleeping environments. *Building and Environment, 43(1), 70–81.* https://doi.org/10.1016/j.buildenv.2006.11.026

Lisboa E-NOVA & AdE-PORTO. (2022). *Estudo Sobre Pobreza Energética.* https://pobrezaenergetica.pt/. Accessed on February 20, 2023

Lourenço, P., Pinheiro, M. D., & Heitor, T. (2014). From indicators to strategies: Key Performance Strategies for sustainable energy use in Portuguese school buildings. *Energy and Buildings, 85, 212–224*. https://doi.org/10.1016/j.enbuild.2014.09.025

Mamica, Ł., Głowacki, J., & Makieła, K. (2021). Determinants of the energy poverty of polish students during the COVID-19 pandemic. *Energies, 14(11), 1–15.* https://doi.org/10.3390/en14113233

Mangus, C. W., & Canares, T. L. (2019). Heat-related illness in children in an era of extreme temperatures. *Pediatrics in Review, 40(3), 97–107*. https://doi.org/10.1542/pir.2017-0322

Marmot Review Team. (2011). *The Health Impacts of cold Homes and Fuel Poverty.* https://www.instituteofhealthequity.org/resources-reports/the-health-impacts-of-cold-homes-and-fuel-poverty.

Mendell, M. J., Mirer, A. G., Cheung, K., Tong, M., & Douwes, J. (2011). Respiratory and Allergic Health Effects of Dampness, Mold , and Dampness - Related Agents : A Review of the Epidemiologic Evidence. *Environmental Health Perspectives, 119(6), 748–756.* https://doi.org/10.1289/ehp.1002410

Middlemiss, L. (2022). Who is vulnerable to energy poverty in the Global North, and what is their experience? *Wiley Interdisciplinary Reviews: Energy and Environment, 11(6).* https://doi.org/10.1002/wene.455

Ministry of the Environment and Energy Transition. (2019). *Roteiro Para A Neutralidade Carbónica 2050 (Rnc2050) Estratégia De Longo Prazo Para A Neutralidade Carbónica Da Economia Portuguesa Em 2050*. Ministério do Ambiente e da Transição Energética. https://unfccc.int/sites/default/files/resource/RNC2050_PT-22-09-2019.pdf

Ministry of the Environment and Energy Transition. (2021). *Estratégia Nacional De Longo Prazo Para O Combate À Pobreza Energética 2021-2050.*

https://participa.pt/contents/consultationdocument/Estrate%CC%81gia%20Nacional%20de%20Longo%20Prazo%20para%20o%20Combate%20a%CC%80%20Pobreza%20Energe%CC%81tica_VConsultaPu%CC%81b_2852.pdf

Minister of Planning and Infrastructure. (2021). *Recuperar Portugal, construindo o futuro - PRR: Plano de recuperação de resiliência.* Ministério do Planeamento. https://recuperarportugal.gov.pt/plano-de-recuperacao-e-resiliencia/. Accessed February 20, 2023

Mohan, G. (2021). Energy Research & Social Science Young , poor , and sick : The public health threat of energy poverty for children in Ireland. *Energy Research & Social Science*, *71*(October 2020), 101822. https://doi.org/10.1016/j.erss.2020.101822

Mumovic, D.,Palmer, J., Davies, M., Orme, M.,Ridley, I., Oreszczyn, T.,Judd, C., Critchlow, R., Medina, H.A., Pilmoor, G., Pearson, C., Way, P. (2008). Winter indoor air quality, thermal comfort and acoustic performance of newly built secondary schools in England. *Building and Environment 44 1466–1477* https://doi.org/10.1016/j.buildenv.2008.06.014

NEA. (2023). *Fuel Poverty in Northern Ireland*. National Energy Action. https://www.nea.org.uk/fuel-poverty-map/fuel-poverty-in-ni/ Accessed March 19, 2023

Nguyen, C. P., & Su, T. D. (2022). The influences of government spending on energy poverty: Evidence from developing countries. *Energy, 238, 121785.* https://doi.org/10.1016/j.energy.2021.121785.

Nishio, A. (2021). When poverty meets climate change: A critical challenge that demands cross-cutting solutions. *World Bank Blogs.* https://blogs.worldbank.org/climatechange/when-poverty-meets-climate-change-critical-challenge-demands-cross-cutting-solutions. Accessed July 2, 2023

Normative order No. 6476-B/2021, July 1st 2021. Approves the selection criteria and methodologies applicable to the verification processes of the quality of the information produced under the Energy Certification System for Buildings (SCE).

Normative order No. 6476-D/2021, July 1st, 2021. Approves the requirements for the preparation of the Energy Performance Improvement Plan for Buildings (PDEE).

Normative order No. 6476-E/2021, July 1st, 2021. Approves minimum thermal comfort and energy performance requirements for the design and renovation of buildings.

Normative order No. 6476-H/2021, July 1st, 2021. Approves the Manual of the Energy Certification System for Buildings (SCE).

Normative order Normativo No. 10-A/2018, de 19 de junho. Establishes the regime for the constitution of groups and classes and the period of operation of education and teaching establishments within the scope of compulsory schooling.

Observatório de Energia. (2022). *Energia em números- Edição 2022.* https://www.dgeg.gov.pt/media/zuffmfm4/dgeg-aen-2022e.pdf

OECD (No Data). *Chronic diseases and disabilities among older people.* https://www.oecd-ilibrary.org/sites/f44c34f1-en/index.html?itemId=/content/component/f44c34f1-en

OECD. (2012). *Modernising Secondary School Buildings in Portugal*. OECD Publishing. http://dx.doi.org/10.1787/9789264128774-en

OECD. (2021b). *Education at a Glance 2021: OECD Indicators*. OECD Publishing. https://doi.org/10.1787/b35a14e5-en

Oliveras, L., Artazcoz, L., Borrell, C., Palència, L., López, M. J., Gotsens, M., Peralta, A. & MarÍ-Dell'Olmo, M. (2020). The association of energy poverty with health, health care utilisation and medication use in southern Europe. *SSM - Population Health, 12 100665* https://doi.org/10.1016/j.ssmph.2020.100665

Oliveras, L., Borrell, C., González-Pijuan, I., Gotsens, M., López, M. J., Palència, L., Artazcoz, L., & Marí-Dell'olmo, M. (2021). The association of energy poverty with health and well-being in children in a mediterranean city. *International Journal of Environmental Research and Public Health, 18(11).* https://doi.org/10.3390/ijerph18115961

Ordinance No. 138-G/2021, July 1st 2021. Establishes the requirements for the assessment of indoor air quality in commercial and service buildings, including protection thresholds, reference conditions and compliance criteria, and the respective methodology for measuring pollutants and monitoring compliance with the approved standards.

Ordinance No. 138-I/2021, July 1st 2021. Regulates the minimum energy performance requirements for the building envelope and technical systems and their application according to the type of use and specific technical characteristics.

P.E. (2011). *Parque Escolar 2007-2011 Intervenção em 106 escolas*. Parque Escolar ISBN: 978-989-96106-6-8

P.E. (No Data). *Enquadramento Histórico. Parque Escolar*. https://parque-escolar.pt/pt/programa/enquadramento-historico.aspx. Accessed February 17, 2023

Palma, P., Gouveia, J. P., Mahoney, K., & Bessa, S. (2022). It Starts at Home: Space Heating and Cooling Efficiency for Energy Poverty and Carbon Emissions Reduction in Portugal. *People, Place and Policy Online, 16(1), 13–32.* https://doi.org/10.3351/ppp.2022.5344968696

Papazoglou, E., Moustris, K. P., Nikas, K. P., Papazoglou, E., Statharas, C., Nastos, P. T., … Corre, O. Le. (2019). Assessment of human thermal comfort perception in a non-air- on District Cooling Assessment of human thermal comfort perception a non-air- conditioned school building in Athens , Greece conditioned s. *Energy Procedia, 157, 1343–1352.* https://doi.org/10.1016/j.egypro.2018.11.299

Pelz, S., Pachauri, S., & Groh, S. (2018). A critical review of modern approaches for multidimensional energy poverty measurement. *Wiley Interdisciplinary Reviews: Energy and Environment*, *7*(6), 1–16. https://doi.org/10.1002/wene.304

Pereira, M. G., Freitas, M. A. V., & da Silva, N. F. (2010). Rural electrification and energy poverty: Empirical evidences from Brazil. *Renewable and Sustainable Energy Reviews, 14(4), 1229–1240.* https://doi.org/10.1016/j.rser.2009.12.013

Pereira. L.D., Raimundo, d., Corgnati S. P., Da Silva, M.G. (2014). Assessment of indoor air quality and thermal comfort in Portuguese secondary classrooms: Methodology and results. *Building and Environment 81 69-80.* http://dx.doi.org/10.1016/j.buildenv.2014.06.008

Perera, A. (2019). *Energy and disability*. Energy and Economic Growth. https://www.energyeconomicgrowth.org/sites/default/files/2019-04/EEG%20Insight%20Paper%20on%20Energy%20%20Disability%2012.4.2019%20CLEAN%20COPYEDITED%20adjus....pdf

Perera, A. T. D., Nik, V. M., Chen, D., Scartezzini, J. L., & Hong, T. (2020). Quantifying the impacts of climate change and extreme climate events on energy systems. *Nature Energy, 5(2), 150–159*. https://doi.org/10.1038/s41560-020-0558-0

Petrova, S., & Simcock, N. (2021). Gender and energy: Domestic inequities reconsidered. *Social & Cultural Geography, 22(6), 849–867.* https://doi.org/10.1080/14649365.2019.1645200

Platt, S.D., Martin, C.J., Hunt, S.M., Lewis, C.W. (1989). Damp housing, mould growth, and symptomatic health state. *Br. Med. J. 298 (6689) 1673–1678.* doi: 10.1136/bmj.298.6689.1673

PORDATA. (2022a). *Alunos matriculados no ensino privado: total e por nível de ensino.* https://www.pordata.pt/portugal/alunos+matriculados+no+ensino+privado+total+e+por+nivel+de+ensino-1004. Accessed February 17, 2023

PORDATA. (2022b). *Alunos matriculados no ensino público: total e por nível de ensino.* https://www.pordata.pt/portugal/alunos+matriculados+no+ensino+publico+total+e+por+nivel+de+ensino-1003. Accessed February 17, 2023

PORDATA. (2022c). *Despesas das Administrações Públicas em educação.* https://www.pordata.pt/portugal/despesas+das+administracoes+publicas+em+educacao-866. Retrieved in February 2023.

PORDATA. (2022d). *Despesas das Administrações Públicas em educação em % do PIB.* https://www.pordata.pt/portugal/despesas+das+administracoes+publicas+em+educacao+em+percentagem+do+pib-867. Accessed February 17, 2023

PORDATA. (2022e). *Estabelecimentos nos ensinos pré-escolar, básico e secundário: por nível de ensino.* https://www.pordata.pt/portugal/estabelecimentos+nos+ensinos+pre+escolar++basico+e+secundario+por+nivel+de+ensino-1237. Accessed February 17, 2023

PORDATA. (2023f). *Despesas da Ação Social Escolar no ensino não superior: total e por tipo de benefício - Continente (1993 - 2019).* https://www.pordata.pt/portugal/despesas+da+acao+social+escolar+no+ensino+nao+superior+total+e+por+tipo+de+beneficio+++continente+(1993+++2019)-1076. Accessed February 17, 2023

PORDATA. (2023g). *Taxa de desemprego segundo os Censos: total e por grupo etário (%).* https://www.pordata.pt/municipios/taxa+de+desemprego+segundo+os+censos+total+e+por+grupo+etario+(percentagem)-397. Accessed May, 20, 2023

PORDATA. (2023h). Remuneração base média mensal dos trabalhadores por conta de outrem: total e por setor de atividade económica. https://www.pordata.pt/municipios/remuneracao+base+media+mensal+dos+trabalhadores+por+conta+de+outrem+total+e+por+setor+de+atividade+economica-238. Accessed May, 20, 2023

PORDATA. (2023i). *Diferença entre o salário mínimo nacional e a remuneração base média mensal dos trabalhadores por conta de outrem.* https://www.pordata.pt/municipios/diferenca+entre+o+salario+minimo+nacional+e+a+remuneracao+base+media+mensal+dos+trabalhadores+por+conta+de+outrem-477. Accessed May, 20, 2023

Putti, R.V., Tsan, M., Mehta, S. & Kammila, S. (2015). *The State Of The Global Clean And Improved Cooking Sector. Energy Sector Management Assistance Program, Global Alliance for Clean Cookstoves,* The World Bank. https://openknowledge.worldbank.org/server/api/core/bitstreams/7295c62e-e29a-5e0a-89fe-8ae6b9c04d39/content

Pye, S., Dobbins, A., Baffert, C., Brajković, J., Deane, P., & De Miglio, R. (2015). Addressing Energy Poverty and Vulnerable Consumers in the Energy Sector Across the EU. *L'Europe En Formation, n° 378(4), 64–89*. https://doi.org/10.3917/eufor.378.0064

Räty, R., & Carlsson-Kanyama, A. (2010). Energy consumption by gender in some European countries. *Energy Policy, 38(1), 646–649.* https://doi.org/10.1016/j.enpol.2009.08.010

Recalde, M., Peralta, A., Oliveras, L., Tirado-Herrero, S., Borrell, C., Palència, L., Gotsens, M., Artazcoz, L. & Marí-Dell'Olmo, M. (2019). Structural energy poverty vulnerability and excess winter mortality in the European Union: Exploring the association between structural determinants and health. *Energy Policy, 133, 110869* https://doi.org/10.1016/j.enpol.2019.07.005

Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and

2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.328.01.0001.01.ENG

Ritchie, H. & Roser, M. (2018) *Urbanization.* OurWorldInData. https://ourworldindata.org/urbanization. Accessed July, 20, 2023

Riva, M., Kingunza Makasi, S., Dufresne, P., O'Sullivan, K., & Toth, M. (2021). Energy poverty in Canada: Prevalence, social and spatial distribution, and implications for research and policy. *Energy Research and Social Science, 81.* https://doi.org/10.1016/j.erss.2021.102237

Robinson, C. (2019). Energy poverty and gender in England: A spatial perspective. *Geoforum, 104, 222–233.* https://doi.org/10.1016/j.geoforum.2019.05.001

Rodrigues, A.M., Da Piedade, A.C., Braga, A.M. (2009). *Térmica De Edificios*. (1st Ed.). 24-28. Amadora. ISBN: 978-972-8620-13-4

Romero-Ortuno, R., Tempany, M., Dennis, L., O'Riordan, D., & Silke, B. (2013). Deprivation in cold weather increases the risk of hospital admission with hypothermia in older people. *Irish Journal of Medical Science, 182(3), 513–518.* https://doi.org/10.1007/s11845-012-0896-4

Rupp, R. F., Vásquez, N. G., & Lamberts, R. (2015). A review of human thermal comfort in the built environment. *Energy and Buildings 105 178–205.* https://doi.org/10.1016/j.enbuild.2015.07.047

Sadrizadeh, S., Yao, R., Yuan, F., Awbi, H., Bahnfleth, W., Bi, Y., Cao, G., Croitoru, C., De Dear, R., Haghighat, F., Kumar, P., Malayeri, M., Nasiri, F., Ruud, M., Sadeghian, P., Wargocki, P., Xiong, J., Yu, J. & Li, B. (2022). Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment. *Journal of Building Engineering, 57(June).* https://doi.org/10.1016/j.jobe.2022.104908

Sajn, N. (2021). *Vulnerable Consumers. Briefing from the European Parliamentary* Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690619/EPRS_BRI(2021)690619_EN.pdf

Sánchez-Torija, J. G., Arranz, B., Oteiza, I., Alonso, C., & Martín-Consuegra, F. (2022). Thermal comfort and air quality assessment in public schools in Madrid. Study of three cases during one year. *Informes de La Construccion*, *74*(567). https://doi.org/10.3989/ic.87607

Santamouris, M., Mihalakakou, G., Patargias, P., Gaitani, N., Sfakianaki, K., Papaglastra, M., Pavlou, C., Doukas, P., Primikiri, E., Geros, V., Assimakopoulos, M. N., Mitoula, R., & Zerefos, S. (2007). Using intelligent clustering techniques to classify the energy performance of school buildings. *Energy and Buildings, 39(1), 45–51.* https://doi.org/10.1016/j.enbuild.2006.04.018

Saraiva, T. S., de Almeida, M., Bragança, L., & Barbosa, M. T. (2018). Environmental comfort indicators for school buildings in sustainability assessment tools. *Sustainability (Switzerland), 10(6), 1–11.* https://doi.org/10.3390/su10061849

Scottish Government. (2017). *A new definition of fuel poverty in Scotland A review of recent evidence.* https://www.gov.scot/binaries/content/documents/govscot/publications/independent-report/2017/11/new-definition-fuel-poverty-scotland-review-recent-evidence/documents/00527017-pdf/00527017-pdf/govscot%3Adocument/00527017.pdf

Snell, C., Bevan, M., & Thomson, H. (2015). Justice, fuel poverty and disabled people in England. *Energy Research & Social Science, 10, 123–132* https://doi.org/10.1016/j.erss.2015.07.012

Somerville, M., Owen, I., Owen, P and Miles, D. (2000). Housing and health: does installing heating in their homes improve the health of children with asthma? *Public Health 114(6),434-439*. https://doi.org/10.1038/sj.ph.1900687

Spalt, E. W., Curl, C. L., Allen, R. W., Cohen, M., Adar, S. D., Stukovsky, K. H., Avol, E., Castro-Diehl, C., Nunn, C., Mancera-Cuevas, K., & Kaufman, J. D. (2016). Time-location patterns of a diverse population of older adults: The Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). *Journal of Exposure Science and Environmental Epidemiology, 26(4), 349–355*. https://doi.org/10.1038/jes.2015.29

Stoerring, D. (2017). *Energy Poverty.* https://www.europarl.europa.eu/RegData/etudes/STUD/2017/607350/IPOL_STU(2017)607350_EN.pdf

Stojilovska, A. Dokupilová, D., Gouveia,J.P., Bajomi, A., Tirado-Herrero, S., Feldmár, N., Kyprianou, I., Feenstra, M. (2023). As essential as bread: Fuelwood use as a cultural practice to cope with energy poverty in Europe, E*nergy Research & Social Science, 97, 102987*, https://doi.org/10.1016/j.erss.2023.102987

Stojilovska, A., Guyet, R., Mahoney, K., Gouveia, J. P., Castaño-rosa, R., Zivcic, L., Barbosa, R., &Tkalec, T. (2022). Energy poverty and emerging debates : Beyond the traditional triangle of energy poverty drivers. *Energy Policy 169, 113181*. https://doi.org/10.1016/j.enpol.2022.113181

Tarantini, M., Pernigotto, G., & Gasparella, A. (2017). A co-citation analysis on thermal comfort and productivity aspects in production and office buildings. *Buildings, 7(2).* https://doi.org/10.3390/buildings7020036

Teariki, M. A., Tiatia, R., O'Sullivan, K., Puloka, V., Signal, L., Shearer, I., & Howden-Chapman, P. (2020). Beyond home: Exploring energy poverty among youth in four diverse Pacific island states. *Energy Research and Social Science, 70.* https://doi.org/10.1016/j.erss.2020.101638

Teli, D., Jentsch, M. F., & James, P. A. B. (2012). Naturally ventilated classrooms: An assessment of existing comfort models for predicting the thermal sensation and preference of primary school children. *Energy and Buildings, 53, 166–182.* https://doi.org/10.1016/j.enbuild.2012.06.022

The Lancet. (2019). *Prioritising disability in universal health coverage*. The Lancet (Vol. 394, Issue 10194, p. 187). Lancet Publishing Group. https://doi.org/10.1016/S0140-6736(19)31638-1

The Velux Group. (2019). *Healthy Homes Barometer 2019.* https://contenthub.velux.com/api/public/content/85459-8eaa3-fd41d_downloadOriginal?v=938858c1&_gl=1*11jx4t5*_ga*MTk2NzA1NTAxLjE2OTc1OTE5MjU.*_ga_QPBMHL46S3*MTY5OTQ4MDk2My4yLjEuMTY5OTQ4MDk4Ni4zNy4wLjA.&_ga=2.132125001.63988140.1699480963-196705501.1697591925

Thewes, A., Maas, S., Scholzen, F., Waldmann, D., & Zürbes, A. (2014). Field study on the energy consumption of school buildings in Luxembourg. *Energy and Buildings, 68, 460–470.* https://doi.org/10.1016/j.enbuild.2013.10.002

Thomson, H., Bouzarovski, S., & Snell, C. (2017). Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data. *Indoor and Built Environment*, *26*(7), 879–901. https://doi.org/10.1177/1420326X17699260

Thomson, H., Snell, C., & Bouzarovski, S. (2017). Health, well-being and energy poverty in Europe: A comparative study of 32 European countries. International Journal of *Environmental Research and Public Health, 14(6).* https://doi.org/10.3390/ijerph14060584

Thomson, H. & Bouzarovski, S. (2019). *Addressing Energy Poverty in the European Union: State of Play and Action.* EU report from the EU Energy Poverty Observatory. https://energy-poverty.ec.europa.eu/system/files/2022-04/paneureport2018_updated2019.pdf

Tonn, B., Hawkins, B., Rose, E., & Marincic, M. (2021). Income, housing and health: Poverty in the United States through the prism of residential energy efficiency programs. *Energy Research and Social Science, 73.* https://doi.org/10.1016/j.erss.2021.101945

Torriani, G., Lamberti, G., Salvadori, G., Fantozzi, F., & Babich, F. (2023). Thermal comfort and adaptive capacities: Differences among students at various school stages. *Building and Environment*, *237*(November 2022), 110340. https://doi.org/10.1016/j.buildenv.2023.110340

UN (No Data). *Income Poverty in Old Age: An Emerging Development Priority.* Department of Economic and Social Affairs programme on ageing. https://www.un.org/esa/sOECDv/ageing/documents/PovertyIssuePaperAgeing.pdf

UNHABITAT. (2022). *World Cities Report 2022.* https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

Valente, I. & Gouveia, J.P. (2023a, July 11-13). *Exploring Energy Poverty and Thermal Comfort In Upper Secondary Students: A Case Study of Lisbon, Portugal* [Conference Presentation]. 29th International Sustainable Development Research Society Conference, University Kebangsaan, Malaysia. https://2023.isdrsconferences.org/wp-content/uploads/2023/07/Final-Day-2-Parallel-12.7.2023-update-120723.pdf

Valente, I. & Gouveia, J.P. (2023a, May 8). *Exploring Energy Poverty and Thermal Comfort In Upper Secondary Students: A Case Study Of Lisbon, Portugal* [Conference Presentation]. Meeting on Energy and Environmental Economics, Aveiro, Portugal. https://doi.org/10.48528/v3b3-fk78.

Van Ruijven, B. J., De Cian, E., & Sue Wing, I. (2019). Amplification of future energy demand growth due to climate change. *Nature Communications, 10(1), 1–12.* https://doi.org/10.1038/s41467-019-10399-3

Wargocki, P., & Wyon, D. P. (2013). Providing better thermal and air quality conditions in school classrooms would be. *Building and Environment*, *59*, 581–589. https://doi.org/10.1016/j.buildenv.2012.10.007

Wargocki, P., Porras-Salazar, J. A., & Contreras-Espinoza, S. (2019). The relationship between classroom temperature and children's performance in school. *Building and Environment, 157, 197–204*. https://doi.org/10.1016/j.buildenv.2019.04.046

Wargocki, P., Porras-Salazar, J. A., Contreras-Espinoza, S., & Bahnfleth, W. (2020). The relationships between classroom air quality and children's performance in school. *Building and Environment, 173, 106749.* https://doi.org/10.1016/j.buildenv.2020.106749

Weather Sparks. (2023). *Compare the Climate and Weather in Vila Franca de Xira and Alenquer.* https://weatherspark.com/compare/y/32192~32070/Comparison-of-the-Average-Weather-in-Vila-Franca-de-Xira-and-Alenquer. Accessed May, 20, 2023

Welsh Government. (2021). *Tackling fuel poverty 2021 to 2035.* https://www.gov.wales/sites/default/files/pdf-versions/2021/12/4/1638465219/tackling-fuel-poverty-2021-2035.pdf

WHO. (2023). *Household Air Pollution*. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. Accessed in March 18, 2023.

Widuto, A. (2022). *Energy poverty in the EU.* https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733583/EPRS_BRI(2022)733583_EN.pdf

Witterseh, T., Wyon, D. P., & Clausen, G. (2004). The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the performance of office work. Indoor Air, Supplement, 14(8), 30–40. https://doi.org/10.1111/j.1600-0668.2004.00305.x

WMO. (2022). *2022 State of Climate Services: Energy*. World Meteorological Services. https://library.wmo.int/doc_num.php?explnum_id=11340

Xu, W., Xie, B., Lou, B., Wang, W., & Wang, Y. (2022). Assessing the effect of energy poverty on the mental and physical health in China—Evidence from China family panel studies. *Frontiers in Energy Research, 10.* https://doi.org/10.3389/fenrg.2022.944415

You, Y., & Kim, S. (2019). Who lives in and owns cold homes? A case study of fuel poverty in Seoul, South Korea. *Energy Research and Social Science, 47, 202–214.* https://doi.org/10.1016/j.erss.2018.10.007

Zhang, D., & Bluyssen, P. M. (2021). Energy consumption, self-reported teachers' actions and children's perceived indoor environmental quality of nine primary school buildings in the Netherlands. *Energy and Buildings, 235, 110735.* https://doi.org/10.1016/j.enbuild.2021.110735

Zhang, Q., Appau, S., & Kodom, P. L. (2021). Energy poverty, children's wellbeing and the mediating role of academic performance: Evidence from China. *Energy Economics, 97, 105206.* https://doi.org/10.1016/j.eneco.2021.105206

Zomorodian, Z., Tahsildoost, M., & Hafezi, M. (2016). Thermal comfort in educational buildings : A review article. *Renewable and Sustainable Energy Reviews*, *59*, 895–906. https://doi.org/10.1016/j.rser.2016.01.033

A

Appendix

A.1 Students' surveys

Introductory section: This survey was developed within the framework of a master thesis to be developed by a student of the Integrated Master in Environmental Engineering at the School of Science and Technology of NOVA University Lisbon (FCT NOVA). The aim of this study is to assess the vulnerability of secondary school students to energy poverty at home and at school. The survey takes approximately 4 minutes to complete. We appreciate your willingness to answer the survey. Your contribution is very important for the advancement of knowledge on this issue.

Q1: The data collected in the survey are pseudonymized and collected for statistical purposes only. statistical purposes. To proceed, please confirm your acceptance of the terms described in the Privacy Policy.

- ☐ I accept the conditions described in the privacy policy.
- ☐ I do not accept the conditions described in the privacy policy.

Section 1: student characterization

Q2: School Year

- ☐ 10th Grade
- ☐ 11th Grade
- ☐ 12th Grade

Q3: Age

- ☐ <15 Years Old
- ☐ 15 Years Old
- ☐ 16 Years Old
- ☐ 17 Years Old

☐ 18 Years Old

☐ >18 Years Old

Q4: Gender

☐ Male

☐ Female

☐ Non-binary

☐ Other

Q5: Do you have any chronic or disabling condition?

☐ No

☐ Yes, cardiovascular

☐ Yes, respiratory

☐ Yes, mental Illness

☐ Yes, other

☐ I prefer not to answer

Q6: School Social Support Level:

☐ Level A

☐ Level B

☐ Level C/I do not have School Social Support

☐ I prefer not to answer

Q7: Indicate the school you go to:

Section 2: Thermal comfort at home/energy poverty

Q8: In your house, the temperature during winter Is comfortable:

☐ Yes.

☐ No.

Q9: In your house, the temperature during summer Is comfortable:

☐ Yes.

☐ No.

Q10: In your house, do you use equipment to warm it during winter:

☐ No.

☐ Yes, air conditioning

☐ Yes, Fireplace.

- Yes, electric heater.
- Yes, natural gas heater.
- Yes, other.

Q11: In your house, do you use equipment to cool it during summer?

- No.
- Yes, portable Fan
- Sim, air conditioning

Q12: Does your house has problems related with mold or dampness:

- Yes.
- No.

Section 3: Thermal comfort at school

Q13: During summer, the temperature Inside classroom Is:

- Hot
- Warm
- Slightly Warm
- Neutral/comfortable
- Slightly cool
- Cool
- Cold

Q14: During winter, the temperature Inside classroom Is:

- Hot
- Warm
- Slightly Warm
- Neutral/comfortable
- Slightly cool
- Cool
- Cold

Q15: I consider that the temperature of the classroom affects my ability to concentrate in class.

- Yes.
- No.

Q16: I consider that the temperature in the classroom affects my academic performance:

- Yes.

- ☐ No.

Q17a: Indicate how often you use blankets in the classroom in winter:

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often

Q17b: Indicate how often you use scarfs in the classroom in winter:

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often

Q17c: Indicate how often you use jackets in the classroom in winter:

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often

Q18: Indicate how often you use paper fan in the classroom in summer:

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often

Q19: When the temperature in the classroom is not comfortable, i:

- ☐ I tell the teacher and ask to open the window or adjust the climatization.
- ☐ I open the windows.
- ☐ I adjust the climatization to a comfortable temperature.
- ☐ I adjust the blinds.
- ☐ I adapt my level of clothing.
- ☐ I do not do anything.

Section 4: Dual vulnerability

Q20: In the warmer months, the temperature is more comfortable:

- ☐ In school.
- ☐ In my house.
- ☐ It is uncomfortable in both.

☐ It is comfortable in both.

Q21: In the coldest months, the temperature is more comfortable:

☐ In school.

☐ In my house.

☐ It is uncomfortable in both.

☐ It is comfortable in both.

Open ended section

Q22: Is there any experience/opinion about thermal comfort at school and energy poverty at home that you wanted to share?

A.2 Teachers' survey

Introductory section: This survey was developed within the framework of a master thesis being developed by a student of the Integrated Master in Environmental Engineering at the School of Science and Technology of NOVA University Lisbon (FCT NOVA). The aim of this study is to assess the vulnerability of secondary school students living in Portugal to energy poverty at home and at school. This survey aims to collect teachers' perception of thermal comfort in classrooms. The survey is anonymous and takes approximately 4 minutes to complete. We appreciate your willingness to answer the survey. Your contribution is very important for the advancement of knowledge on this issue.

Q1: The data collected in the survey are pseudonymized and collected for statistical purposes only. statistical purposes. To proceed, please confirm your acceptance of the terms described in the Privacy Policy.

☐ I accept the conditions described in the privacy policy.

☐ I do not accept the conditions described in the privacy policy.

School Identification section

Q2: Indicate the school where you currently teach:

Thermal comfort section

Q3: Classroom climate conditions are favorable for teaching, regardless of the season.

☐ Yes.

☐ No.

Q4: During summer, the temperature Inside classroom Is:

- Hot
- Warm
- Slightly Warm
- Neutral/comfortable
- Slightly cool
- Cool
- Cold

Q5: During winter, the temperature Inside classroom Is:

- Hot
- Warm
- Slightly Warm
- Neutral/comfortable
- Slightly cool
- Cool
- Cold

Q6: Do the classrooms have heating/cooling equipment?

- Yes.
- No.
- Yes, but they are not working.

Q7: I consider that thermal discomfort can jeopardize the students' attention In classroom.

- Yes.
- No.

Q8: I consider that thermal discomfort can affect students' performance during tests.

- Yes.
- No.

Q9: I consider that thermal discomfort affects my performance as a teacher.

- Yes.
- No.

Q10: The student has the freedom to open the classroom windows.

- Yes.

- No.

Q11: The student has the freedom to use the heating/cooling equipment in the classroom.

- Yes.
- No.

Q12a: Indicate how often you use blankets in the classroom in winter:

- Never
- Rarely
- Sometimes
- Often

Q12b: Indicate how often you use scarfs in the classroom in winter:

- Never
- Rarely
- Sometimes
- Often

Q12c: Indicate how often you use jackets in the classroom in winter:

- Never
- Rarely
- Sometimes
- Often

Q13: What heating equipment is available in classrooms?

- Air Conditioning
- Central heating
- Electric heater
- Natural gas heater
- Other
- It only has cooling equipment.

Q14: What cooling equipment is available in classrooms?

- Portable Fans
- Air conditioning
- It only has heating equipment.

Open ended section

Q15: Is there any experience/opinion about thermal comfort at school that you wanted to share?

A.3 Interview with the school directive board

Q1. How do you perceive the school's consumption: does it spend more, less or the same as other schools? Do you consider consumption to be high?
Q2. Are there Heating, Ventilation and Air Conditioning (HVAC) systems in the school?
In common areas and/or classrooms? Is the consumption related to HVAC high?
What is the main source of energy consumption?
Q3. What energy sources are used? Only electricity, natural gas, other?
Q4. Given the total number of pupils in the school, how many of them are experiencing a situation of economic of economic deprivation? Of these pupils, do you have any insight into the conditions of their homes? Do you consider that they may be experiencing energy poverty?
Q5. How do you perceive the thermal comfort in the classrooms? Are the pupils comfortable inside them?
Q6. Regarding the temperature of the classrooms: is it molded according to the teacher's preference or does teacher's preference or does the teacher ask the pupils about their preferences? Or are there indications from the school to follow?
Q7. What year was the school built? If it was renovated, what year did it occurred? Knowing that it was not renovated, do you know the reason why it was not included in the Parque Escolar Modernization Program?
Q8. Regarding the school building, could you provide some construction details of it?
(Does it have single or double windows? Do all the rooms have functional shutters?
Does it have any kind of insulation? Does the roof still have asbestos? If not, in what year was year was it removed, and what is the constitution of the new roof?)
Q9. Have energy poverty awareness initiatives been carried out in the school?
Q10. Have initiatives been carried out to improve thermal comfort in the school?
Q11. What is the degree of autonomy of the school to improve conditions in terms of thermal comfort and energy efficiency?

2023

Inês Monteiro Valente

Exploring energy poverty and thermal comfort in upper secondary education student

NOVA SCHOOL OF SCIENCE & TECHNOLOGY