EFFICACY HANDBOOK

Energy eFFiciency building and CirculAr eConomY for thermal insulation solutions

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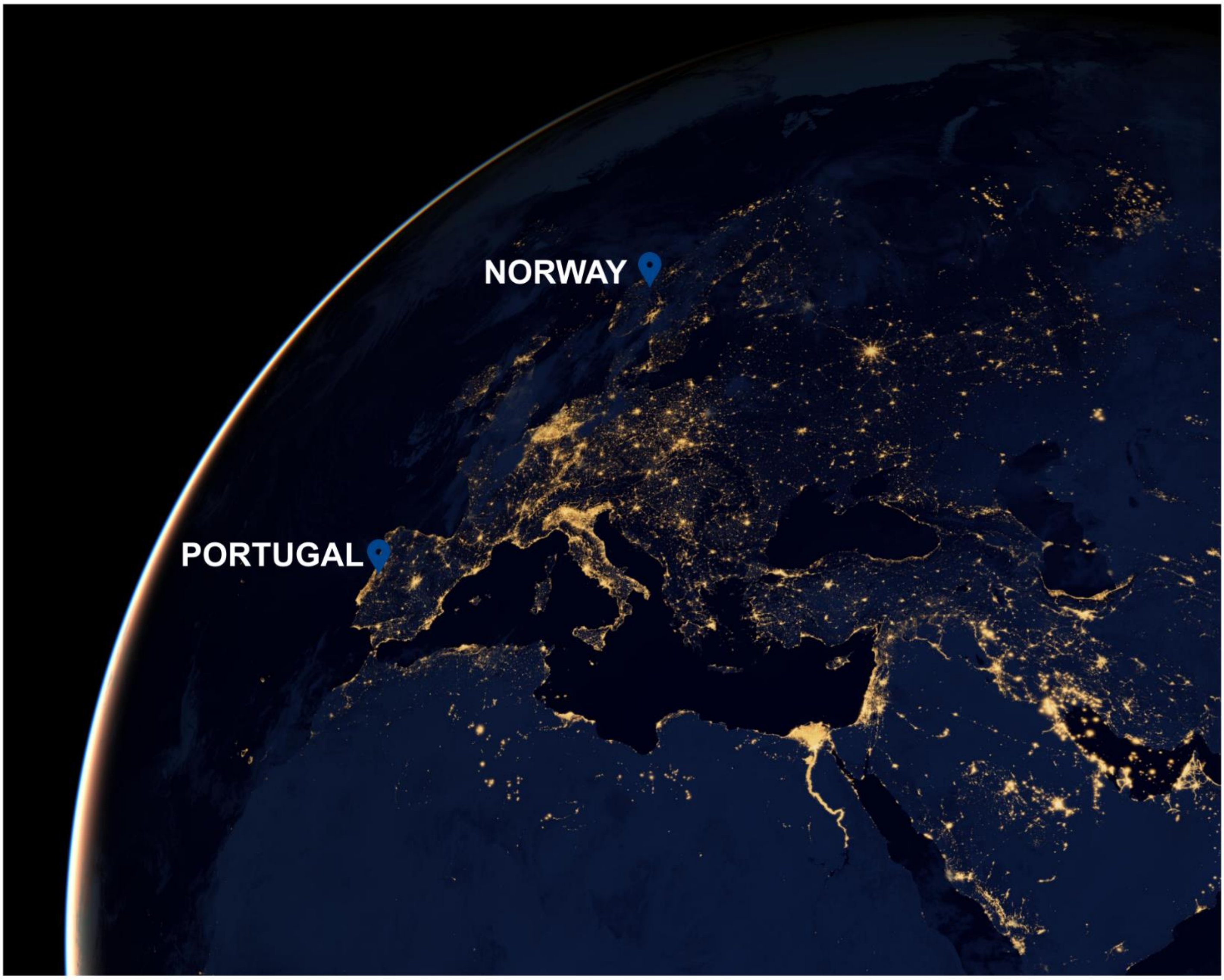

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Preface

The **EFFICACY HANDBOOK** is a comprehensive guide that addresses critical aspects of energy efficiency and sustainability in building design. It covers a broad spectrum of topics, including understanding energy demands, addressing energy poverty, making informed choices about thermal insulation materials and retrofit solutions, considering the impact of climate change, and preparing for future scenarios. It also provides strategies for effectively engaging target groups.

With this publication, the multidisciplinary team of the Efficacy project intends to synthesize and provide the main results of the project, which was completed in September 2023, regarding the **E**nergy e**FF**iciency bu**I**lding and **C**ircul**A**r e**C**onom**Y** for thermal insulation solutions. It also includes some insights from the final workshop and technical guidelines. The main topics covered in this work are the following:

- Energy poverty (EP) and energy demands
- Choice of thermal insulation materials and retrofit solutions
- Climate change and future scenarios
- Target groups engagement

We hope that this publication will be a relevant contribution to the development of criteria for thermal insulation systems and that the results and guidelines presented here will be useful for all professionals involved in the building energy efficiency and climate change.

The coordination.

1. Introduction

The facades and roofs of buildings (Fig. 1) have a significant contribution to thermal exchanges with the exterior, directly affecting the building's energy consumption and associated costs, greenhouse gas emissions, and the well-being of users.

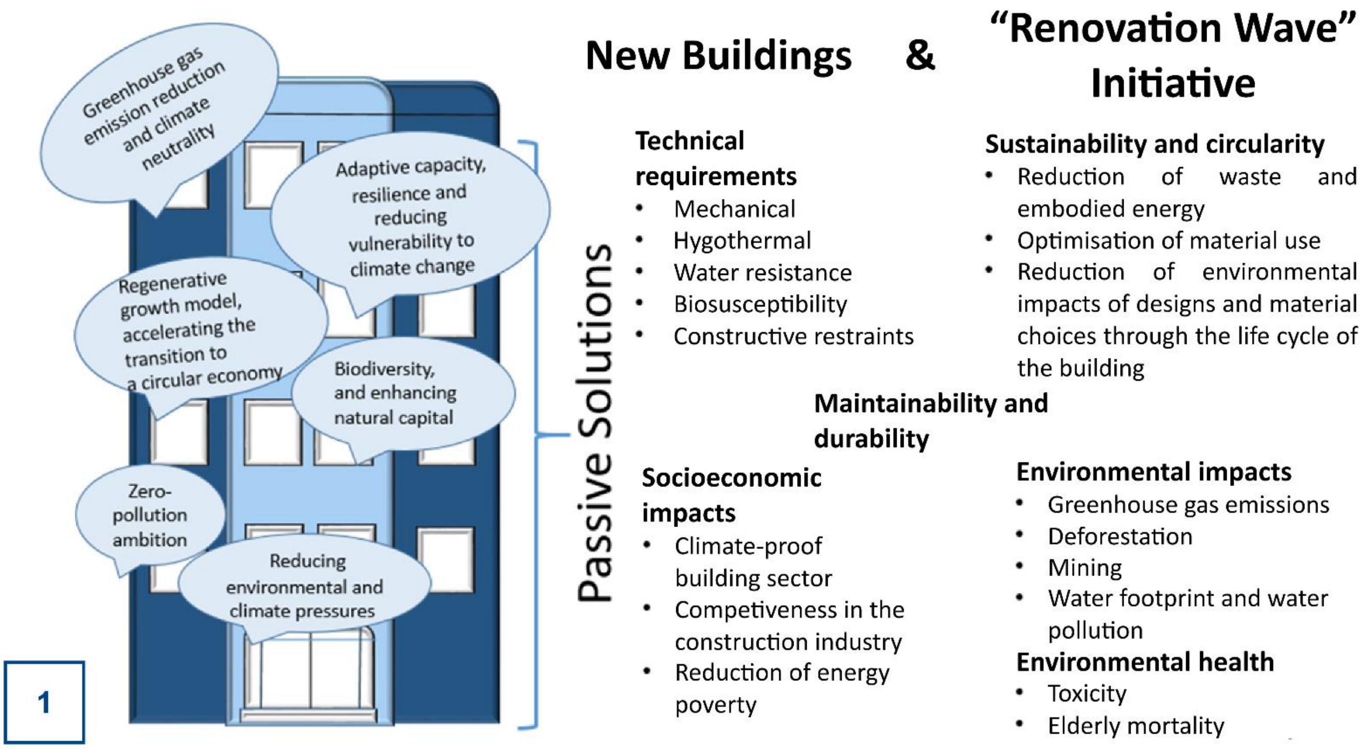

Figure 1: Main discussion topics of EFFICACY Project

The **EFFICACY** project (**E**nergy e**FF**iciency bu**I**lding and **C**ircul**A**r e**C**onom**Y** for thermal insulation solutions – FBR_OC1_114) brings together the Instituto Superior Técnico – IST (University of Lisbon – UL) and the Norwegian University of Science and Technology (NTNU), Faculty of Engineering, in Trondheim, with the sponsoring of the Bilateral Fund Operation Program from EEA Grants.

EFFICACY project addresses the development of guidelines for the use of thermal insulation solutions in the renovation of both new and existing buildings. These guidelines are synthetised in this manual, focusing on different key stakeholders as well as on present and future climate conditions.

Iceland, Liechtenstein, and Norway are cooperating actively with the EU Member States through the agreement on the European Economic Area (EEA). Under the scope of this agreement and to promote a continuous and balanced strengthening of economic relations and trade, the parties have established an annual Financial Mechanism, known as EEA Grants, which aims to reduce social and economic disparities in Europe and strengthen bilateral relations between these three countries and other beneficiary countries.

Instituto Superior Técnico (IST, University of Lisbon) has actively worked with the Norwegian University of Science and Technology (NTNU) to create new business opportunities and boost new research topics, contributing to the reduction of socioeconomic disparities between Portugal and other countries of the European Economic Area.

IST has a solid knowledge of performance and durability of thermal insulation materials, based on experimental data and numerical simulations. In addition, statistical methods and life cycle assessments have been incorporated.

NTNU team brings its extensive network of cooperation in research and practice on climate change, risk assessment and sustainable preparedness measures, which includes the Scandinavian countries. NTNU team also holds expertise in Northern Europe, monitoring the climate change effect, and preparedness measures which include energy efficiency and sustainable options for built cultural heritage.

The knowledge of climates in different regions could strengthen methodologies from both countries and extrapolate the proposed database/guidelines to a European level.

The principal investigators of the project are Professor Inês Flores-Colen (Full Professor at the Department of Civil Engineering, Architecture and Environment - DECivil, Instituto Superior Técnico, University of Lisboa, Lisbon, Portugal), and Professor Chiara Bertolin (Full Professor at the Department of Mechanical and Industrial, Faculty of Engineering Norwegian University of Science and Technology (NTNU), Trondheim, Norway).

The research team also includes:

- Researchers from IST: PhD Maria Paula Mendes (Researcher at CERIS – Civil Engineering Research and Innovation for Sustainability), Eng. João Parracha (PhD candidate at DECivil /IST and LNEC – National Laboratory for Civil Engineering), Eng. Giovanna Bartels (MSc student, Scholarship student at IST);
- Researchers from NTNU: Beatrice Bartolucci (PhD candidate at Department of Earth Sciences of Sapienza University of Rome), PhD Francesca Frasca (Researcher at Physics Department of Sapienza University of Rome), Giulia Boccacci (PhD candidate at Department of Earth Sciences of Sapienza University of Rome), Ozge Ogut (PhD candidate at Department of Mechanical and Industrial Engineering of NTNU; and Department of Architecture, Built Environment and Construction Engineering of Politecnico di Milano), and Professor Anna Maria Siani (Associate Professor at Physics Department of Sapienza University of Rome).

- Under the scope of the project, two Master dissertations were developed in IST by students Beatriz Loura (concluded) and Leo Soares (ongoing).

2. Project Summary and Results

Reducing energy consumption in the construction sector is essential for adapting and mitigating climate change. In the European Union (EU), buildings are responsible for over 40% of the overall energy consumption, with an anticipated increase of more than 80% by 2050, and they account for approximately 36% of CO_2 equivalent emissions.

Nearly 35% of EU buildings are over 50 years old, characterized by low energy efficiency, while approximately 75% of all buildings in the EU suffer from energy inefficiency. This energy poverty (EP) contributes to a significant social issue that affects the health of a large number of people, estimated between 50 to 125 million individuals, and leads to an elevated mortality rate, accounting for 30-50% of excess winter mortality. According to the built environment ranks, Portugal is among the least energy-efficient countries in the EU. Façades play a significant role in thermal exchanges with the exterior, directly affecting a building's energy consumption. In line with environmental and energy-saving EU Directives and Climate Law, recent measures have been implemented to move forward towards the achievement of the UN's 2030 Sustainable Development Goals and the target for reducing CO_2 emissions. These regulations and policies promote the use of thermal insulation solutions to improve building energy efficiency and decarbonisation. The EU is actively encouraging the transition to a circular economy (Directive 2019/904 EU), whereby the construction sector was identified with high resource use and great potential for circularity.

Potential advantages include increasing competitiveness through innovation, reducing socio-environmental impacts, generating jobs and boosting the economy and climate resilience.

The project comprised the following activities:

- A1 - Collection of national and international data - discussion among experts, stakeholders and final users about the available data concerning technical and environmental performance, as well as on maintenance for conventional and innovative thermal insulation solutions in buildings.
- A2 - Development of the EFFICACY project database (DB) comprising a dataset of criteria adopted in Norway and Portugal on the use of thermal insulation solutions in building facades, considering relevant performance parameters and climate-related requirements. This harmonized open-access database can be fed and extended in the future by other stakeholders and is fully available at the following link: https://data.mendeley.com/datasets/z8sphs8vvv/2.
- A3 - Development of EFFICACY guidelines to improve the selection of conventional and innovative thermal insulation solutions to be applied on façades of new and existing buildings. These guidelines are integrated in the EFFICACY manual and were translated in Norwegian and Portuguese.
- A4 - Communication and dissemination of the project results, including social news, web meetings, final workshop with target groups attendance and joint-papers (Figures 2 to 8).

Figure 2: Kick-off meeting held in IST (Lisbon, Portugal) in October 2021.

Figure 3: CHePiCC Summer School held at NTNU (Trondheim, Norway) in May 2022.

Figure 4: Meeting at NTNU and Technical visit to Røros (Preservation Centre), June 2022, Røros, Norway.

Figure 5: Open session of the final workshop, July 2023, with Prof. António Pinheiro (President of DECivil - IST), Prof. Rogério Colaço (President of IST) and Dr. João Telha (EEA Grants, Norwegian Embassy in Lisbon).

Figure 6: Presentation of the project results at the final workshop (with hybrid format.)

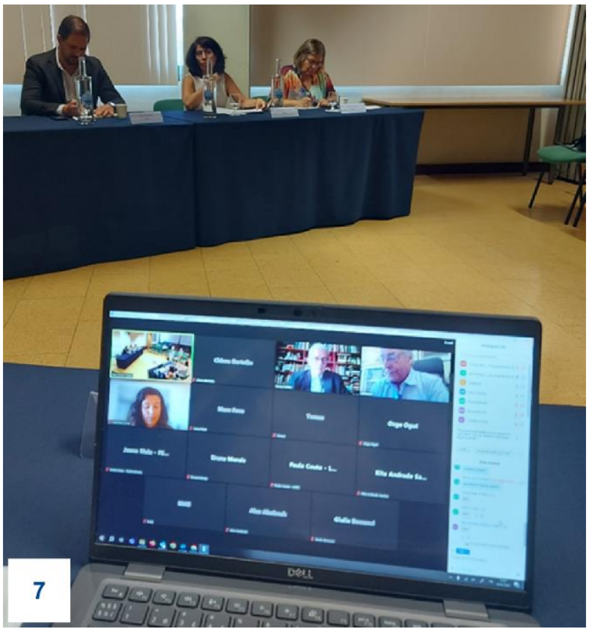

Figure 7: Roundtable discussion with the target groups (Carlos M. Oliveira e Silva from Amorim Cork Insulation, Carolina Costa from ADENE, Margarida Sousa from HCI, Rosário Veiga from LNEC, José Silvestre from IST and Vasco Freitas from FEUP).

Figure 8: Efficacy team members who attended the final workshop in-person: from left to right: Giulia Boccacci, Beatrice Bartolucci, Anna Maria Siani, João Parracha, Maria Paula Mendes, Chiara Bertolin, Inês Flores-Colen, Francesca Frasca and Giovanna Bartels.

EFFICACY project aimed to establish comprehensive guidelines that systematically define essential criteria for thermal insulation solutions, both for buildings retrofitting and new construction. These guidelines facilitate the selection of optimal passive solutions tailored to meet specific building requirements.

Additionally, the project aimed to create a standardized database encompassing both conventional and innovative thermal insulation solutions. This database served as a valuable resource to implement key measures and solutions aiming to catalyse the necessary shift towards a low-carbon, resource-efficient, and climate-resilient economy by 2050.

3. Energy Poverty (EP) Awareness

Together with the energy demand, the EU is experiencing a serious issue, with more than 50 million households living in Energy Poverty (EP) resulting in considerable indoor thermal discomfort. In 2018, the United Nations Economic Commission for Europe (UNECE) calculated that 14% of the global population lived without electricity, and 3 billion people worldwide did not have access to clean fuels and technologies for cooking. In 2020, an EU-wide survey revealed that 8% of the European population had difficulty or inability to maintain adequate comfort (warm temperature) inside their houses, as shown in Figure 9.

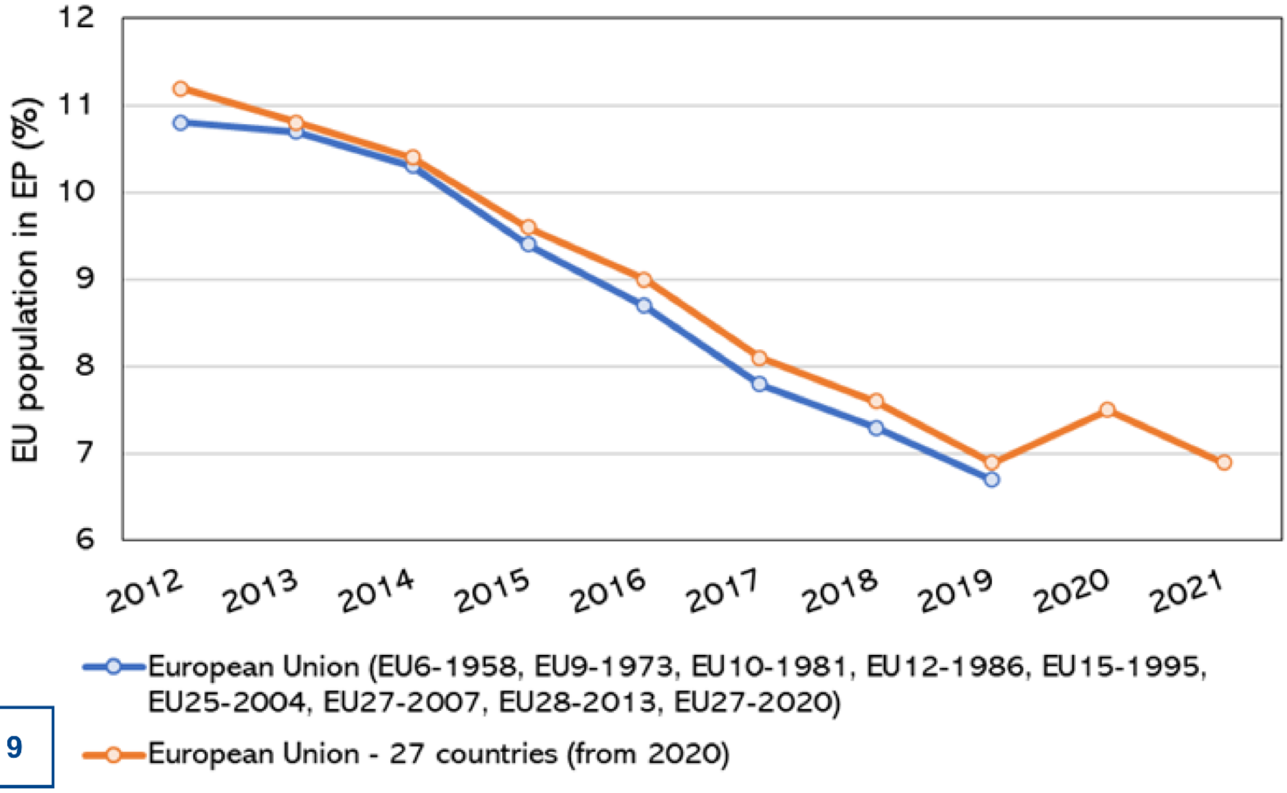

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Figure 9: Percentage of "Inability to Keep Home Adequately Warm" for the geopolitical entities of the European Union (data provided by the EU-SILC Survey, 2023). From 2012 to 2019, the blue line shows real data, and the orange line represents estimated data. From 2020 onwards, only estimated data is available.

In general, EP is associated with the difficulties of affording energy bills for keeping adequate levels of warmth, cooling, lighting, and energy to power appliances in building stock. EP is a combination of low income, high expenditure of disposable income on energy, and poor energy efficiency regarding the performance of existing buildings. Therefore, it can equally affect dwellings as well as public and industrial buildings, contributing to thermal discomfort and loss of productivity. In reality, the need to reduce energy costs affect the physical and mental health, and the well-being of residents.

The COVID-19 pandemic period and the consequent lockdown have forced people to stay at home. In addition, the war in Ukraine has led to a worldwide energy crisis in terms of higher energy prices, changing trade flows, supply shortages and energy policy change (e.g., coal phase-out, accelerated nuclear expansion). Both events have caused an increase in thermal discomfort, and consequently contributed to the growth of EP, mainly due to the rising energy costs and higher unemployment. Since 2019, thanks to the "Clean energy for all Europeans package", EP has become a policy priority. In this regard, the EU Commission is beginning to propose recommendations and tools to eradicate EP, acting in synergy to protect the areas most affected by EP, which are generally remote or low-income areas.

The review of these directives and recommendations is clear, as there are two main types of measures to mitigate the causes and consequences of EP:

- measures aimed at increasing household income and protecting against utility disconnections.
- measures aimed at decreasing energy related expenditures.

The first group includes short-term measures that are affecting the **EP consequences** through protection, price regulation, and direct financial support (e.g., deductions on monthly energy bills and financial allowances) to defend households against utility disconnections. The second group involves long-term measures that aim to address the **causes of EP**, improving the energy efficiency of dwellings. Among the long-term measures, there are energy efficiency improvements, heating system improvements, and implementation of low-cost energy efficiency measures such as including energy counselling and support for Renewable Energy Sources (RES). Concerning energy renovation carried out in a building, the type of intervention measures can be classified as follows: (i) building envelope; (ii) building technical systems; (iii) renewable heat generation systems; (iv) renewable electricity generation systems and; (v) other energy-related measures.

All EU countries should establish long-term measures to support the renovation of their national building stock into a highly energy efficient and decarbonized building stock by 2050. To that end, tackling EP in EU countries is of fundamental importance. In this study, an overview of the EP in Norway and Portugal is presented, and focus on the profiles and indicators (e.g., legislation, energy policies implementation, and the existing energy infrastructures and costs) of these countries, which are involved in the EFFICACY project.

Portugal has been listed among the most vulnerable European countries and pointed out as the fifth EU country with people who cannot afford to keep their home properly heated during the winter (19% in 2018 according to Eurostat data). Moreover, it is estimated that the residential building stock is aged. In fact, one third of the Portuguese building stock needs intervention and half of this proportion demands a deep renovation. This translates in high energy needs to fulfill minimal comfort driving households to an economically poor situation.

Portugal also presents one of the poorest rankings considering many of the most currently used EP indicators, with the second highest percentage in the EU (35.7% considering 2012 data) of people living in homes which were not comfortably cool during the summer. One of the highest mortality rates in the EU during the winter (EP indicator) has been observed in Portugal, mostly due to cold housing in the winter season. A survey conducted in 2017 showed that around 26% of the Portuguese population lives in dwellings presenting leaking roofs, damp walls or floors, or rot and moulds in window frames. In fact, most of the Portuguese buildings were constructed before 1990 and therefore prior to the first Portuguese Thermal Regulation. In 2021, about 80% of the existing buildings (with Energy Performance Certificates – EPCs) still had a low energy rating (values from C to F), with 10% having F rating (ADENE, 2022). Moreover, according to a recent study, 75% of national buildings do not have thermal insulation. Therefore, at a national level, the refurbishment of building envelopes represents an important approach.

Despite the widely conducted research on energy poverty (EP) in the European context, it is not specifically studied in **Norway**. According to the report of the FNI (The Fridtjof Nansen Institute), there are three reasons for this scarcity in research. First, EP is not a mentioned topic in Norwegian energy policy. Secondly, Norway is a decade behind when considering EU energy legislation, as the third energy market package has only been effective since November 2019. Lastly, being an EEA country, Norway is not obliged to report on EP in the EU.

The available information about EP is extremely limited to single statistics and indicators in publications:

- Statistics from 2003 to 2009 show that Norwegian households had the fewest problems among European countries in paying the utility bills, in having energy efficient houses, in heating the dwelling, in having affordable energy costs.
- Italian Agency for New Technologies (2019) shows that in 2016, Norway performed second best among European countries on two EP-related indicators: difficulty in staying warm (0.9% in Norway) and difficulty in paying the electricity bills (2.4% in Norway).
- EPSU (European Federation of Public Service Unions) and EAPN (European Anti-Poverty Network) showed that only 0.3% of the Norwegian population was unable to heat their home, based on Eurostat 2020 data.
- Data from Eurostat 2020 showed that 0.8% of the Norwegian population was unable to keep their home adequately warm, respect to the European average of 8.2%.

Despite being one of the top ten richest (in GDP-PPP, Gross Domestic Product – Purchasing Power Parity, per capita ($)) countries globally in 2022 (updated to the most recent data of 2019) economic inequality in Norway has been growing year after year. In fact, the 10% least wealthy have had a gradual decrease in their incomes since the 1980s, while the 10% most wealthy have had an increase. In total, 10% of Norwegians have persistent low incomes and this problem has steadily worsened since 2011.

3.1. General overview of the two countries

The **Portuguese** building stock is represented by 86% of residential buildings for about 10.5 million inhabitants in an area of approximately 92,226 km^2. Moreover, 14% of all Portuguese buildings were constructed before 1945 and 60% were built before 1990, i.e., prior to the first Portuguese thermal regulation.

Twenty-five percent of the Portuguese buildings can be considered historic and were designed using traditional constructive techniques (e.g., stone masonry, wood windows, floors, and roofs) without the application of any thermal insulating material. Therefore, these buildings present an extremely poor thermal performance.

Nevertheless, the thermal performance of the main constructive elements (e.g., walls and windows) has been improving, with significant progress verified in 1990, 2006 and 2013, which is in line with the publication of national regulations on buildings thermal performance. A web survey conducted in 2017 (n = 795) revealed that 74% and 25% of respondents considered their houses to be too cold during the winter or too warm during the summer, respectively. Only 1% reported that their houses provided thermal comfort. In this survey, 44% of respondents considered their houses both cold in the winter and too hot in the summer and reported the lack of thermal insulation as the main cause, while 27% did not identify any cause. Therefore, at the national level, the refurbishment of building envelope represents an important approach.

In **Norway**, the building stock is represented by around 40% of residential buildings until February 2022. In 2018, this percentage was smaller (37.11%). 76.34% of the total existing buildings and 81.40% of the existing residential buildings were built before 1997.

The total stock is mostly constituted by detached houses (75.52%). In 2021, there is a coverage ratio of energy performance certificate EPC labels equal to 44% of the residential building stock. 5% of the overall stock, excluding just buildings which were constructed before 2009, is anticipated to receive a C label class or higher. These are the ones that have either been constructed from the ground up or have undergone renovations to achieve higher energy efficiency standards than the building year (and associated building code) would suggest.

3.2. Legislation and Requirements

In **Portugal**, the first thermal regulation "Thermal Performance Building Regulation (RCCTE)" was published in 1990. This document introduced the use of thermal insulation in the Portuguese construction sector and imposed requirements on the design of new buildings to "raise awareness" of thermal comfort, insulation, and shading. In 1998, the publication of the Air-Conditioning Energy Systems Codes (RSECE) allowed to improve the indoor thermal comfort and Indoor Air Quality (IAQ), by providing further requirements to complement those prescribed in RCCTE. However, these guidelines and requirements were not enough to significantly reduce energy consumption of buildings.

Then, the EPBD (Directive 2002/91/EC) was transposed in Portugal, originating the Buildings Energy Certification System and indoor quality (SCE 2006) and the Air-Conditioning Energy Systems Codes (RSECE 2006), which defined a set of minimum characteristics required for the thermal properties of the building envelope. This regulation has provided the basis for the energy performance certificate (EPC).

In Europe, the EPBD recast (2010/31/EU) was introduced in 2010, whose main objective was to improve the energy efficiency performance of buildings. Moreover, Under the National Action Plan for Energy Efficiency, the Energy Efficiency Fund launched "*Aviso 25*", whose objectives are to promote the rational use of energy in the building sector, which represents around 30% of total energy consumption in Portugal, and to provide soft loan-based schemes for building renovation which have been implemented at a national level (e.g., *"Casa Eficiente"*). With regard to residential buildings the definition of requirements and the assessment of energy performance are based on the thermal behavior and efficiency of the systems, while for commercial and services buildings, they are based on the installation, management, and maintenance of technical systems.

General principles are also defined for each definition of requirements, materialized in specific requisites for new buildings, buildings subject to major intervention, and existing buildings.

In **Norway,** the first thermal regulation for buildings is the “Building Code” from 1949, which includes four climatic zones. For each climatic zone it assigns a thermal transmittance value to the elements (opaque and otherwise) of the buildings. The same applies to the “building Code” from 1969. In 2010, Norway has fully implemented the European Directive 2002/91/EC. In 2015, specific requirements applied only for residential buildings are those of TEK17. In TEK10, the chapter 14 was expressly dedicated to the topic of ‘energy’ as well as in TEK17. Based on TEK17 (still in effect), the total net energy demand cannot exceed 95 kWh/m^2 heated bruksareal (available area) (BRA) per year for residential blocks.

The calculations of the buildings’ energy needs, and heat loss must also follow the Norwegian Standard NS3031:2014 Calculation of buildings’ energy performance that is derived from EN15603. In chapter 14.3 of TEK10, the minimum requirements for energy efficiency are specified. These regulations remained the same in TEK17. Additionally, according to TEK10, the insulation must satisfy Euroclass E or NT Fire 035 Building products: Flammability and smoldering resistance of loose-fill thermal insulation (section 11.9). In accordance with TEK17, an extension is integrated into Part D, emphasizing insulation within building components. TEK17 can be considered one of the strictest building requirements in Europe to achieve carbon-neutral initiatives by 2027.

An agreement made in the Norwegian Parliament in 2012 stated that all new buildings must reach the ‘Passive House’ level by 2015, and the NZEB (Nearly zero-emission building) level by 2020; thus, the requirements for 2020 and the national definition of NZEB are complying with the European Directive 2010/31/EU.

Since 2017, TEK17 standard reduces the existing gap between “normal” houses and passive houses– NS 3700:2013 (Norwegian passive house standard for residential).

3.3. Scenarios-trends in renewable energy use

Portugal is highly dependent on imported energy. In 2021, more than two-thirds of the energy consumed in the country resulted from imported fossil fuels. However, Portugal is making progress in shifting to renewable energy and in 2017, 21% of the energy in Portugal was renewable, increasing to 27% in 2018 and rising to 33% in 2021.

In fact, in 2021, 63% of the electricity used for buildings came from renewable resources, mainly from wind and hydropower. Concerning the IRENA statistics about renewable energy resources, Portugal frequently reports high levels of power capacity from renewable sources, which have been gradually but steadily rising. The type of renewable energy that has seen an increase in capacity data in recent years is solar energy, which increased from 238 MW (2012) to 1801 MW (2021) of power capacity. Considering the industrial users, 58% of the energy costs are also due to tariffs and taxes. This greatly prevents electricity from competing with other fuels, which represents a barrier to the fulfilment of Portugal’s goals for electrification. It is worth noting that Portugal’s energy and climate policies are focused on electrification of building energy demand towards carbon neutrality.

In fact, Portugal has already achieved a high level of electrification, with electricity covering 25% of the total final energy demand and 56% of building energy demand.

In **Norway**, the energy consumption of the building is dependent upon hydroelectric power, with some district heating or based on bioenergy. The share of fossil fuels is very low and is declining over the years. This is also happening with data on power capacity from renewable resources such as wind energy, solar energy, and bioenergy. The charts show that hydroelectric power is the most capacitive in terms of generation of energy and the other renewable resources, despite having low values, remain constant or have increased over time. For example, there is a gradual increase in the capacity of generating energy from solar resources: in ten years, the power capacity has increased from 10 MW to 225 MW. After an almost constant period (from 2012 to 2016), the power capacity of wind energy has also recorded an increase of 285% for the period 2017 – 2021.

3.4. Awareness, Barriers, and Facilitators to alleviate Energy Poverty

Figure 10 presents a conceptual frame of the factors that influence energy poverty (EP) awareness, energy use behavior, in addition to external barriers and facilitators. The figure highlights the interconnectedness of these factors and the potential for cascading effects, whereby small changes in individual behavior can lead to larger-scale behavioral revolutions.

It shows what can be used to start the development of interventions and policies that promote EP awareness and behavior change.

For further reading [1].

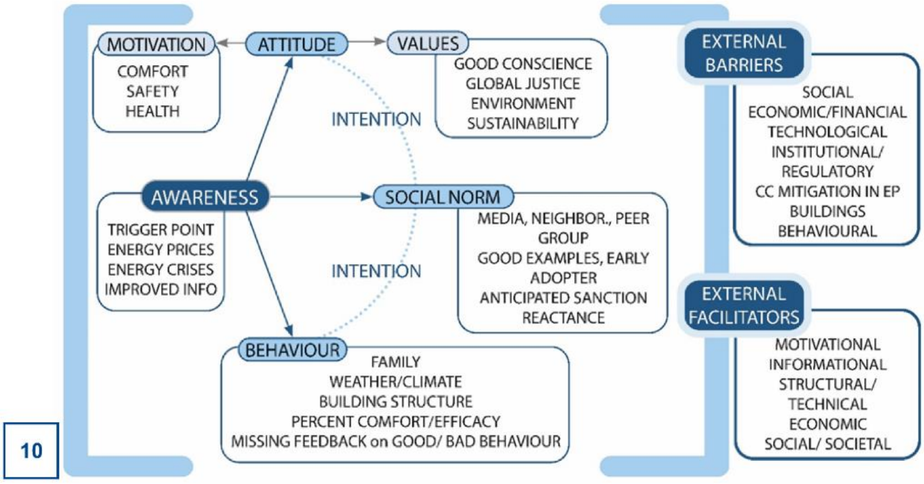


Figure 10: EP awareness relation

For instance, by understanding the role of social norms in influencing energy use behavior, policymakers can design interventions that leverage these norms to encourage more sustainable energy practices. Similarly, by understanding the economic barriers to energy efficiency, policymakers can develop financial incentives to support individuals and businesses in making energy-efficient investments.

People may become more aware of the need to conserve energy after a trigger point in their lives, such as an increase in energy prices, the spread of an energy crisis, or greater transparency. In this framework, EP awareness depends on three parameters i.e., attitude, social norm, and behavior. Each parameter is summarized below:

a) Attitudes:

- People are motivated to conserve energy to achieve minimum standards of health, safety, and comfort inside their homes.
- People are more likely to conserve energy if they value carbon free energy transition, energy use reduction, and Climate Change mitigation actions.

b) Social norms:
   - People are influenced by the flow of information coming from mass media, neighborhoods, peers' group, and family members.
   - People may be triggered to conserve energy by social shocks (i.e., reactance to a strong energy crisis) or by the fear of sanctions.

c) Behavior:
   - People's behavior is influenced by weather/climate, building structure, the ratio for comfort/efficacy, and missing feedback on good/bad behavior.

In addition to these factors, there are also external barriers and facilitators, which have significant impact on EP awareness. The **external barriers** can be divided as social, economic, and technological as follows:

- <u>Social barriers:</u>
  - People may mistrust governmental policies.
  - People may not understand legislative support for energy retrofitting interventions.
  - People may feel politically invisible.
  - People may lack information or receive contradictory information.
  - People may not receive feedback on their energy use.
- <u>Economic barriers:</u>
  - People may lack the money to afford long-term energy efficiency measures.
  - The payback period for energy efficiency measures may be too long.
  - The payback rate of the investment in energy efficiency measures may be too low.

- Technological barriers:
  - The climate, geography, and building structure.

On the other hand, external factors can work as **facilitators** as well:

- People may be motivated to conserve energy to save money, reduce their environmental impact, and improve their health and comfort.
- People may be more likely to conserve energy if they have access to accurate and easy-to-understand information about energy efficiency.
- Energy-efficient appliances and building materials can make it easier for people to conserve energy.
- Government subsidies and tax breaks can make energy efficiency measures more affordable.
- Community programs and social norms can encourage people to conserve energy.

4. Criteria to select thermal insulation materials

4.1. Types of insulation materials

Figure 11 shows the most used thermal insulation materials in Portugal and Norway, whereas Table 1 briefly reports some technical and environmental features of such materials extracted from the Environmental Product Declarations (EPD) [2]. In the following subsections, a brief description of these materials is provided.

Organic plant thermal insulation materials

- *Wood Fiber*

Wood Fiber is a natural-based insulation material with a thermal conductivity ranging from 0.037 W/(m.K) to 0.047 W/(m.K), and it has a high-water vapor permeability, with μ = 4 [1]. It is a good acoustic insulator, and it is the most sustainable material from the CO_2 equivalent emissions point of view (-198.4 $kgCO_{2eq}$) [1]. As for CF and considering the resistance to fire, it is a non-fireproof insulator, belonging to Euroclass E [1, 2]. WF panels are used to realize external thermal insulation and internal coverings and for the insulation of cavities of wooden or brick-concrete structures in Italy.

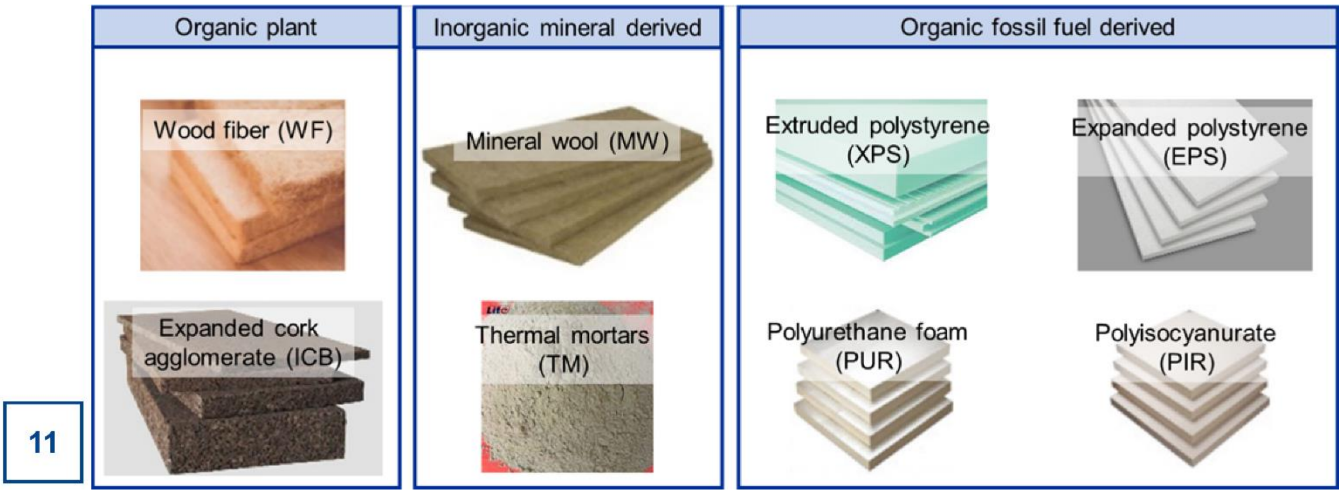


Figure 11: Most used thermal insulation materials in Portugal and Norway, adapted from [3, 4].

- *Expanded cork (ICB)*

ICB is a renewable, 100% natural, and fully recyclable material made from natural cork without chemical adhesives or additives that can be applied on the envelope of new and refurbished buildings to improve their energy efficiency. The thermal performance of ICB is highlighted by its low thermal conductivity, between 0.040 and 0.045 W/(m.K) (0.043 W/(m.K) for [7]).

The physical and mechanical properties of cork lead to an elastic, steam permeable and durable product, with excellent thermal and acoustic insulation characteristics. ICB is normally commercialized in boards, which are still easily handled (density is higher than EPS or XPS), perforated and cut in the construction site without losing their thermal performance.

Table 1. Information on the most used thermal insulation materials in Norway, and Portugal clustered by type (organic plant, inorganic mineral derived, organic fossil fuel derived, structure (fibrous, cellular, porous), and building application location. A relevant parameter (p) is provided. C = cellular, F = fibrous, P = porous.

Thermal insulation material based on EPDs	**Type**	**Internal microstructure**	**Building main applications**	**Parameter (p) and unit**		
				Thermal conductivity	**GWP total [A1-A3]**	**Reaction to fire**
				$W \cdot m^{-1} \cdot K^{-1}$	$kgCO_{2eq} \cdot m^{-2}$	A1/F
Expanded cork agglomerate (ICB) (1)	Organic plant	C	Roofs, floors, walls	0.043	-612.00	E
Wood fibre (WF) (2)	Organic plant	F	Roofs, floors, walls	0.037	-47.62	E
Mineral wool (MW) (3)	Inorganic mineral derived binder	F	Roofs, walls	0.032	3.6	A1
Thermal mortars (TM) (4)*	Inorganic mineral derived binder	P	Walls	0.045	21.89	A1
Expanded polystyrene (EPS) (5)	Organic fossil fuel derived	C	Roofs, floors, walls	0.038	21.96	E
Polyisocyanurate (PIR) (6)**	Organic fossil fuel derived	C	Roofs, walls	0.023	0.33	B-S2, d0
Polyurethane foam (PUR) (7)	Organic fossil fuel derived	C	Roof, vertical cavities	0.020	13.8	E
Extruded polystyrene (XPS) (8)	Organic fossil fuel derived	C	Roofs, floors, walls	0.034	7.56	E

(1) Amorim Cork Insulation, (2) IBU – Institut Bauen und Umwelt e.V., (3) KnaufInsulation, (4) DIASEN srl, (5) Finja, (6) Europerfil, (7) Polyurethan dammt besser, (8) DANOSA; *Thermo-plaster ecological thermal and breathable, formulated with cork, natural hydraulic lime, clay, and diatomaceous powders; **Fire reaction of PIR varies according to additives (from B,s2-d0 to F). B,s2-d0 was chosen as it was the most commonly used material. It is worth noticing that in this paper the criterion is related to safety of households, although it could be considered as a technical parameter.

The thermal conductivity of this material is significantly affected by temperature, moisture content, and density. As an organic-based material composed of suberin, lignin and polysaccharides (cellulose and hemicellulose), ICB is more vulnerable to fungal deterioration triggered by high moisture content values since they provide ample nutrients through their composition to fungal growth.

Portugal is the world's largest producer and exporter of cork-based materials. Nevertheless, there is no local system of incentives or support programs for the application of cork or insulation cork boards as a sustainable material that can also provide an improvement in the energy efficiency of buildings. ICB is one of the most used thermal insulating materials in Portugal due to its enhanced thermal and acoustic performances, local availability, and sustainability. In Portugal, there are two ICB products and three ETICS systems with ICB thermal insulation with an Environmental Product Declaration (EPD) for the built environment [8].

In Italy, cork is widely used in green building due to its features: it is ecological, renewable, recyclable, and reusable. It is biocompatible and it can be applied to internal or external insulation or in a cavity. It has excellent thermal insulation properties and water vapor permeability of $\mu = 10$ [7]. It has also enhanced acoustic performance. CO_2 equivalent emissions for stages A1-A3 for ICB is about -0.21 $kgCO_{2eq}$ for a thickness of 20 mm, and -0.61 $kgCO_{2eq}$ for a thickness of 100 mm [7].

<u>Inorganic mineral derived thermal insulation materials</u>

- *Mineral Wool*

Mineral wool covers glass wool and rock wool. Glass wool is obtained by mixing natural sand and glass (usually recycled) at 1300-1450°C, while rock wool is manufactured by melting at 1600°C several kinds of rocks (e.g., dolostone, basalt, diabase), thus obtaining fibers bound together using resins.

Both are commercialized as panels, felt pipe sections, or rolls. MW is quite common in Italy, Norway, and Portugal due to its enhanced thermal performance, low cost, ease of application, good acoustic properties, and enhanced fire behavior. Glass wool is available in the form of thin strands of intertwined glass [9]. This permits the material to be a perfect minimizer of heat transfer and fire risk: its Euroclass reaction to fire is A2-s1, d0, that means it is fireproofed with a low probability of fumes (s1) and no dripping when exposed to heat (d0) [4]. Rock wool has no additives to make it resistant to fire, and its Euroclass classification is A1 in semi-rigid or rigid panels without any coating [10]. Many standards define the specification of this material, for example:

- EN 13162 Thermal insulation products for buildings. Factory made mineral wool (MW) products. Specification.
- EN 14064-1 Thermal insulation products for buildings. In-situ formed loose-fill mineral wool (MW) products. Part 1: Specification for the loose-fill products before installation.
- EN 14064-2 Thermal insulation products for buildings. In-situ formed loose-fill mineral wool (MW) products. Part 2: Specification for the installed products.
- EN 14303 Thermal insulation products for building equipment and industrial installations. Factory made mineral wool (MW) products – Specification.
- EN 13964 Suspended ceilings - Requirements and test methods

The thermal conductivity values of MW range between 0.032 W/(m.K) [11] and 0.037 W/(m.K) [12]. The thermal conductivity of this material is significantly affected by temperature, moisture content and density. They provide good acoustic insulation characteristics and high-water vapor permeability.

Moreover, MW boards are easily handled, perforated, and cut in the construction site without losing their thermal performance. The main disadvantage of MW is related to health risk: the glass fibres are so thin that if handled without (or with inappropriate) protection, fibres may be inhaled potentially damaging the respiratory system or damaging eyes, and skin [9]. Considering the CO_{2eq} emissions for A1-A3 LCA phases, the value of mineral wool insulation is 3.6 $kgCO_{2eq}$ (for λ = 0.032 W/(m.K)) [11] and 17.5 $kgCO_{2eq}$ (for λ = 0.037 W/(m.K)) [12].

- *Thermal mortars (TM)*

Thermal mortars are defined by the standard EN 998 as mortars with thermal insulation properties (i.e., a dry thermal conductivity lower than 0.2 W/(m.K) at 10 ºC). These mortars are formulated using different lightweight aggregates (e.g., expanded polystyrene, cork, expanded clay, silica aerogel) and some admixtures (e.g., air entraining agents), which strongly contribute for a significant reduction of the mortar thermal conductivity [13]. The trend and the market of these mortars is spreading throughout Europe (also in Portugal), being applied in new construction but also for the thermal retrofitting of building façades. These mortars have enhanced thermal performance and have very low density. They are also being applied as thermal insulation layers of ETICS. Nevertheless, they present some advantages over traditional thermal insulation board materials (EPS, XPS, MW, ICB), such as the possibility of leveling uneven surfaces, direct application over the substrate, and the possibility of being adopted for retrofitting external walls of historic buildings. Their low mechanical resistance and considerable high cost are some of the drawbacks.

<u>Organic fossil fuel derived thermal insulation materials</u>

- *Expanded and extruded polystyrene (EPS and XPS)*

Expanded polystyrene (EPS) is made from small spheres of polystyrene containing an expansion agent: this process allows the production of a white, rigid, and closed-cell foam with thermal conductivity values of 0.037/0.038 W/(m.K) and density of about 15/18 kg/m^3 for the EPDs [14, 15]. The acoustic performance of this material is neglected, and EPS is easily flammable and its burning releases dangerous gases to the environment and people (E Euroclass related to the fire behavior). The CO_{2eq} emissions range from 61.0 (EPS80) to 73.2 $kgCO_{2eq}$ (EPS100). EPS is described and defined in the following standards:

- EN 13163: Thermal insulation products for buildings. Factory made products of expanded polystyrene (EPS). Specification.
- EN 14309: Thermal insulation products for building equipment and industrial installations. Factory made products of expanded polystyrene (EPS). Specification.
- EN 14933: Thermal insulation and lightweight fill products for civil engineering applications. Factory made products of expanded polystyrene (EPS). Specification.

Extruded polystyrene (XPS) is produced by melting the polystyrene grains (from crude oil) into an extruder, with the addition of a blowing agent. XPS has a closed pore structure, and its thermal characteristics are remarkably similar to those of EPS, though absorbing less moisture (μ_{XPS} ~ 200 [16] and μ_{EPS} ~ 50, according to [6]). Thermal conductivity of XPS is approximately 0.034 W/(m.K) for a density of 32.41 kg/m^3, and the emissions for A1-A3 stages are lower than EPS [16].

The thermal conductivity of EPS and XPS is significantly affected by temperature, moisture content and density, i.e., the higher the moisture content and the density, the greater the thermal conductivity. Both materials are normally commercialized in boards, which are easily handled, perforated, and cut in the construction site without losing their thermal performance. Nevertheless, XPS is about 10% to 30% more expensive than EPS. The XPS is defined within the standards:

- EN 13164 (Thermal insulation products for buildings. Factory made products of extruded polystyrene foam (XPS). Specification.
- EN 14307 (Thermal insulation products for building equipment and industrial installations. Factory made extruded polystyrene foam (XPS) products. Specification).

EPS and XPS are widely used in the Italian, Norwegian, and Portuguese markets mostly due to their enhanced thermal performance, ease of application, and low cost. However, there is an increasing awareness of the need for sustainable thermal insulating materials, i.e., eco-efficient, renewable, and locally available materials with low carbon footprint.

Some studies concluded that ETICS with ICB is environmentally advantageous both in terms of carbon footprint and consumption of nonrenewable primary energy (i.e., the production stage of ICB is less polluting than EPS). Nevertheless, ETICS with EPS still perform better in the economic dimension. The latter continues to have a greater importance for designers and promoters.

- *Polyurethane foam (PUR)*

Polyurethane foam (PUR) is also a common thermal insulating solution in Italy, Norway, and Portugal, as defined by the standards:

- EN 13165: Thermal insulation products for buildings. Factory made rigid polyurethane foam (PUR) products. Specification.
- EN 14308: Thermal insulation products for building equipment and industrial installations. Factory made rigid polyurethane foam (PUR) and polyisocyanurate foam (PIR) products. Specification.

This material is formed by a reaction between isocyanates and polyols (alcohols containing multiple hydroxyl groups). During the expansion process the closed pores are filled with an expansion gas (e.g., HFC, CO_{2eq} or C_6H_{12}). PUR can be used to produce panels, or it can be expanded in the building site as foam. It is commonly used for flat roofs, under-tile insulation, and for vertical surfaces and cavities.

The thermal conductivity of this material is between 0.022 W/(m.K) and 0.040 W/(m.K), depending also on the type of insulator (i.e., boards or liquid). For the EPD here cited [17], λ = 0.023 for a density of 32.29 kg/m^3. Thermal conductivity varies with moisture content, temperature, and density. Its major issue is related to fire. In fact, during a fire, PUR will burn and release hydrogen cyanide (HCN) and isocyanates, which are extremely toxic substances. The emissions of CO_{2eq} for this material are remarkably high, reaching 13.8 $kgCO_{2eq}$ [17], however the energy savings that can be reached by applying this thermal insulation are within 40%. Additionally, this material has enhanced acoustic performance, and a water vapor permeability μ = 4.15.

PUR foams are widely used in these three countries due to their enhanced thermal performance (better than EPS, XPS and ICB) and ease of application (i.e., it can be applied as cavity insulation). Flame-retardant PU have been studied in recent years. Moreover, a study from ANPE showed that PUR foams do not excessively modify their functional features for at least 28 years [18].

- *Polyisocyanurate (PIR)*

Polyisocyanurate boards (PIR) are one of the most common thermal insulating materials identified in Norway. PIR was developed in 1967 (i.e., 17 years later PUR's invention) to improve thermal stability and flame resistance. PIR is a commonly used solution in Norway due to its low density, good compressive resistance, high thermal conductivity, high closed-cell content, low water absorbance, low water vapor permeability, and high flame and smoke performance [19].

It requires only half of the thickness of mineral-based insulation products, which is especially relevant in countries with harsh winters. PIR is usually cut into boards, can be used in insulated metal panels, wall cavities and as insulated plasterboard [20]. Additionally, PIR insulation products are described in the same standards where PUR is described (EN 14308, Thermal insulation products for building equipment and industrial installations. Factory made rigid polyurethane foam (PUR) and polyisocyanurate foam (PIR) products. Specification).

The thermal conductivity of PIR ranges between 0.021 W/(m.K) and 0.028 W/(m.K), (0.023 W/(m.K) for EPD [21]) with a CO_{2eq} emission of approximately 0.325 $kgCO_{2eq}$ for A1-A3 phases of Life Cycle Assessment. This material has a good acoustic performance, and a fire behaviour, which depends on the type of PIR. The most common is B,S2-d0, but it can also be B,s1-d0, or D,s2-d0, or E or F. The service life of PIR boards was estimated to be approximately 50 years [19, 21]. Figure 12 shows two Venn diagrams which represent the most commonly used thermal insulation materials commonly used in Norway and Portugal.

12

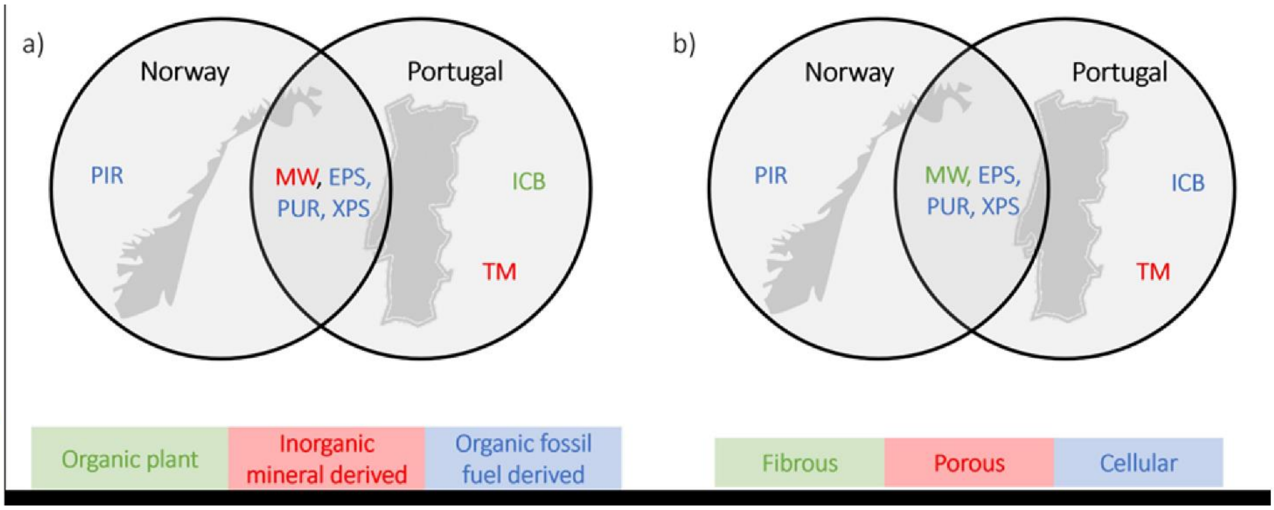


Figure 12: Venn diagrams of the most used thermal insulation materials divided by (a) type (green: organic plant, red: inorganic mineral derived, and blue: organic fossil fuel derived) and (b) fibrous (green), porous (red), cellular (blue) structure in Norway, and Portugal.

In **Norway** the most common thermal insulation materials are wood fibre (WF), mineral wool (MW), polyurethane foam (PUR), polyisocyanurate (PIR), expanded and extruded polystyrenes (EPS and XPS). In Portugal, and according to the manufacturers, the most used thermal insulation materials expanded and extruded polystyrenes (EPS and XPS, respectively), expanded cork agglomerate (ICB), mineral wool (MW), rigid polyurethane foams (PUR), polyisocyanurate (PIR), and thermal mortars (TM).

The **Portuguese** Montado agro-forestry-pastoral system produces approximately half of the cork harvested annually worldwide, even though no incentives or support programs for the application of cork or insulation cork boards as a sustainable material are available.

It is worth noticing that PIR, usually employed in Norway and Portugal, requires only half of the thickness of mineral-based insulation products (e.g., MW), which is especially relevant in countries with harsh winters (ET climate zone according to Köppen-Geiger classification) and, being usually cut into boards, can be used in insulated metal panels, wall cavities and as insulated plasterboards.

PIR, commonly used in Norway, is characterised by a low thermal conductivity (λ < 0.025 W/(m.K)) and a good reaction to fire (B-S2, d0). Both features would allow meeting wooden Norwegian vernacular architecture requirements of high thermal resistance (even with low thickness) and high safety against fire.

As the global market is moderately competitive due to many suppliers in the building insulation market, prices do not significantly differ, especially in the case of organic fossil fuel derived in each country. Most thermal insulation products have a unit cost less than 10.00 $€\cdot m^{-2}$.

The Norwegian market applies the lowest unit cost to WF (unit cost comparable with Italian market), MW, TM and EPS (price comparable with the Portuguese market) and the highest unit cost to ICB, PIR and PUR. The low unit cost of WF in Norwegian markets might be due to the availability of the raw material and its large implementation in Norway vernacular architecture, typically characterised by wooden building stocks. The high unit cost of ICB in Norway is mainly due to import expenses. The Portuguese market applies the lowest prices to EPS, PUR and XPS, and the highest prices to TM.

Thermal insulation materials could highly affect the overall energy efficiency and sustainability of buildings as they contribute to improve the thermal performance of the building envelope, appliances, or other equipment. However, there is no material (or technology) that alone can solve the energy issue either in new buildings (near-zero-energy buildings) or in retrofitting/refurbishment (renovation) projects.

Indeed, the improvement in energy efficiency through passive thermal insulations may contribute to reducing both energy bills (hence, Energy Poverty) and the greenhouse gases emissions from fuel combustion.

The differences that exist in both Norwegian, and Portuguese approaches to thermal insulation of external wall show the complexity of future problems associated with preparing uniform European thermal legislation.

4.2. Choice of insulation materials

The new policies connected to population densification and decarbonisation encourage the adaptive reuse of existing buildings, their maintenance, refurbishment, and retrofit.

Regarding the selection of the most suitable thermal insulation material for building retrofitting, a set of requirements has been adopted rather than only the thermal performance of the material itself. The choice of the most suitable thermal insulation material for building retrofitting, should consider a dataset of criteria, such as the TEnSE approach: *T:* urgency and attitude towards the necessity of building retrofit, considering the overall energy consumption and supply; *En:* attention to environmental contexts based on the specific climate conditions of the area under study; *S:* capability of population to live in satisfactory and safety conditions inside their dwelling; and *E:* capability of population to face building-related expenses and of country to produce primary energy [2].

However, there is a series of other parameters that must be considered, such as the availability of raw materials; the knowledge and implementation of traditional applications; embodied energy, end of life recycle capability, CO_2 storage capability, toxicity; constructive restraints; and well-being impacts. These aspects can widely vary with each country.

Further reading [22, 23, 24].

4.3. Efficacy database

Data was gathered from an online questionnaire survey on the use of thermal insulation solutions for new construction and thermal retrofitting of building façades in Norway and Portugal. The questionnaire was prepared using Google Forms and disseminated online via email and social media in the period between November 2022 and February 2023. A poster with the questionnaire survey available via a QR code was also displayed at the authors' universities. To avoid duplicate responses, the questionnaires included a section for participants to enter their email addresses. Additionally, all responses were initially screened to identify possible duplicates, which were removed from the sample.

The main objective of this study was to analyse the level of knowledge and perception of the respondents related with thermal insulation performance, as well as the needs regarding thermal comfort inside their dwellings. The questionnaire was developed by the EFFICACY research team considering the relationships among the various Political, Economic, Social, Technological, and Environmental key factors (i.e., PESTE analysis) involved in the choice of thermal insulation solutions. Demographic and calibration information (e.g., age, gender, nationality, level of education, among others) was also considered.

The respondents were randomly selected to have a wider range of answers from professional and non-professional figures. Nevertheless, particular focus was put on stakeholders, researchers working in the field of the energy efficiency of buildings and thermal insulation materials, private research institutions and non-profit associations working on energy efficiency of buildings and circularity, building professionals, manufacturers of thermal insulation solutions, university professors and students from related fields (e.g., energy efficiency, circular economy, social impacts, climate change).

A questionnaire-based rating system was also developed, with people rating several of the most used thermal insulation solutions (i.e., insulation cork board (ICB); mineral wool (MW); expanded polystyrene (EPS); extruded polystyrene (XPS); polyurethane foam (PUR); natural fibers (NF); aerogel blankets (AB), thermal insulating mortars (TM); vacuum-insulation panels (VIP); and vegetation – green walls (VEG)) according to their performance characteristics.

Some of the results are the following:

- We have obtained 203 responses to the questionnaire (124 from Portugal, 22 from Norway, and 57 from other EU countries); 52% and 77% of Portuguese and Norwegian respondents have thermal insulation in their building, respectively; 57% and 45% of Portuguese and Norwegian respondents believe their building needs an energy retrofit, respectively; however, 49% and 59% of Portuguese and Norwegian respondents is satisfied with the indoor comfort level.
- Norwegian respondents considered MW, EPS and XPS the most durable solutions, and ICB, AB and VIP the least durable. In the case of Portugal, ICB, MW and XPS were pointed out as the most durable solutions, and VEG the least durable.

- Based on the opinion of the Portuguese respondents, the most expensive solutions are ICB, AB and VIP, and the least expensive are MW, EPS and PUR. The Norwegian respondents consider AB and VIP as the most expensive solutions, and MW and EPS the least expensive.
- VEG was pointed out as the solution with the highest need of maintenance by Portuguese and Norwegian respondents. ICB and XPS were the solutions with lower need of maintenance according to several Portuguese respondents. MW, EPS, XPS and PUR were the solutions presenting lower need of maintenance in the opinion of the Norwegian respondents.
- Based on the opinion of the Norwegian respondents, the solution with the worst fire behaviour in the opinion of the Norwegian respondents is NF. According to the Portuguese respondents EPS and PUR show the worst fire behaviour.
- Norwegian respondents considered VEG as the solution with the highest bio-susceptibility, and EPS, XPS and PUR the solutions with the lowest bio-susceptibility. Results are in accordance with those obtained considering the Portuguese responses.
- Both countries considered VEG as the solution with the highest water retention. The solutions with the lowest water retention for the Portuguese respondents are EPS, XPS, PUR and VIP. The Norwegian respondents considered PUR and VIP as the solutions with the lowest water retention.
- In the opinion of the Portuguese respondents, TM is the solution with the highest mechanical resistance, and MW and VEG the solutions with the lowest mechanical resistances. Norwegian respondents considered both MW and VIP the solutions with the lowest mechanical resistances, and TM the solution with the best mechanical performance.

- ICB and VEG were considered the most sustainable solutions in Portugal and Norway. PUR was pointed out as the least sustainable solution in Portugal, whereas EPS and PUR were considered the least sustainable solutions in Norway.

The data provide a new understanding on the use of thermal insulation solutions in building façades located in Norway and Portugal and can be useful for researchers working in the field of the energy efficiency of buildings and thermal insulation materials who seek to further understand the use of different thermal insulation solutions. A data article was published in *Data in Brief* journal [25].

5. Energy Demand and Indoor Climate Control in time of Climate Change

5.1. Climate, social and economic factors

Norwegian Köppen-Geiger climate zones are mainly continental (Dfb and Dfc), moderately polar in the central (ET) and poorly temperate in southern coasts (Cfb and Cfc) [26]. Portuguese climate zones are mainly temperate (Csa and Csb, mainly corresponding to ASHRAE [27] 3A) and partially arid in southern region (Bsk). Norway has the highest value of heating degree-days (HDD = 5098.68°C), whereas Portugal has the highest value of CDD = 266.79°C.

As for Norway, while it is not densely populated as a whole, there are concentrated population centers primarily located in the southern regions, particularly in coastal areas.

Cities such as Oslo (Cfb), Bergen (Cfb), and Stavanger (Cfb) are among these population centers. Mainland Portugal exhibits a pronounced disparity in population density, characterized by densely populated coastal areas juxtaposed with sparsely inhabited interior regions. Specifically, the northern coastal zone, notably the Oporto district (Csb climatic zone), in conjunction with the central region, particularly the

Lisbon district (Csb climatic zone), and the southern Algarve region (Csa climatic zone), demonstrate a notably higher population density. The elevated temperatures, especially prevalent in the southern and inland areas, engender a substantially heightened rate of evapotranspiration in comparison to Northern European countries.

This heightened evapotranspiration rate, along with other factors, plays an important role in exacerbating interior desertification. The ramifications of desertification in the interior regions of Portugal extend beyond environmental concerns, influencing ecosystems, poverty alleviation efforts, socioeconomic stability, and the pursuit of sustainable development objectives. Notably, the changing climate amplifies the process of interior desertification through a confluence of factors, including warmer temperatures and a pronounced decline in usable precipitation. These combined influences pose a significant challenge to the region's ecological and societal well-being, requiring comprehensive mitigation and adaptation strategies.

When comparing social and economic factors, Norwegians can take advantage from high GDP per capita (68.850 €), good equivalized disposable income (25.3) and a high energy productivity (12.775 € $kg^{-1}_{o,eq}$, in terms of economic output per unit of energy use).

As a result, they can adequately heat their homes (with only 0.8% of the population reporting unfavorable thermal conditions) and live in high-quality dwellings (with only 6.3% of the population residing in homes with leaking roofs, damp walls/floors/foundations, or rotting window frames/floors), data according to EUROSTAT data in 2020. On the opposite side, Portuguese have a lower GDP per capita (18060 €), a higher equivalized disposable income (31.2) and a lower energy productivity (7.973 € $kg^{-1}_{o,eq}$, in terms of economic output per unit of energy use).

As a result, they have difficulties in heating their homes (17.5% of the population reporting unfavorable thermal conditions) and live in lower-quality dwellings (25.2%).

5.2. Climate change

Europe is witnessing an increasing frequency and intensity of extreme climatic and meteorological events. Based on NASA data [29], average global temperatures are on track to reach 1.5°C above pre-industrial levels by 2032, and 2.0°C by 2043. Consequently, these events include prolonged droughts, intense heatwaves, and wildfires, together with devastating floods, storms and storms surges.

Climate projections and their impact on energy demand and indoor climate control in existing buildings may help:

- to understand future dynamics in the reduction of social disparities
- to define proper strategies through environmental policies.

Although this can be a 'what-if' exercise, i.e., a hypothetical condition, climate projections and their impact on energy demand and population may help policymakers to understand future country dynamics and to define proper mitigation and adaptation decision-making strategies. Both projections on energy and population can be considered valid if thermal properties of the existing building and demographic flows are assumed invariant over the whole projection period.

Heating and cooling degree-days (HDD/CDD) are weather-based technical indices designed to describe the need for the heating and cooling energy requirements of buildings. The formulas are reported in Figure 13.

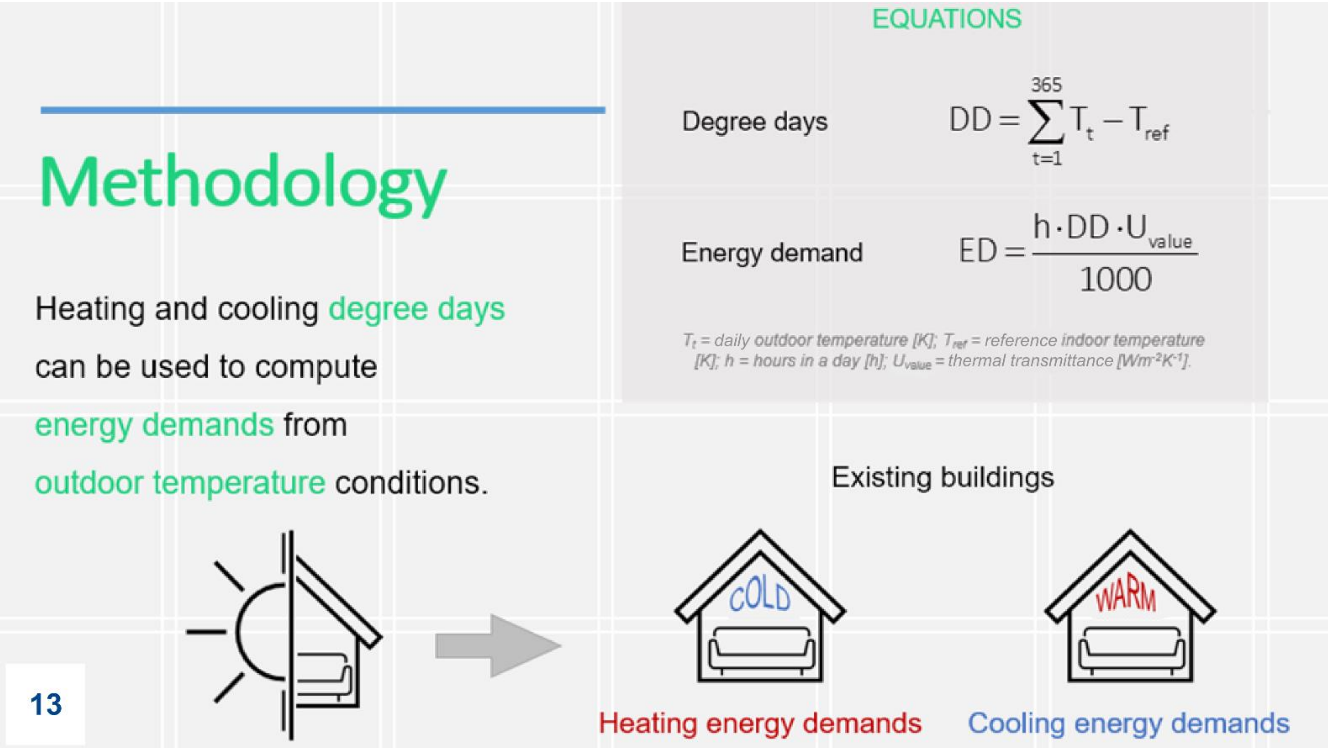


Figure 13: Methodology explanation from EFFICACY Workshop 2023.

Here, HDD/CDD projections were extracted from the Copernicus Climate Data Store (CDS) [28] taking into account two representative concentration pathways (RCP), namely RCP4.5 (i.e., moderate scenario corresponding to a radiative forcing at 4.5 $W{\cdot}m^{-2}$ with a temperature (T) increase of approximately 1.8–2.0°C by 2100) and RCP8.5 (i.e., more extreme scenario corresponding to a radiative forcing at 8.5 $W{\cdot}m^{-2}$ with a T increase close to 4°C by 2100) [29].

Data on HDD and CDD used in this study was the output from [28], over two 30-year periods, i.e., near future (NF, 2021-2050) and far future (FF, 2071-2100). For the overview of the methodological approach used, see Figure 14.

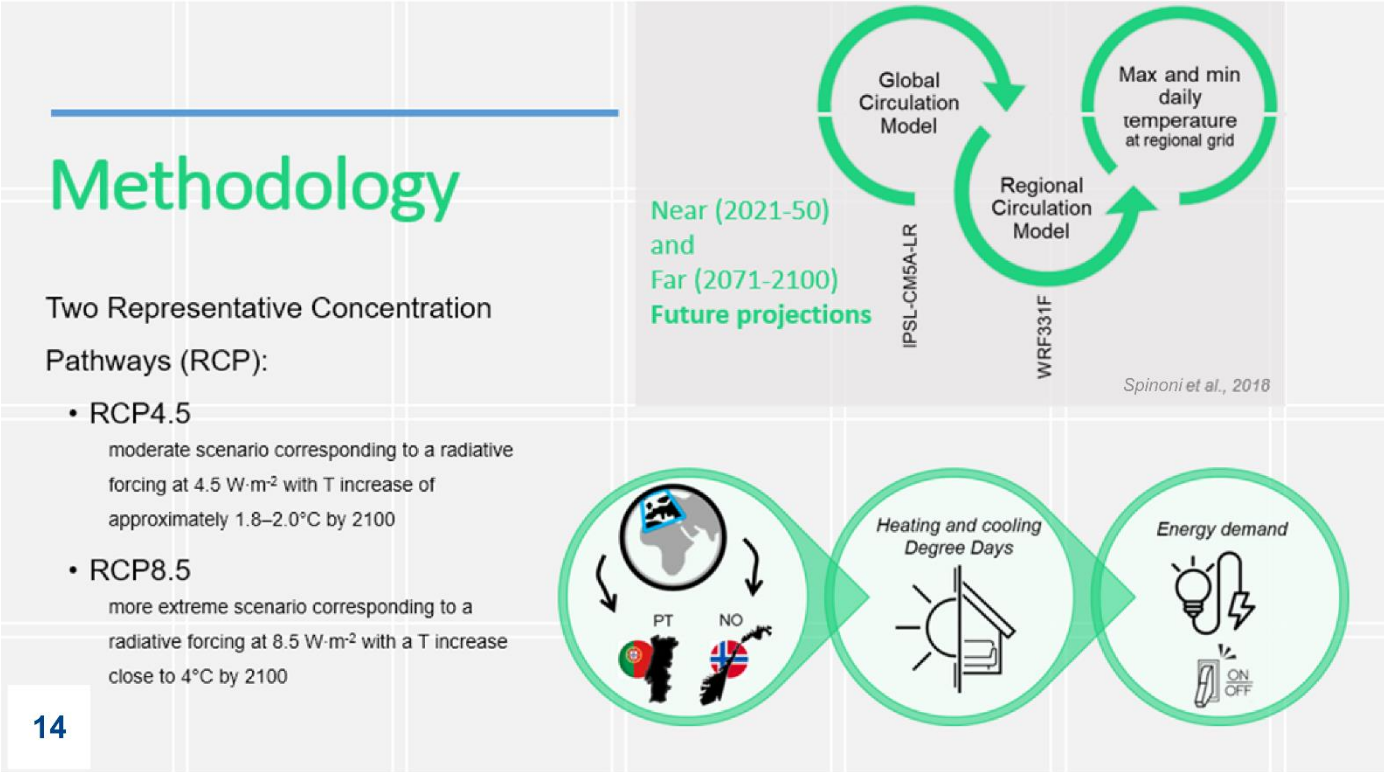


Figure 14: Methodology explanation from EFFICACY Workshop 2023.

Climatological scenarios may exacerbate migration flows and depopulation/population of some EU regions, becoming responsible for the intensification of Energy Poverty and social disparities.

• **Norway**: the heating energy demand (ED_{heat}) will tend to homogeneously decrease from 10% (RCP4.5 in NF) to 20% (RCP8.5 in FF), with an annual daily heating degree days (HDD) of -2°C per day over the country except for the southern coastline; whereas the cooling energy demand (ED_{cool}) will tend to more than double in all circumstances (ED_{cool} = 1 kWh·m^{-2}·year^{-1}), although cooling degree days (CDD) seem to be unaffected with respect to the current conditions.

• **Portugal**: the ED_{heat} will tend to decrease from 8% (RCP4.5 in NF) to 43% (RCP8.5 in FF), especially in the northern regions where the annual daily HDD will be up to -1°C per day; whereas ED_{cool} will tend to increase from 18% (RCP4.5 in NF) to 61% (RCP8.5 in FF), especially in the inner southern area close to the broader with Spain (Figure 15).

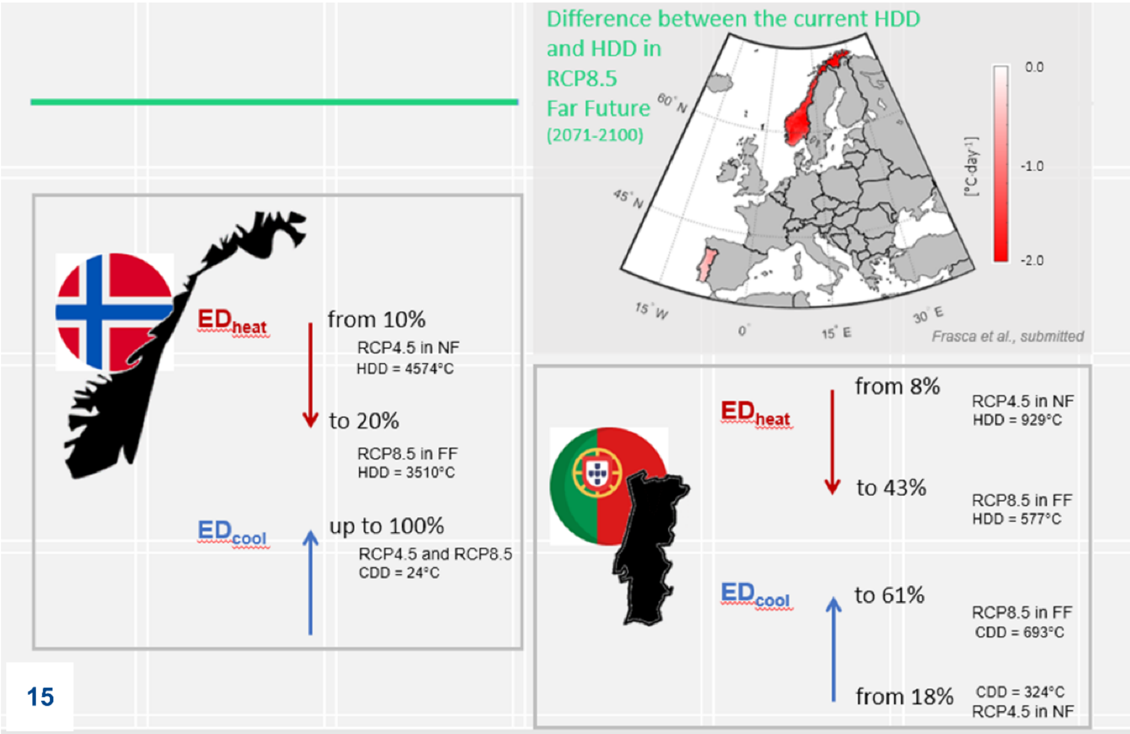


Figure 15: HDD from Portugal and Norway, from EFFICACY Workshop 2023.

Generally, together with the increase in cooling energy demand the increase of temperature will, very likely, be responsible for prolonged exposure to thermal stresses both indoors and outdoors and for migration flows with a probable depopulation of southern EU countries in favor of northern ones with consequences for inhabited centers that will be progressively abandoned in the areas most affected by climate changes creating alteration of landscape and environmental impacts (see Figure 16 for a schematic overview).

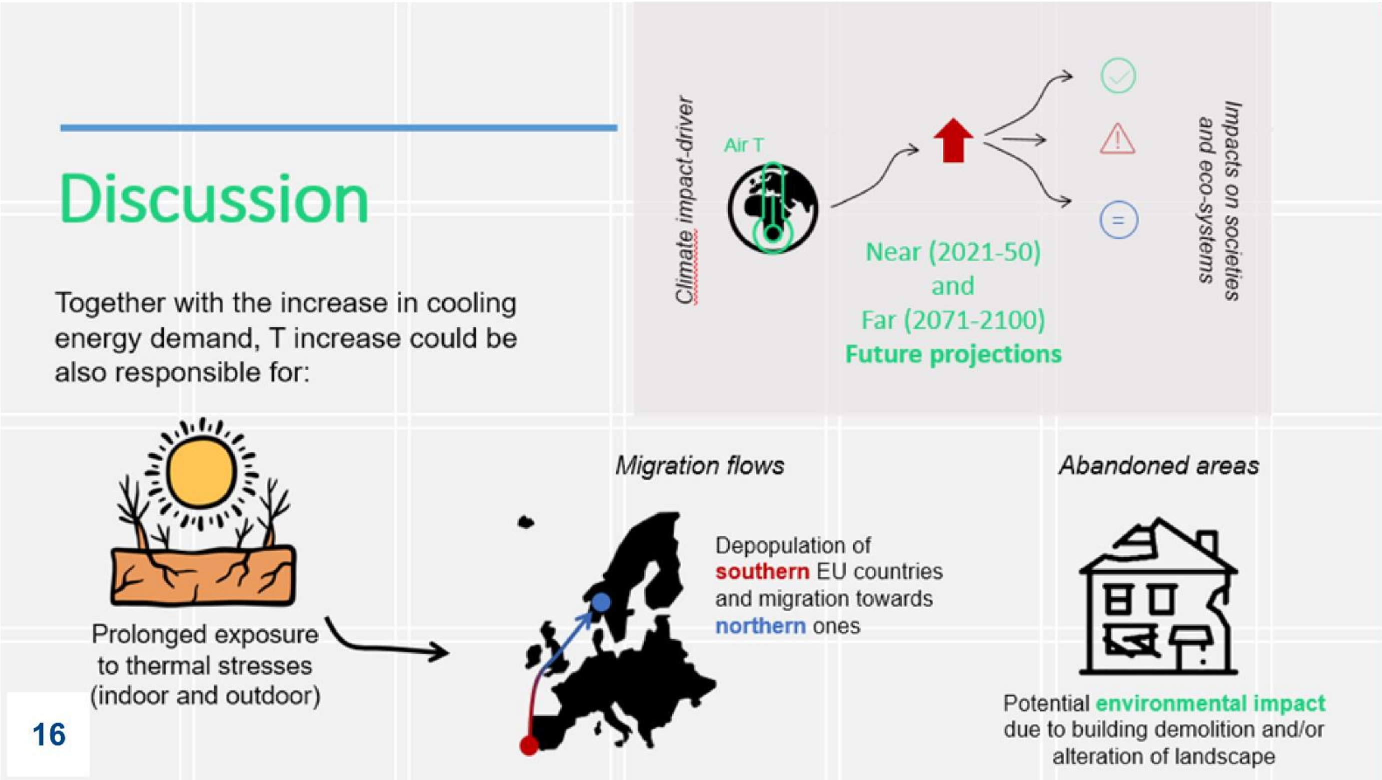


Figure 16: Overview of alterations to the landscape and environmental impacts.

Some comments: In Portugal, the areas that are more affected by the climate change and will be warmer and drier are already suffering from desertification; Norway's housing stock is ill-prepared for warmer temperatures, as most houses are designed primarily for cold climates; wooden houses in Norway may face challenges related to wildfires.

To sum up, the energy efficiency of existing buildings through thermal insulation materials opens to outbreaking challenges and opportunities in this climate change era. Although most organic fossil fuels-derived materials are being replaced by organic plant or mineral-based ones, some considerations should be outlined to understand if their implementation could be potentially beneficial or disadvantageous in mitigating and adapting to climate change scenarios.

Further reading [22, 30, 31].

6. Stakeholder engagement

6.1. Target groups

The guidelines intend to cover the different target groups involved in the EFFICACY project: researchers; private and public institutions; associations; construction companies; building users; and policy makers:

i) stakeholders of NTNU and other Scandinavian Universities/University of Lisbon (ULisboa) and other Mediterranean Universities to strengthen international collaboration and exchange knowledge and experience, to identify the relevant criteria and good practices;

ii) researchers/Ph.D. students from related fields (energy efficiency, circular economy, social impacts, climate change) to discuss building retrofitting in different geographic areas and future scenarios;

iii) private research institutions who work with energy efficiency improvement in the existing building and that may be interested in the outcome of the project (database and guidelines);

iv) non-profit associations with a mission on public interest on energy efficiency and circularity, who can add the guidelines in their role in the society;

v) private companies/designers that usually select the thermal insulation retrofitting on existing buildings and can provide useful input on the criteria to select the right or better performing thermal insulation solution;

vi) craftsmen/workers/manufacturers that usually carry out thermal insulation interventions on buildings and can provide useful input related to the restraints on constructive details and incorporation of waste and reuse materials in construction;

vii) buildings users - users in different typologies of buildings with various thermal insulation solutions who can provide input about indoor comfort in different climate areas and also the perception of visual impact on the surroundings;

viii) political decision-makers on local, municipal, and regional administration who may be interested in being involved (especially to know missing parameters) and have the chance to create an effective database at local/municipal/regional or national level that can be used in the decision-making process.

6.2. Insights from Final EFFICACY workshop, according to the different stakeholders

At the beginning of the Efficacy workshop, a survey consisting of 16 questions was proposed to all participants. Approximately 16-17 among them responded in real time and observed the results projected for all on a shared screen. The outcomes of the short survey are reported in Figures 17 to 28.

Q1: Where do you work? **11 out of 17 worked in Portugal, 2 out of 17 worked in Italy, 1 out of 17 in Norway, 1 out of 17 in Brazil, 1 out of 17 in Iran, 1 answer out of 17 is not valid.**

Figure 17: Map with the answers to Question 1.

Q2: What is your level of education? **1 out of 17 had a bachelor's degree, 8 out of 17 had a master's degree, 7 out of 17 had a doctoral degree.**

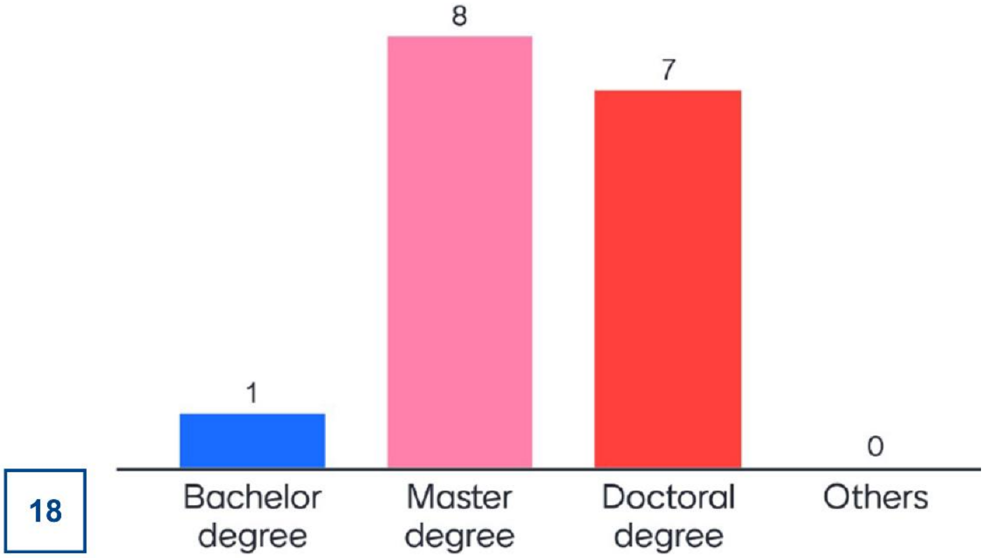


Figure 18: Visualization of the answers to Question 2.

Q3: To which category do you belong? **13 out of 17 were academic, 3 out of 17 were professional, 1 out of 17 belonged to some other category.**

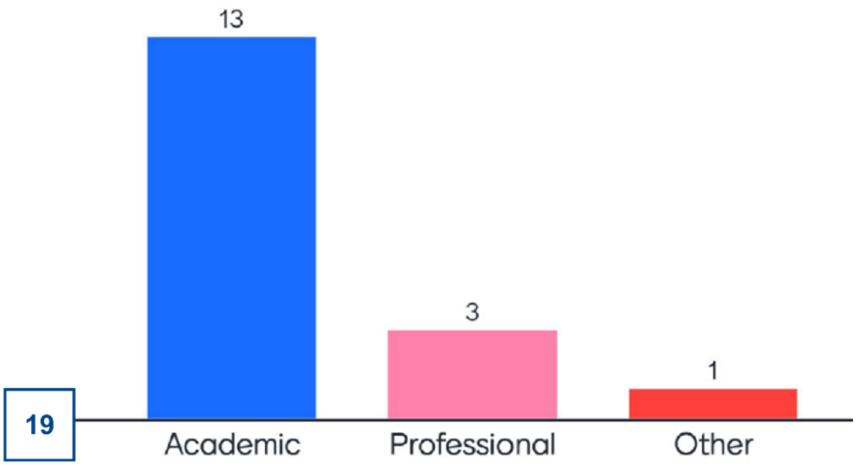


Figure 19: Visualization of the answers to Question 3.

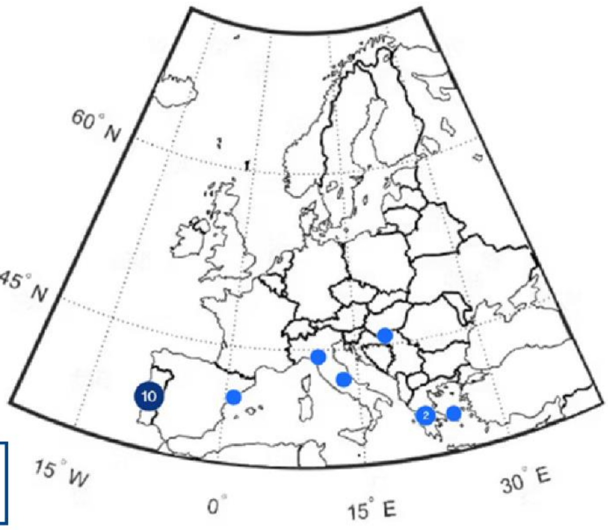
Q4: Describe your expertise in one word: **Most of them defined themselves as "specialist".**

20

Figure 20: Visualization of the answers to Question 4.

Q5: Do you think that European Economic Area (EEA) suffers from Energy Poverty (EP)? **All the respondents voted YES.**

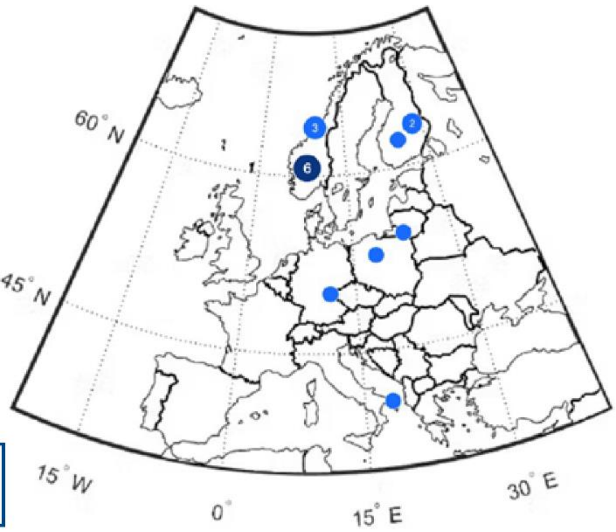
Q6: What do you think is the most affected country? **10 out of 17 voted Portugal, 1 out of 17 voted Spain, 2 out of 17 voted Italy, 3 out of 17 voted Greece, 1 out of 17 voted Croatia.**



21

Figure 21: Visualization of the answers to Question 6.

Q7: What do you think is the least affected country? **9 out of 17 voted Norway, 3 out of 17 voted Finland, 2 out of 17 voted Poland, 1 out of 17 voted Germany, 1 out of 17 voted Italy.**



22

Figure 22: Visualization of the answers to Question 7.

Q8: What are the aspects hindering EP in EEA? **Most of the respondents said: "efficiency" and then "poverty and energy costs"**

23

Figure 23: Visualization of the answers to Question 8.

Q9: Do you think thermal insulation can be useful to decrease EP? **16 respondents out of 17 voted YES, 1 out of 17 voted NO.**

Q10: Which DB do you consult for selecting thermal insulation materials? **Most of the respondents said: "technical information" and then "google".**

Figure 24: Visualization of the answers to Question 10.

Q11: What is the most relevant parameter you consider? **Most of the respondents said: "material", "cost", "durability" and then "sustainability".**

Figure 25: Visualization of the answers to Question 11.

Q12: What is the missing parameter you would like to consider? **Most of the respondents said: “compatibility” and “social impact”.**

Figure 26: Visualization of the answers to Question 12.

Q13: Do you know the meaning of the term “climate migration”? **16 respondents out of 17 voted YES, 1 out of 17 voted NO.**

Q14: Do you think that the Europeans could become “climate refugees” due to the combined effect of climate change extreme events and energy poverty? **11 respondents out of 17 voted YES, and 6 out of 17 voted NO.**

Q15: What tool would you suggest to researchers for communicating the impacts of climate change on energy issues to citizens? **Most of the respondents said: “social media”, “tv” and then “university” and “internet”.**

27

Figure 27: Visualization of the answers to Question 15.

Q16: What tool would you suggest to researchers for communicating the impacts of climate change on energy issues to policy makers? **Most of the respondents said: “workshop” and then “conferences”, further “publications” and “social media”.**

28

Figure 28: Visualization of the answers to Question 16.

7. Final Considerations

This manual systematizes the main considerations from the EFFICACY project related to energy poverty, criteria to select thermal insulation materials, climate change and stakeholder engagement. The main goal was to significantly contribute to the field of thermal insulation by promoting energy efficiency and sustainability in building design.

EFFICACY guidelines are included in annex. A glossary with the main definitions is also presented. The EFFICACY guidelines were also synthetized and translated to Portuguese and Norwegian.

We believe that the EFFICACY guidelines will be an invaluable resource for all stakeholders in this field.

We hope that you will find these HANDBOOK and GUIDELINES informative and useful in your endeavors to create more energy-efficient and sustainable buildings.

Glossary

Term	Designation/references (examples)
Adaptation	The process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. [32]
Adaptive reuse	The conversion of outmoded or unused structures, such as buildings and objects of historic value, to new uses or application in new contexts. [33]
Adverse side-effect	A negative effect that a policy or measure aimed at one objective has on another objective, thereby potentially reducing the net benefit to society or the environment. [32]
Ageing	Degradation due to long-term influence of agents related to use. [34]
Bio-susceptibility or Bio-receptivity	The ability of a material to be colonized by living organisms.[35]
Climate change	A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. [32]
Compatibility	The state that occurs when two (or more) materials can coexist together, without any short- or long-term damage. [36]
Cooling Degree Days	Summation of the differences between the outdoor temperature and some reference (or base) temperature for summer thermal comfort over a specified time period [37]
Cost-Benefit Analysis	The process of comparing the projected or estimated costs and benefits (or opportunities) associated with a project. [38]
Durability	The state that describes the ability of a material to resist extreme and non-extreme events for a long time
Energy poverty	The inability to secure sufficient energy services in the home. [39]

Global warming	Long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere [32]
GDP-PPP (Gross Domestic Product – Purchasing Power Parity) rate	Rate at which the currency of one country would have to be converted into that of another country to buy the same amount of goods and services, it is used to compare economic productivity and standards of living between countries. [40]
Hazard	A substance, activity or event that may, in some circumstances, cause chemical or physical change in an object, collection or building. [41]
Heating Degree Days	Summation of the differences between the outdoor temperature and some reference (or base) temperature for winter thermal comfort over a specified time period [37]
Impact	The consequences of realized risks on natural and human systems. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services, and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial [32]
Life Cycle Assessment	A process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities [42]
Life Cycle Cost	A methodology that enables cost comparisons over a specific period of time, taking into account relevant integral economic factors [43]
Maintainability	The ability of a functional unit, under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function when maintenance is performed under given conditions and using stated procedures and resources [44]
Mitigation	A human intervention to reduce emissions or enhance the sinks of greenhouse gases [32]
Mitigation measures	Technologies, processes or practices that contribute to mitigation (e.g., renewable energy technologies, waste minimization processes) [32]

Mitigation option	A technology or practice that reduces greenhouse gas emissions or enhances sinks [32]
Multi-criteria decision making	A discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making. [45]
Non-destructive testing (NDT)	A test that causes no significant structural damage to buildings components [46]
Refurbishment	Modification and improvements to an existing building or its parts to bring it up to an acceptable condition [34]
Retrofitting	providing something with a component or feature not fitted during manufacture or adding something that it did not have when first constructed. [47]
Renovation	Process of returning something to a good state of repair
Resilience	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure [32].
Risk	The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species [32].
Scenario	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change (TC), prices) and relationships [32].
Stakeholder	A person, group, or organization who has a particular interest in a topic on the basis of special associations, meanings, and/or legal and economic interests, and who can affect, or be affected, by decisions. [48]

Sustainable Development Goals	The 17 global goals for development for all countries established by the United Nations through a participatory process and elaborated in the 2030 Agenda for Sustainable Development, including ending poverty and hunger; ensuring health and well-being, education, gender equality, clean water and energy, and decent work; building and ensuring resilient and sustainable infrastructure, cities and consumption; reducing inequalities; protecting land and water ecosystems; promoting peace, justice and partnerships; and taking urgent action on climate change [32].
Sustainability	Involves ensuring the persistence of natural and human systems, implying the continuous functioning of ecosystems, the conservation of high biodiversity, the recycling of natural resources and, in the human sector, successful application of justice and equity [32].

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Energy eFFiciency buIlding and CirculAr eConomY for thermal insulation solutions

ANNEX
EFFICACY
guidelines

Cover design by Ozge Ogut

Iceland Liechtenstein Norway grants

TÉCNICO LISBOA

NTNU

The EFFICACY HANDBOOK is a comprehensive guide that addresses critical aspects of energy efficiency and sustainability in building design. It covers a broad spectrum of topics, including understanding energy demands, addressing energy poverty, making informed choices about thermal insulation materials and retrofit solutions, considering the impact of climate change and preparing for future scenarios. It also provides strategies for effectively engaging target groups.

The main goal is to significantly contribute to the field of thermal insulation solutions by promoting energy efficiency and sustainability in building design. We believe that these EFFICACY GUIDELINES will be an invaluable resource for all stakeholders in this field. We hope that you will find these guidelines informative and useful in your endeavors to create more energy-efficient and sustainable buildings, and thus contribute towards a more sustainable built environment.

1. Empowering a sustainable and inclusive energy future

- **Conduct Comprehensive Assessments:** Carry out a thorough assessment and analysis of the building's structural and energy performance to identify vulnerabilities, weaknesses, and potential energy-saving opportunities.
- **Conduct Cost-Benefit Analysis:** Perform a cost-benefit analysis to determine which short and long-term measures, or their combination, should be adopted also considering current projections on future climate conditions.
- **Develop Evaluation Protocols:** Formulate protocols to evaluate and monitor the condition and energy performance of buildings.
- **Equip Users with Knowledge:** Facility managers should provide users with knowledge on energy codes, thermal insulation solutions and renewable energy sources.

- **Implement Energy Performance Observatories:** Establish Energy Performance observatories and local advisory hubs. The European Union has the Energy Poverty Advisory Hub, where municipalities or supra-municipalities can apply to receive direct support in the process of addressing energy poverty.
- **Implement Energy Poverty (EP) Reduction Strategies:** EP reduction strategies should include short-term measures such as reduced local taxes; reduced rents for social housing; investment in the creation of green jobs; financial support for low-income households.
- **Implement Long-Term Measures:** Implement long-term measures to facilitate an effective energy transition towards a green and equitable society. These measures could include energy-efficient mortgages to certify energy-efficient building renovations, promoting investments in energy-efficient buildings for public authorities and reducing the perceived risks associated with such investments, to name just a few.
- **Inform Decision Makers:** Inform decision-makers about the impact of severe events related to natural and anthropic hazards, as well as climate change in the near and far future to issue tailored technical regulations and economic incentives.
- **Monitor Key Performance Indicators (KPIs):** Keep track of KPIs such as energy consumption reduction, energy use intensity, energy demand profile, building energy integration, thermal comfort improvement, payback period, Life Cycle Cost (LCC), Life Cycle Analysis (LCA), historic and heritage value preservation, water efficiency, renewable growth energy rate and public awareness and engagement.
- **Promote Education:** Education can significantly enhance people’s knowledge, understanding and foster improved energy-related behaviors at various levels such as school, work, and political life.

- **Promote Sustainable Practices:** Sustainable practices such as tree planting can contribute to reducing EP through mechanisms like shade, cooling, and windbreaks.
- **Stay Updated on Building Codes:** Keep abreast of building codes, regulations and incentives related to seismic retrofitting and energy efficiency of buildings.

Further reading:

"Ogut et al, 2023. Energy poverty in Portugal, Italy, and Norway: awareness, short-term driving forces, and barriers in the built environment", IOP Conf. Ser.: Earth Environ. Sci. 1176 012023, https://iopscience.iop.org/article/10.1088/1755-1315/1176/1/012023/meta.

2. Key Considerations for selecting thermal insulation materials and retrofit solutions

- **Balance**: Balance energy savings with the health and well-being of building occupants, as well as with the preservation of the style, significance, and visual appearance of the district in which the building is located.
- **Bio-susceptibility**: Predisposition to, or sensitiveness to, developing-microbial deteriogens, i.e., fostering microbiological growth, and hence sick building syndrome (SBS) due to the capability of holding vapor and/or liquid water by percolation, infiltration, or capillary rise.
- **Buildability**: Consider the buildability of materials and their compatibility with retrofit processes. Moreover, consider the potential disruption to building occupants during installation.
- **Compatibility**: Evaluate the compatibility of insulation materials with existing building elements, such as wall types, framing and finishes.
- **Durability**: Examine the maintenance requirements, durability and expected lifespan of insulation materials to ensure sustained thermal performance over time without the need for frequent and costly maintenance or replacement actions.

- **Employ energy simulation software** to simulate and forecast the energy efficiency of retrofitted buildings using various insulation materials under diverse conditions. This process involves assessing the thermal resistance of these materials to ascertain their efficiency in minimizing heat transfer. Energy simulation software provides predictive insights into the energy efficiency outcomes considering different retrofitting options, thus guiding decision-making processes.
- **Examine adaptive reuse strategies** that prolong the building's life cycle and align with circular economy principles. These strategies contribute to sustainability by extending the useful life of buildings and promoting resource conservation.
- **Explore Non-Destructive Testing (NDT) techniques** for assessing the condition and integrity of structures without causing damage, especially for historic buildings (e.g., ultrasound, ground-penetrating radar, infrared thermography, acoustic emission, etc.). NDT techniques enable safe and effective assessment of structural integrity, particularly important for preserving historic buildings.
- **Fire Safety**: Consider fire safety ratings and flammability characteristics of insulation materials to ensure compliance with safety regulations and codes.
- **Implement monitoring systems** to track the actual energy performance and effectiveness of selected insulation materials post-retrofit. Monitoring systems provide real-time data on the performance of insulation materials, enabling continuous improvement in energy efficiency.
- **Maintainability**: Ability of the thermal insulation material to be retained in or restored to a state in which it can perform its required functions, providing useful information on the environmental impact and service life costs.
- **Maintain comprehensive documentation** of NDT assessments, findings, and interventions for future reference and for repeating the monitoring after the energy retrofit to assess the effectiveness of interventions and track any changes in the

structural condition. Thorough documentation supports ongoing monitoring efforts and provides a valuable reference for future retrofit projects.

- **Material Selection**: Choose retrofit materials and technologies with a focus on seismic compliance (especially for seismic areas like Portugal) and energy efficiency. These materials should be compatible with existing building components.
- **Moisture Resistance**: Check the moisture resistance of insulation materials to prevent further anomalies, such as biological colonization and other moisture-related issues.
- **Monitor data obtained from actual maintenance and retrofit**, refurbishment projects to validate applied simulations and models or learn from real case studies. This practice enhances the accuracy of simulations and models by grounding them in real-world data.
- **Perform Life Cycle Assessments** to gauge the long-term environmental impact of retrofit choices: Contrast the long-term energy bill savings with the initial retrofitting costs (payback period) and assess the durability of the adopted thermal insulation solutions (including seismic measures, in the case of Portugal).
- **Performance Objectives**: Set clear performance objectives using appropriate methods and tools. These objectives should balance legislative and safety requirements, energy savings, economics, and environmental impact.
- **Promote the use of sustainable and locally sourced materials** and maximize the re-use of materials and spaces to minimize waste and resource consumption. For instance, implement an adaptive re-use and repurposing materials approach to reduce the carbon footprint.
- **Resilience and Efficiency**: Give priority to solutions that contribute to a more resilient and energy-efficient built environment.
- **Safety and Comfort**: Ensure that retrofit measures do not compromise safety, indoor comfort, or air quality.

• **Undertake a life cycle analysis** for insulation materials to assess their environmental impact. This analysis should consider factors such as embodied energy, greenhouse gas emissions, manufacturing processes, installation procedure, maintenance, and end-of-life considerations (waste process).

Further reading:

Parracha et al., 2023. A dataset of criteria on the use of thermal insulation solutions in building facades located in Norway, Portugal and Italy", Data in Brief, 50, October 2023, https://doi.org/10.1016/j.dib.2023.109622

Frasca et al., 2023. A quantitative comparison on the use of thermal insulation materials in three European countries through the TEnSE approach: challenges and opportunities, Building and Environment, 245, November 2023, https://doi.org/10.1016/j.buildenv.2023.110973.

3. Enhancing Building Resilience in the face of climate change and future scenarios

• **Adaptive Façade Systems**: Develop façade systems that can adapt to Europe's changing weather patterns and extreme conditions due to climate change. Incorporate multifunctional aspects into these systems, such as daylight optimization, ventilation, and rainwater harvesting.

• **Climate-Responsive Design**: Update building standards and codes to include design criteria responsive to both heating and cooling requirements, incorporating improved insulation, energy-efficient windows, and passive cooling features.

• **Climate-Specific Insulation**: Choose thermal insulation materials based on the specific climate conditions of the building's location, considering factors such as air temperature fluctuations, air humidity levels and insulation requirements. Monitor microclimatic conditions like surface temperature, and relative humidity.

• **Community Engagement**: Foster community engagement and utilize citizen science participation to raise awareness about monitoring climate-related changes in cities. Educate stakeholders about circular economy principles. Utilize building energy modeling (e.g., BEM) to address the impact of climate change on buildings while emphasizing the importance of comprehensive data collection for reliable model input (e.g., building geometry, materials, occupancy patterns, energy consumption). Community engagement and education are key to raising awareness about climate change impacts and promoting circular economy principles.

- **Compliance with Standards**: Ensure that the chosen insulation materials comply with EU, national and local building codes, and standards for energy efficiency.
- **Energy-Efficient Practices**: Encourage energy-efficient building practices like using sustainable materials, efficient HVAC systems and promoting green building certifications.
- **Fire-Resistant Materials**: Promote the use of fire-resistant building materials in wildfire-prone areas, including fire-resistant roofing, siding, and windows.
- **Green Spaces and Blue Infrastructure**: Evaluate the presence, distribution and quality of green spaces and blue infrastructure to understand their effectiveness in mitigating urban heat and enhancing overall climate resilience. Green and blue infrastructure play a crucial role in urban heat mitigation and climate resilience.
- **Mediterranean Context**: Acknowledge the challenges posed by heat and sun exposure in Mediterranean countries. Focus on shading, ventilation and cooling strategies while preserving historical aesthetics. Integrate strategies to enhance building resilience against climate change impacts and potential hazards, including sea-level rise, tsunamis, weatherproofing, flood protection and seismic strengthening as relevant to each region.
- **Public Awareness**: Raise public awareness about the importance of climate-resilient housing and the benefits of energy-efficient construction through educational campaigns and incentives for sustainable housing. Raising public awareness is crucial for promoting climate-resilient housing and energy-efficient construction.

- **Refurbishment**: A process of improvement by cleaning, decorating, and re-equipping. It may include elements of retrofitting.
- **Renovation**: A process of returning something to a good state of repair, ensuring compatibility with the existing building components, as well as the reversibility of the intervention, especially in the case of historic buildings.
- **Retrofitting and Upgrading**: Advocate for retrofitting and upgrading existing buildings to improve energy efficiency and adaptability to warmer temperatures. Provide incentives and subsidies to homeowners for these efforts.
- **Scandinavian Context**: Address the specific challenges posed by the cold climate and high-energy demands of Scandinavian countries by considering suitable insulation, heating systems and materials for cold weather conditions. Integrate strategies that enhance the building's resilience to climate change impacts and potential hazards.
- **Use of Digital Tools**: Leverage digital tools to inform adaptive urban planning considering climate resilience, hazard mitigation and circular economy strategies. Foster a collaborative approach between stakeholders (i.e., local communities, city officials, urban planners, researchers) and/or support regulatory frameworks. Digital tools can significantly enhance adaptive urban planning and stakeholder collaboration.
- **Use of Light-Colored Materials**: Utilize light-colored materials with high albedo to achieve lower surface temperatures. High-albedo materials can significantly reduce surface temperatures, contributing to cooler urban environments.
- **Water-Sensitive Urban Design Practices**: Adopt water-sensitive urban design practices to enhance climate resilience against challenges like increased rainfall, flooding, and water scarcity. Examples include permeable pavements, green roofs, natural drainage systems, rain barrels and cisterns, and smart stormwater

management. Water-sensitive design practices are essential for managing water-related climate challenges.

- **Zoning Regulations**: Implement zoning regulations that restrict construction in high-risk wildfire areas and mandate the use of fire-resistant construction materials and designs.
- **Implement wireless sensor networks** for real-time data collection from multiple points on the building, enabling continuous monitoring. Transmit data to cloud-based platforms for real-time analysis and backup. This enhances data accessibility and facilitates timely decision-making based on real-time information.
- **Install prototype façade systems** in real-world conditions to monitor their performance over extended periods. Use collected data to validate simulation results and identify any discrepancies. This ensures that façade systems are effective and user-friendly in real-world conditions.

Further reading:

"Mendes et al, 2021. Discussion of Performance Criteria for Thermal Insulating Solutions for Building Facades under Different Climate Change Projections", CEES 2021, International Conference Construction, Energy, Environment & Sustainability. 12 - 15 October 2021, Coimbra, Portugal, 6 p.

4. Engaging target groups for inclusive and informed decision-making in energy efficiency and sustainability in building design

- **Collaborate with various professionals** to ensure comprehensive assessments of technique implementation and informed decision-making. This fosters a multidisciplinary approach, enhancing the quality of assessments and decisions.
- **Cultivate a shared understanding of the importance of sustainable preservation, even when planning energy retrofit projects for existing buildings.** Building a collective understanding encourages sustainable practices even in retrofit projects for non-historical buildings.

- **Engage building owners, occupants, architects, engineers, and contractors in the decision-making process to cater to their preferences and needs.** Involving all relevant parties in the decision-making process ensures that the implemented solutions meet everyone's needs and preferences.
- **Ensure that the selected strategies align with the needs and values of all stakeholders.** Aligning strategies with stakeholder needs and values fosters acceptance and successful implementation.
- **Investigate available incentives, subsidies, and funding options that can alleviate the costs of renewable energy sources as solar energy installations in heritage urban areas.** Exploring financial aids can make solar energy installations more affordable, promoting their adoption in heritage urban areas.
- **Involve relevant stakeholders**, including conservation scientists, fire safety experts, architects, and local authorities, in the assessment process. This ensures that all relevant perspectives are considered, leading to more comprehensive and effective assessments.
- **Promote policies and incentives at the policy-makers level and feedback at the public-private level to encourage energy efficiency, circular economy practices, and resilience in non-residential building development and operation. This will raise awareness among stakeholders about the importance of reducing energy demand and achieving sustainable indoor climate control.** Advocacy for supportive policies and feedback mechanisms can enhance energy efficiency and sustainability in non-residential buildings.
- **Propose region-specific strategies that strike a balance between energy efficiency, cultural preservation, and environmental sustainability.** Offering balanced strategies helps to achieve energy efficiency while preserving cultural heritage and promoting environmental sustainability.

- **Provide training and education** about the benefits of energy-efficient retrofitting in historic buildings or based on best practices case studies. This raises awareness and builds capacity for sustainable practices in historic preservation and at community level.
- **Stakeholders should adhere to guidelines that consider the unique characteristics and challenges of both Scandinavian and Mediterranean contexts.** Following region-specific guidelines ensures that solutions are tailored to local conditions, enhancing their effectiveness.
- **Train stakeholders** involved in the assessment, monitoring, and retrofitting of historic buildings, emphasizing the implementation of Non-Destructive Testing (NDT) techniques suitable for historical buildings' condition monitoring. This equips stakeholders with the necessary skills to effectively monitor and maintain historic buildings.
- **Use statistical methods**, to assess vulnerability, as an early warning tool for potential issues and to aid stakeholders in making informed decisions about maintenance and interventions. This proactive approach helps prevent potential issues and guides effective maintenance strategies.

The EFFICACY team.

EFICCACY GUIDELINES (SUMMARY)

(IN ENGLISH)

The EFFICACY HANDBOOK is a comprehensive guide that addresses critical aspects of energy efficiency and sustainability in building design. It covers a broad spectrum of topics, including understanding energy demands, addressing energy poverty, making informed choices about thermal insulation materials and retrofit solutions, considering the impact of climate change and preparing for future scenarios. It also provides strategies for effectively engaging target groups.

The main goal is to significantly contribute to the field of thermal insulation solutions by promoting energy efficiency and sustainability in building design. We believe that the EFFICACY GUIDELINES will be an invaluable resource for all stakeholders in this field. We hope that you will find these guidelines informative and useful in your endeavors to create more energy-efficient and sustainable buildings, and thus contribute towards a more sustainable built environment. The following aspects should be considered:

i) Understanding energy demands and addressing energy poverty

Based on these guidelines, the general conclusion is that effective energy management and sustainable practices in buildings require a comprehensive and multi-faceted approach. This includes monitoring Key Performance Indicators, conducting thorough assessments of building performance, developing evaluation protocols, and staying updated on building codes and regulations.

Equipping users with knowledge about energy codes and renewable energy sources, establishing Energy Performance Observatories, as well as promoting education and capacitation. Implementing both short-term Energy Performance increase strategies and long-term measures are necessary for an effective energy transition towards an equitable society.

Performing cost-benefit analyses can help determine the most effective measures to adopt based on future climate conditions. Informing decision-makers about the impact of severe climate change events can lead to the issuance of tailored technical regulations and economic incentives. Lastly, promoting sustainable practices can contribute to improve Energy Performance.

In essence, reducing the risk of energy poverty is about integrating energy efficiency into all aspects of building design, operation, and user behavior while considering the socio-economic background of people, owners living in the built environment as well as the ongoing changes triggered by urbanization and climate change.

ii) Making informed choices about thermal insulation materials and retrofit solutions

When undertaking a retrofit project, it is crucial to select appropriate materials, traditional or innovative, that are compatible with existing structures, easy to install, durable, safe, environmental-friendly, moisture-resistant, and fire-resistant. These materials should contribute to a more resilient and energy-efficient built environment without compromising occupant comfort or safety.

Furthermore, they should respect the architectural integrity of the building and its surrounding district. These guidelines provide a comprehensive approach to building retrofitting that prioritize sustainability, efficiency, and long-term value. By considering factors such as life cycle assessment, material sourcing, significance of original materials and/or assets, adaptive reuse strategies, monitoring systems, and energy simulation software, we can ensure that our retrofitting efforts are environmentally friendly, cost-effective, respectful of historical significance, and beneficial in the long term. This approach not only enhances building performance but also contributes significantly to our broader sustainability goals.

iii) Considering the impact of climate change and preparing for future scenarios

In summary, these guidelines advocate for an integrated approach to building design that is responsive to climate conditions, complies with energy efficiency standards, incorporates adaptive systems, promotes fire resistance, encourages energy-efficient practices, and supports retrofitting and upgrading efforts. The use of Non-Destructive Testing (NDT) techniques and wireless sensor networks for real-time data collection and analysis is also emphasized. The installation and monitoring of prototype façade systems in real-world conditions are recommended to ensure their effectiveness and user-friendliness. This approach not only enhances the sustainability of buildings but also their resilience in the face of climate change. Urban planning and building design should be context-specific, addressing the unique challenges and opportunities presented by different climates. In Scandinavian countries, this means focusing on insulation, heating systems, and cold-weather resistant materials to manage high-energy demands and cold climates.

In contrast, Mediterranean countries require strategies for coping against heat and sun exposure, such as shading, ventilation, and cooling systems. They should also address high levels of air humidity in coastal areas. A multifaceted approach that considers local context, utilize appropriate materials and technologies, engages communities, and raises public awareness is crucial for creating urban environments that are resilient to climate change.

iv) Engaging target groups effectively

In conclusion, successful implementation of energy-efficient retrofitting in existing buildings requires a comprehensive, stakeholder-inclusive, and region-specific approach. This includes engaging all relevant parties in decision-making, aligning strategies with stakeholder needs and values, investigating financial aids for passive and active solutions, promoting energy efficiency policies, and cultivating a shared understanding of sustainable preservation. It also involves adhering to region-specific guidelines, proposing balanced strategies, collaborating with various professionals for informed decision-making, and providing training about the benefits of energy-efficient retrofitting.

This integrated approach aims to achieve energy efficiency while preserving cultural heritage and promoting environmental sustainability in both Scandinavian and Mediterranean contexts.

The guidelines suggest a comprehensive approach to maintenance and interventions using vulnerability assessments. This approach involves the use of statistical methods as an early warning tool, thorough suitable methods, results, and interpretations, and the involvement of all relevant stakeholders in the assessment process. This strategy not only aids in making informed decisions but also ensures transparency, effective communication, and comprehensive assessments by considering all relevant perspectives.

Thus, it can be concluded that this proactive and inclusive approach can lead to effective maintenance strategies and prevent potential issues.

The EFFICACY team.

EFICCACY ORIENTAÇÕES (SUMÁRIO)

(IN PORTUGUESE)

O MANUAL EFFICACY é um guia abrangente que aborda aspetos essenciais da eficiência energética e da sustentabilidade dos edifícios. Este manual abrange um vasto espetro de tópicos, que incluem a compreensão das necessidades energéticas, a pobreza energética, a tomada de decisões informadas sobre materiais de isolamento térmico e soluções de reabilitação térmica, considerando também o impacte das alterações climáticas e a preparação para cenários futuros. O manual também fornece estratégias para o envolvimento efetivo dos grupos-alvo.

O principal objetivo é o de contribuir significativamente para o tema das soluções de isolamento térmico, promovendo a eficiência energética e a sustentabilidade no projeto de edifícios. Deste modo, consideramos que estas ORIENTAÇÕES são um ótimo recurso para todos os interessados nesta temática. Esperamos que estas orientações sejam informativas e úteis na conceção de edifícios mais eficientes energeticamente, contribuindo para um ambiente construído mais sustentável. Os seguintes aspetos devem ser considerados:

i) Compreender as exigências de energia e combater a pobreza energética

A gestão eficiente de energia e as práticas sustentáveis em edifícios requerem uma abordagem abrangente e multifacetada, que inclui a monitorização de indicadores de desempenho, a realização de avaliações detalhadas do desempenho dos edifícios, o desenvolvimento de protocolos de avaliação e a atualização constante de normas e regulamentos da construção.

Os utilizadores dos edifícios devem ser dotados de informações sobre normas/regulamentos de eficiência energética e fontes de energia renovável, estabelecendo-se Observatórios de Desempenho Energético e promovendo-se a educação e a capacitação. A implementação de estratégias de aumento do desempenho energético a curto prazo é necessária, assim como de medidas a longo prazo, para que haja uma transição energética eficiente que contribua para uma sociedade equitativa.

A realização de análises de custo-benefício pode ajudar na adoção de medidas eficazes que sejam resilientes face às condições climáticas futuras. Os decisores devem ser informados sobre o impacto das alterações climáticas, e refletir essa realidade nos regulamentos técnicos e incentivos económicos. Por fim, a promoção de práticas sustentáveis é fundamental para a melhoria do desempenho energético.

Em suma, a redução do risco de pobreza energética passa pela integração da eficiência energética em todos os aspetos relacionados com a conceção e operação dos edifícios, bem como do comportamento dos utilizadores, considerando aspetos relacionados com o contexto socioeconómico dos utilizadores, bem como possíveis mudanças desencadeadas pela urbanização e pelas alterações climáticas.

ii) Tomar decisões informadas sobre materiais de isolamento térmico e soluções de reabilitação

Ao se realizar um projeto de reabilitação, é crucial selecionar materiais adequados, tradicionais ou inovadores, que sejam compatíveis com as estruturas existentes, fáceis de instalar, duráveis, seguros, amigos do ambiente, resistentes à humidade e com boa reação ao fogo.

Estes materiais devem contribuir para um ambiente construído mais resiliente e energeticamente eficiente, sem comprometer o conforto ou a segurança dos utilizadores. Além disso, devem respeitar a integridade arquitetónica do edifício e da envolvente. Estas orientações fornecem uma abordagem abrangente para a reabilitação de edifícios que prioriza a sustentabilidade, eficiência e valor a longo prazo.

Ao se considerar fatores como a avaliação do ciclo de vida, a origem dos materiais, a importância dos materiais originais e/ou ativos, as estratégias de reutilização adaptativa, os sistemas de monitorização e *software* de simulação energética, pode garantir-se que os esforços de reabilitação são amigos do ambiente, economicamente viáveis, que consideram a importância histórica do edificado e que são, consequentemente, benéficos a longo prazo. Esta abordagem não só melhora o desempenho do edifício, como também contribui significativamente para metas de sustentabilidade mais amplas.

iii) Considerar o impacto das alterações climáticas e preparação para cenários futuros

Estas recomendações defendem uma abordagem holística para a conceção de edifícios que responda às condições climáticas, cumpra os padrões de eficiência energética, incorpore sistemas adaptativos, promova o bom comportamento ao fogo, incentive práticas de eficiência energética e apoie esforços de reabilitação e modernização. A utilização de Técnicas Não Destrutivas (TND) e redes de sensores *wireless* para a recolha e análise de dados em tempo real é também enfatizada.

Recomenda-se a instalação e monitorização de protótipos de sistemas de fachada em condições reais para garantir a sua eficácia e facilidade de utilização. Esta abordagem não só aumenta a sustentabilidade dos edifícios, mas também a sua resiliência face às alterações climáticas. O planeamento urbano e a conceção de edifícios devem ser específicos do contexto, abordando os desafios e oportunidades únicos apresentados por diferentes condições climáticas e geográficas. Nos países escandinavos, isto significa focar-se no isolamento, nos sistemas de aquecimento e nos materiais resistentes ao frio para gerir as elevadas exigências energéticas dos climas frios. Em contrapartida, os países mediterrânicos requerem estratégias para lidar com o calor e a exposição solar, tais como sombreamento, ventilação e sistemas de refrigeração. Devem também ter em conta os elevados níveis de humidade do ar nas zonas costeiras. Uma abordagem multifacetada que tenha em conta o contexto local, utilize materiais e tecnologias apropriados, envolva as comunidades e sensibilize o público, é crucial para a criação de ambientes urbanos resilientes às alterações climáticas.

iv) Envolver efetivamente os grupos-alvo

A implementação bem-sucedida da reabilitação energética em edifícios existentes requer uma abordagem abrangente, que inclua as partes interessadas e seja específica da região analisada. Isto inclui o envolvimento de todas as partes relevantes na tomada de decisões, o alinhamento de estratégias de acordo com as necessidades e os valores das partes interessadas, a investigação de ajudas financeiras para soluções passivas e ativas, a promoção de políticas de eficiência energética e o cultivo de um entendimento compartilhado da preservação sustentável.

Envolve também a adesão a recomendações específicas da região, a proposta de estratégias equilibradas, a colaboração com vários profissionais para uma tomada de decisões informada e a disponibilização de formação sobre os benefícios da reabilitação energeticamente eficiente. Esta abordagem holística visa alcançar a eficiência energética, preservando simultaneamente o património cultural e promovendo a sustentabilidade ambiental nos contextos escandinavo e mediterrâneo.

As orientações sugerem uma abordagem ampla da manutenção e das intervenções, utilizando avaliações de vulnerabilidade. Esta abordagem envolve a utilização de métodos estatísticos como uma ferramenta de alerta precoce, métodos, resultados e interpretações adequados e exaustivos, e o envolvimento de todas as partes interessadas no processo de avaliação. Esta estratégia não só ajuda na tomada de decisões informadas, como também assegura a transparência, a comunicação eficaz e avaliações abrangentes, considerando todas as perspetivas consideradas relevantes. Assim, pode concluir-se que esta abordagem pró-ativa e inclusiva pode levar a estratégias de manutenção eficazes e prevenir potenciais problemas.

A equipa EFFICACY.

EFICCACY RETNINGSLINJENE (SAMMENDRAG)

(IN NORSK)

EFFEKTIVITETSHÅNDBOKEN er en omfattende veileder som tar for seg viktige aspekter ved energieffektivitet og bærekraft i bygningsdesign. Den dekker et bredt spekter av temaer, inkludert forståelse av energibehov, bekjempelse av energifattigdom, å ta informerte valg angående varmeisolasjon og oppgraderingsløsninger, vurdering av effekter av klimaendringer, og forberedelser for fremtidige scenarioer. Håndboken foreslår også strategier for effektiv involvering av målgruppene.

Hovedhensikten er å bidra til løsninger innen fagfeltet varmeisolasjon ved å promotere energieffektivitet og bærekraft i bygningsdesign. Vi mener at EFFEKTIVITETSHÅNDBOKEN vil være en uvurderlig ressurs for alle interessenter i bransjen. Vi håper disse retningslinjene er nyttige for ditt arbeid med å skape mer energieffektive og bærekraftige bygninger, og dermed bidra til et mer bærekraftig bygd miljø. Følgende aspekter bør vurderes:

i) Forståelse av energibehov og bekjempelse av energifattigdom

Basert på disse retningslinjene er den generelle konklusjonen at effektiv energistyring og bærekraftig praksis for bygninger krever en omfattende og fasettert tilnærming. Dette inkluderer overvåkning av nøkkelindikatorer for ytelse, gjennomføring av grundige vurderinger av bygningens ytelse, utvikling av evalueringsprotokoller, og være oppdatert på lover og byggeforskrifter.

Brukerne må rustes med kunnskap om energimerking og fornybare energikilder, det må etableres observatorier for energieffektivitet, samt at utdanning og kompetansebygging må fremmes. Implementering av både kortsiktige strategier for økt energieffektivitet og langsiktige tiltak er nødvendige for en effektiv overgang til en rettferdig samfunnsutvikling. For å velge de mest effektive tiltakene for framtidens klima kan det være nyttig å utføre kost-nytte-analyser. Beslutningstakere må informeres om konsekvensene av alvorlige hendelser som skyldes klimaendringer slik at det kan opprettes økonomiske insentiver og utarbeides skreddersydde tekniske forskrifter. Oppmuntring til bærekraftige tiltak, som treplanting, kan bidra til å forbedre energiytelsen. For å redusere risikoen for energifattigdom må energieffektivitet integreres i alle aspekter ved bygningsdesign, drift og brukeradferd. Samtidig må det tas hensyn til folks sosioøkonomiske bakgrunn, for beboere i det bygde miljøet, og endringer som utløses av urbanisering og klimaendringer.

ii) Å ta informerte valg angående varmeisolasjon og oppgraderingsløsninger

Når et oppgraderingsprosjekt gjennomføres, er det avgjørende å velge tilpassende materialer som er kompatible med eksisterende strukturer, enkle å installere, har lang holdbarhet, er trygge, fuktsikre og brannsikre. Materialene bør bidra til et mer motstandsdyktig og energieffektivt bygd miljø uten å gå på bekostning av beboernes komfort eller sikkerhet. Videre bør de respektere både omgivelsene, og bygningens arkitektoniske integritet. Disse retningslinjene har en helhetlig tilnærming til bygningsoppgradering som prioriterer bærekraft, effektivitet og langtids verdi. Ved å vurdere faktorer som livssyklusanalyse (LCA: Life Cycle Assessment), materialopprinnelse, viktigheten av originale materialer og/eller eiendeler, tilpasningsdyktige gjenbruksstrategier, overvåkningssystemer og programvare for energisimulering, kan vi sikre at oppgraderingene gjøres miljøvennlige, kostnadseffektive, og gunstige på lang sikt. Tilnærmingen forbedrer ikke bare bygningsytelsen, men bidrar også betydelig til å oppfylle de mer generelle bærekraftsmålene.

iii) Vurdere påvirkningen av klimaendringer og forberedelse for fremtidige scenarioer

Retningslinjene fremmer en helhetlig tilnærming til bygningsdesign som tar hensyn til klimaforhold, overholder energieffektivitetsstandarder, innlemmer tilpasningsdyktige systemer, fremmer brannsikkerhet, oppfordrer til energieffektive løsninger, og støtter oppunder oppgraderingsprosjekter. Bruken av ikke-destruktiv testing (NDT: Non-Destructive Testing) og trådløse sensornettverk for sanntidsdatainnsamling og analyse må også fremheves. Det anbefales å installere og overvåke prototypefasadesystemer under reelle forhold for å sikre effektivitet og brukervennlighet. Denne tilnærmingen forbedrer ikke bare bygningens bærekraftighet, men også dens motstandsdyktighet i møte med klimaendringer. Byplanlegging og bygningsdesign bør tilpasses konteksten og ta hensyn til de unike utfordringene og mulighetene ulike klima byr på. I de skandinaviske landene betyr dette fokus på isolasjon, oppvarmingssystemer, og kuldetolerante materialer for å håndtere høye energibehov i kalde klimaer. Derimot trenger middelhavsland strategier for å takle varme og sollys, som solskjerming, ventilasjon og kjølesystemer.

De bø også tas hensyn til høy luftfuktighet langs kysten. En fasettert tilnærming som tar lokale hensyn, bruker tilpassende materialer og teknologi, involverer samfunn og øker bevisstheten i befolkningen, er avgjørende for å skape urbane miljøer som er motstandsdyktige mot klimaendringer.

iv) Effektiv involvering av målgrupper

Avslutningsvis kreves en omfattende, regionsspesifikk tilnærming som inkluderer interessentene for å gjennomføre energieffektive oppgraderinger av eksisterende bygg. Dette inkluderer involvering av alle aktuelle parter i beslutningsprosessen, tilpasning av strategier etter interessentenes behov og verdier, undersøkelser rundt muligheter for økonomisk støtte for å installere solcelleinstalasjoner, promotering av energieffektivitetspolitikk og å fremme en felles forståelse for bærekraftig bevaring. Det involverer også overholdelse av regionsspesifikke retningslinjer, forslag til balanserte strategier, samarbeid med fagfolk for å ta informerte beslutninger, og opplæring om fordelene ved energieffektive oppgraderinger. Denne helhetlige tilnærmingen tar sikte på å oppnå energieffektivitet samtidig som kulturell arv bevares og miljømessig bærekraft fremmes, både i skandinavisk- og middelhavskontekst. Retningslinjene foreslår en bred tilnærming til vedlikehold og inngrep, ved å bruke sårbarhetsanalyser. Denne tilnærmingen innebærer bruk av statistiske metoder som et tidlig varslingssystem, grundige egnede metoder, resultater og tolkninger, og involvering av alle relevante interessenter i vurderingsprosessen. Strategien bidrar ikke bare til å kunne ta informerte valg, men sikrer også en transparent prosess, effektiv kommunikasjon og omfattende vurderinger ved å ta hensyn til alle relevante synsvinkler. Det kan dermed konkluderes med at denne proaktive og inkluderende tilnærmingen kan føre til effektive vedlikeholdsstrategier, og forhindre potensielle utfordringer.

EFFEKTIVITETS-teamet.

EFFICACY Handbook

Energy eFFiciency buIlding and CircularA eConomY for thermal insulation solutions

The **EFFICACY HANDBOOK** is a comprehensive guide that addresses critical aspects of energy efficiency and sustainability in building design. It covers a broad spectrum of topics, including understanding energy demands, addressing energy poverty, making informed choices about thermal insulation materials and retrofit solutions, considering the impact of climate change, and preparing for future scenarios. It also provides **technical guidelines** and strategies for effectively **engaging target groups**.

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