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D2.3 – Socio-economic assessment and end users' segmentation

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Executive Summary

This document provides an in-depth socio-economic evaluation of the BIO4EEB countries: Germany, France, Spain, and the Czech Republic. It is a significant step towards creating accurate user archetypes for energy modelling and reducing the performance gap in a virtual demo country, Hungary.

Section 1 sets the context, states the research background, aims, objectives, and primary audience

Section 2, the literature review, examines current EU legislation related to thermal comfort, discusses socio-economic influences across multiple countries, and explores the existing knowledge on end-user preferences and expectations.

Section 3 outlines the methodology for survey design and analysis, and for the identification, categorization, and segmentation of key socio-economic factors across countries.

Section 4 presents the results of the survey and the socio-economic segmentation on a country-by-country basis, offering a concise outline of user archetype generation.

Section 5 outlines the framework for stakeholder analysis, mapping and engagement.

Section 6 undertakes a thorough stakeholder analysis and mapping, examining the power structures of key stakeholders.

Section 7 delves into the identification of stakeholder drivers and needs.

Section 8 develops an initial BIO4EEB strategy for engagement, assessing stakeholder engagement strategies.

Section 9 discusses the limitations of the current study and suggests potential mitigation strategies.

The document concludes with the References and Annexes sections, where the reader can find the user archetypes based on the survey. The attached Masterplan of interaction below shows the contributions created by WP2 deliverables and explains the position and the impact in this framework.

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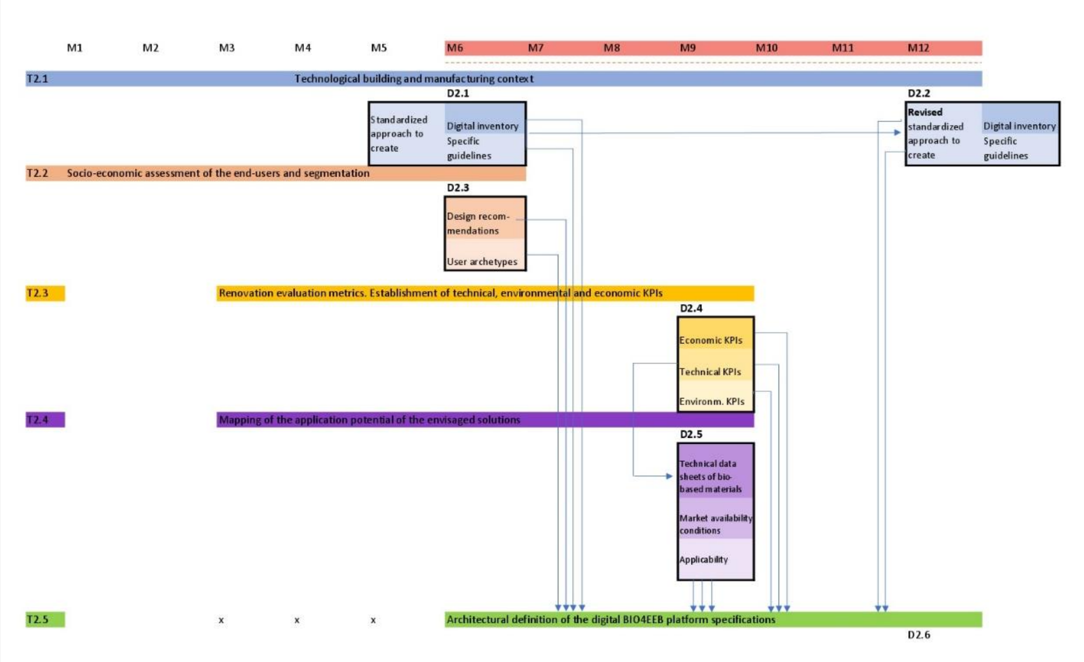

Figure 1 Masterplan of interaction WP2

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Abbreviations and Acronyms

Abbreviation and acronyms	Description
AC	Air Conditioning
ALG II	Unemployment Benefit II
ATG	Adaptive Temperature Limits
BPIE	Buildings Performance Institute Europe
DBT	Dry Bulb Temperature
DGNB	German Sustainable Building Council
EET	Energy Efficient Technology
EN	EN: European Norm (used before a number to indicate a European standard, e.g., EN 16798-1)
EnEV	Energy Conservation Ordinance
EU	European Union
GB	Green Building
GTO	Weighted Temperature Exceeding Hours
HVAC	Heating, Ventilation, and Air Conditioning
IEQ	Indoor Environmental Quality
INE	National Statistics Institute
INSEE	National Institute of Statistics and Economic Studies
ISCO	International Standard Classification of Occupations
KPI	Key Performance Indicator
NUTS1	Nomenclature des Unités territoriales statistiques level 1
NZEB	Nearly Zero-Emission Building
OECD	Organisation for Economic Co-operation and Development
PMV	Predicted Mean Vote
PPD	Predicted Percentage Dissatisfied
PV	Photovoltaic
SOEP	Socio-Economic Panel
SGB II	Book 2 of the German Social Code
WHO	World Health Organization

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1 Introduction

1.1 Background

This report is part of Work Package 2 (WP2) within the BIO4EEB project (101091967), funded by the European Commission under the new Horizon Europe programme. BIO4EEB aims to close the increasing gap of insulation material shortage caused by the regular growing demand and the mismatch caused by lacking production potential and the outcome of the current energy crisis by boosting the use of available bio-based qualified materials as alternative solutions. To do this, BIO4EEB focuses on putting the specific needs and requirements of end users at the centre of the project, this task is dedicated towards the early analysis, characterization and segmentation of the end users (investors, building owners) according to a number of key economic and socio-cultural variables which will prove critical in designing pertinent renovation approaches. In order to effectively plan and design the BIO4EEB framework, it is indispensable to understand and cross reference information on the in-depth building typology make-up of the main European member states represented in the consortium. T2.2 will focus on user behaviour analysis which will be used to reduce the performance gap between the predicted and real energy consumption of buildings. Furthermore, in T2.3 there will be a stakeholder engagement methodology developed, which will later be used for the whole construction process providing options for different levels of engagement (from information provision to occupant led process).

1.2 Aims and objectives

Task 2.2 and the corresponding deliverable of D2.3 set out to deliver the following:

Table 1 Aims and objectives of Task 2.2

From an academic perspective:	From a practical perspective:
• Provide country specific knowledge on socio-economic factors influencing decisions on thermal comfort • Provide more accurate users-profiles for energy modelling in specific countries.	• Provide input for energy modelling in WP4 • Provide an initial stakeholder engagement methodology for the Advisory board set up in T6.3.1 • Provide clarity on relevant stakeholders and segmentation of end-users for the BIO4EEB platform in T3.7

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1.3 Target audience

- Scientific research organizations and researchers who can use these findings as a base for further investigations.

- Professionals in social and behavioural sciences and in the energy field who are engaged in research in these fields and can use this report for consultation.

2 Summary of existing literature

2.1 Thermal comfort standards, and guidelines

Thermal comfort is a condition of mind that describes the satisfaction rate of the thermal condition of the individual. The same indoor or outdoor conditions may lead to different subjective responses. One obvious reason is that people differ and therefore not all are satisfied by the same conditions. The thermal comfort level in residential buildings has a great impact on the emotional and physical profile of the residents. For example, high temperature or overheating in the dwelling may lead to various problems (sweating, tiredness, decreased efficiency, sleep disorders and skin allergies). Therefore, the acceptable and comfortable indoor environment should be considered to improve the resident's emotional status, health, and well-being.

There are many references to the World Health Organization (WHO) guidance on thermal comfort in housing, but not to the original source material. It can be however concluded that while the term "thermal comfort" is used to refer to several factors affecting human satisfaction (Figure 2), the WHO's guidance for the home environment aims at protecting health, particularly the health of those most susceptible and fragile to temperatures outside that range, such as the children, elderly and diseased people. The main WHO guidance is following:

- Indoor housing temperatures should be high enough to protect residents from the harmful health effects of cold. For countries with temperate or colder climates, 18 °C has been proposed as a safe and well-balanced indoor temperature to protect the health of general populations during cold seasons.

- In climate zones with a cold season, efficient and safe thermal insulation should be installed in new housing and retrofitted in old housing. Thermal insulation, housing location, building materials and house orientation, window shades, green spaces and ventilation (including use of cooler night-time air) and air conditioning can help to mitigate high indoor temperatures. Passive mitigation measures or mechanical ventilation systems that are free or low-cost to run, such as those powered by solar technology, are often preferable.

- In populations exposed to high ambient temperatures, strategies to protect populations from excess indoor heat should be developed and implemented.

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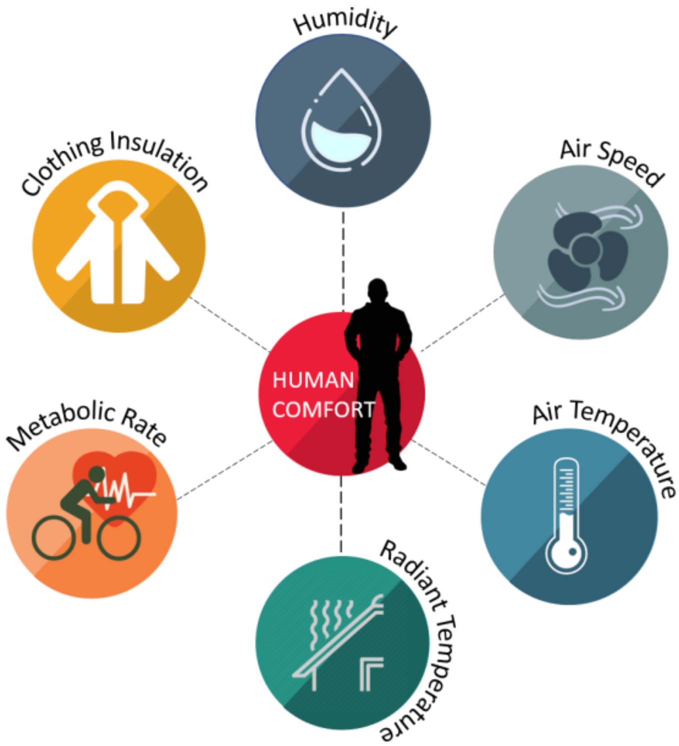

Figure 2 Factors affecting human thermal comfort (Jadhav, 2018)

The leading standards defining thermal comfort conditions are ASHRAE 55 and ISO 7730, both based on the same thermal comfort model by Fanger (Fanger, 1970). Both standards cover the evaluation of indoor, thermal environments including residential and industrial. They both provide definitions, requirements, and parameters that need to be met to achieve thermal comfort.

ISO 7730-2005 is a global standard that aims to estimate the general sensation of comfort and dissatisfaction experienced by individuals in environments with moderate temperatures. The standard utilizes two key indices: Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) (Zare et al., 2018). PMV predicts the average collective sensation of a group of people exposed to a similar environment, considering factors such as dry temperature, average radiation temperature, relative humidity, air velocity, metabolism, and clothing. On the other hand, PPD estimates the percentage of individuals who feel either warm/hot or cool/cold, representing the proportion of people likely to express discomfort. The standard proposes three categories of comfort (A, B, C) based on the range of PMV values (±0.2, ±0.5, ±0.7) and allows for flexibility in applying these categories to different types of buildings. The standard also offers methods for assessing local discomfort caused by draughts, asymmetric radiation, and temperature gradients. It provides a comprehensive framework for evaluating and interpreting thermal comfort, enabling designers and practitioners to create environments that meet the occupants' needs.

The ASHRAE-55 standard, developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, serves the purpose of specifying the combinations of indoor thermal environmental parameters (temperature, thermal radiation, humidity, and air speed)

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and personal factors (clothing insulation and metabolism rate) that will result in thermal conditions deemed acceptable to the majority of occupants, similarly to ISO 7730 (Taleghani et al., 2013). The ASHRAE-55 standard focuses on evaluating acceptable thermal environments for occupant-controlled naturally conditioned spaces and is used in the design, operation, and commissioning processes. It categorizes thermal acceptability based on occupant satisfaction levels, with two categories representing 80% and 90% acceptability, equivalent to 20% and 10% dissatisfaction, respectively. ASHRAE-55 has been continuously updated over the years and is predominantly recognized within the United States, although it has international applicability.

Other standards include EN 16798-1, the Dutch Adaptive Temperature Limits (ATG) guideline, and it is also worth mentioning some green building certification standards' approaches and guidelines for thermal comfort i.e. DGNB.

EN 16798-1 is a standard that provides guidance on how to establish and utilise design criteria for dimensioning building systems, as well as input parameters for energy calculations and long-term evaluation of indoor environments. It also emphasizes the parameters to be monitored and displayed in accordance with the Energy Performance of Buildings Directive. The standard focuses on non-industrial buildings such as single-family houses, apartments, offices, and educational buildings. Overall, the standard aims to provide a framework for establishing appropriate environmental conditions and ensuring occupant comfort in various European building contexts.

In the Netherlands, a guideline for thermal comfort called the ATG was introduced in 2004 as an alternative to the previous Weighted Temperature Exceeding Hours (GTO) method. The GTO method lacked flexibility in predicting thermal comfort for different types of buildings. The ATG guideline divided buildings into two types: alpha and beta. Alpha buildings are naturally ventilated, while beta buildings are mechanically conditioned with sealed facades. The development of the ATG guideline was driven by the need for clearer communication among stakeholders involved in building design, construction, and operation (Linden et al., 2006). It aimed to address the fact that occupants in different types of buildings had varying perceptions of thermal comfort, even when the GTO method predicted similar indoor climates. The ATG guideline provides a practical tool for assessing thermal comfort as building performance during design phases and for evaluating actual performance after the building's completion.

DGNB – the abbreviation (in German) for the German Sustainable Building Council, is a non-profit organisation based in Stuttgart, which has developed a certification system for sustainable construction. The system is not only used in Germany and Europe, but it is internationally recognised as the Global Benchmark for Sustainability. The DGNB System includes the criterion "thermal comfort" for new buildings, which include the specifications of DIN EN 15251, DIN EN ISO 7730, DIN EN ISO 13786, DIN EN ISO 10211, together with the DIN EN ISO 13370, (or) DIN EN ISO 13789, DIN EN 12831 and the workplace regulation (from German Employers' Liability Insurance Association).

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Table 2 Factors affecting human thermal comfort

Factor affecting human thermal comfort	**Explanation**
Airspeed (Environmental factor):	The rate of air movement at a given point in time regardless of the direction.
Air temperature (Environmental factor):	The air contact temperature measured by the dry bulb temperature (DBT).
Clo (Personal factor):	The unit used to represent the thermal insulation from clothing, where 1 clo = winter clothing and 0,5 clo = summer clothing. There is a difference between clothing insulation (Icl), which includes even parts of the occupants' body uncovered by clothing, and garment insulation (Iclu), which only refers to heat transfer obtained from skin-to-clothing contact.
Relative Humidity (Environmental factor)	The ratio of the partial pressure (or density) of the water vapor in the air to the saturation pressure (or density) of water vapor at the same temperature and the same total pressure.
Mean Radiant Temperature (Environmental factor):	The uniform surface temperature of an enclosure where an occupant would exchange the same amount of heat as in the actual non-uniform space, calculated from the weighted temperature average of each surface divided by the total area of the space.
Metabolic Rate (Personal factor):	The rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism is usually expressed in terms of the unit area of the total body surface. In this standard, the metabolic rate is expressed in met units. This unit is accounted for as the personal activity of occupants, where 1 met is a person at rest.

It is also known, that the energy efficiency and performance of buildings are significantly influenced by the interactions of occupants with the energy system, largely determined by their comfort needs. Stazi et al identified four core factors: occupant presence and equipment usage; window and door usage patterns; setpoints and usage of heating appliances; and shading usage patterns (Stazi et al., 2017).

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Below, key standards that define these factors are explored in detail:

- Occupant presence and equipment usage:

The EN 16798-1:2019 standard provides EU-wide guidelines on considering occupancy and equipment use in different types of buildings. It includes simplified schedules that don't account for regional differences and also prescribes usage schedules for heat-generating appliances and lighting. Data for occupant presence, collected from countries such as the Netherlands and Italy highlight considerable variation in residential buildings. Still, the lack of representative data for each country is a hurdle in creating standardized norms. The standard outlines indoor environmental requirements for building design and energy performance calculations. It presents design criteria for factors like thermal discomfort, radiant temperature asymmetry, and floor surface temperature. The Annex of the standard offers default schedules for occupancy and equipment usage if specific values are unavailable.

EN 16798-1:2019 also offers guidelines for equipment usage and lays out requirements for several indoor environmental parameters, including thermal environment, air quality, lighting, and acoustics. These parameters are designed to guide building system design and energy performance calculations. The standard is relevant in settings where human occupancy shapes indoor environment conditions and where production or industrial processes have minimal influence. Included in the standard, Annex C provides default schedules for lighting and appliances that can be used for energy calculations when specific values aren't available. These schedules cover various building use cases such as different types of offices, classrooms, day-care facilities, department stores, restaurants, and various residential scenarios. The standard suggests that the equipment use in residential buildings should be 3W/m^2. However, it does not differentiate these schedules based on the days of the week or seasons, and the same schedule is suggested for all types of residential buildings. Lighting should be determined based on the installed lighting power per room. For more guidance on lighting power, reader can refer to the EN 15193-1 and FprCEN/TR 15193-2 documents.

- Window and door usage patterns

The EN 16798-1:2019 standard, primarily focused on buildings with mechanical cooling and ventilation, does not specify schedules for window use. While country-specific regulations provide data for window sizing, guidelines for their usage, especially for space heating calculations, are rare. Window operations are influenced by numerous environmental factors, such as humidity and high heat loads, as well as individual habits. Strategic window use could help reduce space heating requirements.

In an energy modelling context, window and door usage usually can be translated into changes in specific airflow and air change rates.

Reviewed regulations like EN 15665, EN 13779, or EN 16798 set minimum airflow rates for mechanically ventilated spaces, leading to airflow between 0.23 and 1.21 h^{-1} in test dwellings (Brelih, 2012). However, these standards don't define ventilation rates for naturally ventilated spaces. For such calculations, EN 16798 suggests using design opening areas as predefined airflow rates, with specifics on local climate and building attributes.

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Dimitroulopoulou's review on European ventilation rates found that a minimum air change rate of 0.5 per hour is typical in dwellings, which could impact health effects in vulnerable groups (Dimitroulopoulou, 2012). But Nordic studies found no association between ventilation rates above 0.5 h^{-1} and asthma or allergies in children. However, a large portion of Nordic dwellings didn't meet this minimum requirement. Meanwhile, higher rates were observed in the Netherlands, Greece, Portugal, and mechanically ventilated dwellings. A 2015 BPIE (Kunkel et al., 2015) study found varying regulations across eight EU states regarding indoor air quality and thermal comfort. Some countries mandated mechanical or natural ventilation, with mandatory mechanical ventilation in multifamily and high-rise buildings in Denmark and Poland respectively. While Belgium and Germany recommended mechanical ventilation, Italy favored natural ventilation. Requirements for heat recovery system efficiency and airtightness varied across the EU.

- <u>Setpoints and usage of heating appliances</u>

The EN16798 standard, which is the foundation for energy calculations throughout Europe, sets the heating setpoints at 20°C during the day (from 7 am to 9 pm) and 16 °C during the night (from 10 pm to 6 am). In addition to this, Italy has specific requirements under the Presidential Decree 74/2013. This decree, which applies to both public and private buildings, mandates that the average air temperature in each heated space should not rise above 18°C, with a tolerance of 2°C. Germany, on the other hand, uses the DIN V 18599 standard. This series provides a methodology for evaluating the overall energy efficiency of buildings, taking into account all energy quantities required for heating, ventilation, air conditioning, and lighting. Part 10 of this standard defines the boundary conditions of use and climatic data. For non-residential buildings, the internal set-point temperature for heating operation is maintained at an average value of 21 °C during normal usage time, with a minimum temperature for heating operation set at 20° C. Finally, in Hungary, the national calculation methodology for building energy performance is defined by the 7/2006 (V.24.) TNM Decree. This decree allows for following the MSZ EN 15251 standard or the settings defined in the decree for internal temperatures. Here the minimum temperature for heating is define as 20°C for occupied spaces (i.e. rooms, dining, bedrooms) and 16°C in other rooms (i.e. kitchen, storage).

- <u>Shading usage patterns</u>

Shading technical details are typically defined by the combined g-value of the shading and its glazing, as per EN 410, but operational guidelines are undefined. With shading, most standards and guidelines focus on the avoidance of overheating problems.

In Hungary, the 7/2006 TNM Decree Appendix 1 establishes energy efficiency standards. Transparent surfaces' orientation dictates a maximum g-value, with solar protection mandatory for certain orientations, aiming for g-value<0.3.

A BPIE study identified specific shading regulations:

- In Brussels, overheating is limited to 5% yearly, with the Building Energy Performance regulation considering solar protection. Efficient solar shading (g<0.5) is advised for large sun-facing glazing surfaces.

- France mandates mobile solar shades for sleeping quarters in CE1 category buildings. The solar factor is dependent on window orientation and noise level.

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- German GEG limits the maximum solar gains during summer based on the g-value indicator. The DIN V 18599, Part 2 provides seasonal shading efficiency calculation methods.

- In Italy, external shades are mandatory for new builds and major refurbishments unless windows have a solar factor ≤ 0.5. Some regional laws specify minimum window surface shading percentages.

- Sweden has no mandatory shading requirements but recommends various methods to utilize shading, such as solar shading and window size modification.

Country-specific g-value regulations for summer exist, but shading usage schedules remain undefined. Guidelines on shading operation schedules are available and correlate with environmental parameters, indicating that strategic shading can have an effect on space heating needs.

2.2 Socio-economic effects on thermal comfort

When occupied, performance of the building depends on how well the building design addresses the needs of its occupants, how much control the designers have given to occupants and how well the design team's foresee occupants' use preferences of the building and its systems in the future (Bleil de Souza & Tucker, 2015). During the occupation, thermal comfort of the occupants is hence one of the most influential factors on energy use. Thermal comfort can be defined as the condition of mind which expresses satisfaction with the thermal environment(International Organization for Standardization, 2006). Concept of human thermal comfort dates back to 1774 developed by a British physician. However, quantification of thermal comfort has been a challenge. The range of temperatures which are presenting the comfort condition can differ based on cultural, environmental, and personal factors (Taleghani et al., 2013). The time of the occupants spending in-door has been increasing, especially due to COVID-19 pandemic since which home-office work has increased.

Although occupant behaviour is a significant factor affecting building energy consumption, there is still lack of knowledge regarding the interaction between humans and buildings. It has been recognized that maintaining occupants' comfort conditions is the main reason for energy consumption in buildings. So, there are two approaches to achieving reduction in energy use in buildings, to either invest in technology or change occupant behaviour.

Paauw et al. identified four energy user profiles based on interviews about potential drivers for energy use behaviour, environmental protection or personal convenience:

1. 'Convenience/ease'- act because of comfort needs without interest in energy use, money nor environment;
2. 'Conscious'- choose for comfort, but have awareness about the consequences on their economic situation and environment;
3. 'Costs'- aware of the cost (economic and/or energy) and consume less energy to save money;
4. 'Climate/environment'- entirely basing their actions on environmental concerns (Paauw et al., 2009).

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Unlike buildings, the occupants are more flexible to changes in climate conditions, lifestyle, attitudes etc. Moreover, socio-economic characteristics might influence lifestyle, attitudes and preferences (Harputlugil & de Wilde, 2021). Hence, the understanding the socio-economic effects on thermal comfort could provide with more efficient approach in wider adoption of energy efficient solutions.

Sovacool et al. addressed the gap about the consumer readiness and social acceptability, knowledge, and engagement by investigating satisfaction regarding existing heating system, expectations concerning thermal comfort, resistance to changing the heating system and relationship between level of satisfaction and carbon intensity of the heating system.

The method relied on analysing data from surveys conducted in five European countries (i.e. Germany, Italy, Spain, Sweden and UK). They reported heat literacy and self-reported knowledge as having low variation across different cultures and countries considered (low to moderate). Moreover, satisfaction by the existing heating system is typically high with less than 10% of population indicating dissatisfaction. In all five countries higher temperatures are preferred during the winter compared to summer. Temperature preference for winter was between 20-21 °C with Spain reporting the highest average temperature. On the other hand, for summer the preferred temperature range was between 19 and 20 °C with the UK respondents indicating the lowest value. Moreover, it was concluded that people in considered countries have common understanding what is a preferred/acceptable level of comfort (Sovacool et al., 2021).

In a study on decarbonizing household heating based on demographics, geography and low-carbon practices and preferences conducted on the same set of countries as specified above findings showed that decisions made about heating, space cooling and hot water are sometimes purposefully irrational. Respondents who were willing to adopt low-carbon heat, highly preferred reliability and ease of use(Sovacool et al., 2021). Hence, these two factors could be considered as significant from end-user side when developing energy efficient solutions. Moreover, technology suppliers and professional technicians were opted for as most trustworthy entities (Sovacool et al., 2021) which emphasis importance of their engagement as stakeholders.

In the case of cultural aspect, Sovacool et al. found significant difference in actions, preferences and practices regarding the heating among respondents coming from considered European countries. The high variation in heating literacy, practices, preferences and priorities emphasis the significance of altering from pushing the “one-size-fits-all” policy options which could lead to dissatisfaction based on variety of preferences (Sovacool et al., 2021).

Moreover, Rinaldi et al. conducted a research on uses of energy in buildings by extraction of influential factors of occupant behaviour. They found high correlation between occupant behaviour (e.g. set-point temperature) and characteristics of the built environment (e.g. year of construction). This was mainly demonstrated through the challenges in adjusting to discomfortable conditions in the older buildings lacking energy and cost efficiency measures. Hence, assuming the same set-point temperature value irrespective of the building characteristics may lead to differences in predicted and observed energy consumption. Additionally, socio-economic status (i.e. family size, monthly income) has been recognized to have an influence on the occupants’ behavioural patterns. Families with higher income tend to have a lower tolerance in adapting to the environmental conditions and tend to rely on energy- and cost-intensive active conditioning systems (Rinaldi et al., 2018).

On the other hand, Guerra Santin conducted a study on occupant living in the buildings built after introduction of the energy performance regulation in Netherlands (1995). His findings showed that singles' and couples' behaviour was not highly related to temperature comfort or intensive use of appliances and space, while high-income couples considered less saving energy and more convenient use of the dwelling. However, seniors prompt for comfort with high scoring for both ventilation and temperature comfort. Overall, the difference in energy consumption was also noted with families showing higher, while seniors lower (Guerra Santin et al., 2009).

Overall, considering socio-economic factors when evaluating thermal comfort of occupants seems to be one of the essential parameters. As part of this projects by means of questionnaire survey and available literature, investigation of the possible socio-economic factors influencing thermal comfort and willingness to invest in energy efficient solutions will be assessed in the next chapters (3 and 4).

2.3 End-user preferences and expectations

Thermal comfort standards outline desired indoor conditions in buildings, but research highlights a gap between these standards and what occupants actually want. To bridge this gap, understanding occupants' expectations of indoor thermal conditions and their impact on perception is crucial for improving building design and control strategies.

In an attempt to investigate the impact of people's expectations on thermal comfort and sensation in the built environment, Schweiker et al. conducted a study which confirmed that the level of expectation influences thermal perception. The findings revealed several key points. Firstly, people have a wide range of expectations for indoor conditions, and when these expectations are not met, thermal comfort decreases. Secondly, indoor conditions and previous experiences in the environment have the strongest influence on thermal expectations, while outdoor conditions have a lesser impact. The study partially confirmed hypotheses related to demographic differences in expectations and the influence of location and number of days in the laboratory environment. However, the hypothesis that people's expectations are based on outdoor conditions and common indoor conditions was rejected (Schweiker et al., 2019).

In a study in China, Luo et al. examined the relationship between occupants' indoor thermal experiences and their perception of thermal comfort. The findings validated that people's understanding of thermal comfort is influenced by their exposure to different thermal environments. Long-term exposure to comfortable conditions can raise occupants' expectations, while exposure to non-neutral environments can lead to thermal adaptation. The study also highlighted the asymmetry of thermal adaptation, with it being easier for occupants to adapt to a thermally neutral lifestyle compared to lowering their expectations and adapting to non-neutral indoor climates. The results suggest the need for more flexible approaches and new comfort strategies in indoor environmental quality assessment to improve occupants' satisfaction (Luo et al., 2018).

Another survey by Kalmár found that thermal background impacted the thermal perception of warm indoor environment. The findings revealed that subjects from warmer climates who were accustomed to air conditioning systems preferred lower indoor temperatures initially.

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However, their thermal sensation decreased significantly during the two-hour measurements. The evaluation of air freshness and air velocity varied among the different groups. The study suggests that designers should consider the advantages of physiological and psychological thermal adaptation to maximize energy savings in buildings (Kalmár, 2016).

An aspect that affects indoor thermal comfort is recent past experience. A study by Chun et al. investigated how our past experiences with outdoor temperatures affect our comfort indoors. The researchers conducted surveys and measurements and found that the temperatures people were exposed to before entering a controlled environment influenced their feelings of warmth or coolness inside. Even when the conditions inside the room were the same, people who experienced hotter weather outside felt cooler inside, while those who experienced cooler weather outside felt warmer. The study also showed that people who had air conditioning at home felt slightly warmer indoors compared to those without air conditioning. The findings suggest that our daily experiences with outdoor temperatures play a significant role in how we perceive and adapt to our indoor thermal environment (Chun et al., 2008).

Moreover, Lipczynska et al. conducted a climate chamber study on 76 subjects in four body mass index (BMI) categories (i.e. underweight, normal, overweight and obese). The major influence of BMI on the thermal sensation was not noted, but participants in overweight and obese category preferred considerably lower temperatures. Based on the fact that globally 39% of adults are overweight and 13% are obese, these results can have practical implications for implementing control strategies (Lipczynska et al., 2020).

When comparing these articles, a common theme emerges; occupants' expectations and experiences significantly influence their perception of thermal comfort. Meeting occupants' expectations for indoor conditions is crucial, as unmet expectations can result in decreased comfort. Long-term exposure to comfortable or non-neutral environments can shape occupants' understanding of thermal comfort and their ability to adapt. The findings also suggest that individuals from different climates or with different home environments may have varying preferences and adaptations to indoor thermal conditions.

3 Methodology for developing user archetypes and socio-economic segmentation

3.1 Survey design and sampling

In developing the research design, the methods of previous research and the literature on the study of heating and cooling patterns were taken into account.

Due to the subjectivity of thermal comfort, practitioners have typically used methods (e.g., through user interfaces), where continuous feedback is required from the occupants (Zagreus et al., 2004). Despite accurately capturing the thermal comfort of an individual via the survey method, this approach may induce survey fatigue among participants, leading to increasing uncertainty of subjective votes (Wang et al., 2018), and making it arguably inefficient and time-consuming (Ghahramani et al., 2020).

Logging activities are the best way to get a detailed, accurate assessment of users' daily activities (Hiller, 2015). However with the spread of online tools and smartphones, there

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is the possibility to directly collect individual thermal comfort perceptions (Jung & Jazizadeh, 2019).

Social researchers cite low response rates and a non-representative sample as disadvantages of the online survey. In order to avoid this, researchers often use online panels of market research companies to obtain a representative sample.

According to the literature (Deme Belafi et al., 2018; Memon, 2022; Zhang et al., 2018), the survey technique has been most commonly used to investigate:

- Relationship between the actions of the occupants and the characteristics of the building;
- Relationship between the performance of air conditioning systems, occupant behaviour and the characteristics of the building;
- Relationship between the type of ventilation chosen by occupants, indoor thermal comfort and air quality requirements;
- Relationship between actions of the occupants and the characteristics of the building;
- Occupants' behavioural patterns related to energy consumption for heating and cooling;
- Impact of social characteristics and building features on heating behaviour;
- The potential for energy savings based on occupants' heating behaviour.

Some research points to the importance of obtaining information on contextual factors (e.g., available control options, social factors, etc.), to enable accurate prediction of occupant thermal response (Becker & Paciuk, 2009; Wei et al., 2010).

Some aspects of energy use - such as, valid information on energy use in a detailed timely breakdown - cannot be investigated with survey methods. For such purposes, monitoring of energy use through e.g., loggers may be used. The BIO4EBB survey could therefore not provide a detailed schedule of hourly occupancy, lighting, heating practices, electrical appliances, metabolic rate and clothing, differentiated by weekdays, weekends and holidays. Such issues were addressed in the questionnaire, for specific dates. However, the survey method can be used to obtain an idea on heating behaviour patterns, temperature preferences and other important social factors of energy use.

3.2 Data collection and analysis techniques

A nationally representative survey was conducted by one project partner (Hungary) as a pilot study to better understand the heating preferences and behaviour patterns of residents (section 4.1.1). It covers a wide range of factors that determine preferences and choices at both the individual and household level in order to understand the socio-cultural, economic and technological factors that influence the everyday practices of citizens.

The survey covered external (e.g., infrastructure) and internal factors (e.g., attitudes and habits) that affect both individual and collective heating behaviour, thus providing an insight into the factors that influence individual and collective decision-making. For some topics (e.g., energy consumption patterns and everyday heating practices), the possible gender-specific perceptions were given special consideration.

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Five interrelated issues were addressed:

1. **Patterns of energy demand, energy efficiency**, and energy use in everyday situations (e.g. home office, use of smart meters), with a focus on heating;
2. **Schedules of occupancy,** differentiated by weekdays and weekends; The temporal resolution of occupations and practices;
3. **Space heating related comfort requirements**; Thermal comfort and practices, including coping strategies with cold weather;
4. **Location and characteristics of dwelling**: housing type and size, tenure; insulation of dwelling, heating and cooling systems, and availability of smart meters;
5. **Characteristics of households**: socio-economic characteristics as gender, age, education level and financial situation.

The main research questions of the survey were elaborated in accordance with the corresponding objectives of the project and the addressed interrelated issues:

- What are the main daily household activities related to heating and how do they differ in different dwellings?
- What is the combination of factors that influence the heating behaviour on individual and household levels and how they differ across dwellings?

The questionnaire comprised 5 sections and was to be completed in 20 minutes. The first section contained questions about location and building characteristics and household composition. The second section investigated schedules of occupancy. The third section examined heating related comfort requirements. The fourth section analysed the thermal comfort and practices and set-points. The fifth section looked for temporal resolution of occupancy and practices. Several Likert scale questions (1 = strongly disagree, 5 = strongly agree) were used for the questions designed to capture respondents' opinions.

To comply with the working language of the consortium and future adaptability, the questionnaire was prepared in English. The pilot study was made in Hungary. The questionnaire was fully translated into the national language by the Hungarian team.

The pilot phase of the survey took place in early April 2023. The final data collection lasted one month between mid-April and mid-May 2023.

The survey was conducted online using a pool of 165000 possible respondents from a survey panel of a market research company. The panel was created using incentives to reward participation in the survey. Unique personal links were sent to the respondents of the panel.

The sample consisted of residents 18 years and older. A 1000 respondents quota sample was used with a combination of age, gender, education, region (NUTS1) and settlement type. Respondents were selected randomly. The response rate was high: 99,9% of the respondents completed the entire questionnaire.

3.3 Identifying key socio-economic factors

The identification of key socio-economic factors for all BIO4EEB demo countries is a critical part of socio-economic segmentation. This process begins with the assessment of the professional status and roles of individuals, classified into distinct socio-professional

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categories such as managers, salaried employees, retirees, and unemployed individuals. In addition to professional status, age is also considered as a factor influencing career progression and socio-economic standing.

Furthermore, economic capacity is gauged using the measure of equivalized disposable income, which offers a detailed view of the financial resources available to households for spending or saving. This is a composite measure calculated by taking the total income of a household, subtracting tax and other deductions, and then dividing this amount by the number of household members, with each member weighted according to age. Other significant factors include home ownership status, investment trends, savings rates, and spending habits.

These economic KPIs serve as indicators of financial stability, long-term investment tendencies, and the overall financial behaviour of the population segments. The inclusion of utility bills and housing costs in the analysis helps in understanding the financial burden on different segments and the potential incentives that may drive their financial decisions.

3.4 Categorization and segmentation approaches

The categorization and segmentation of the population are carried out based on the identified socio-economic factors.

The population is first divided into groups according to their socio-professional categories. Age is also factored in, offering insights into how professional roles and status evolve with age. Wealth segmentation is achieved using the equivalized disposable income measure. By utilizing this approach, a comparison across diverse households can be made, taking into account the size and composition of each household.

Following the socio-professional and income-based categorization, the identified segments are then further characterized by studying economic KPIs. The purpose of this step is to contextualize the socio-economic data and provide a more comprehensive view of the economic behaviours of different segments. An additional layer of segmentation is conducted by analysing the distribution of socio-economic segments across various residential building typologies. Factors like the size, location, and number of units in a building are considered, contributing to the detailed understanding of the socio-economic profiles of the residents.

In summary, the approach to identifying, categorizing, and segmenting socio-economic factors is a comprehensive process that integrates a variety of dimensions to gain a nuanced understanding of socio-economic behaviours and trends. This multifaceted methodology can provide rich insights for diverse broader applications, including policy-making, market research, and social analysis. Specific to BIO4EEB it can provide insight to the platform design and development in WP3 and to exploitation, business models and marketing strategies in WP5.

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4 End user archetypes and socio-economic segmentation

4.1 Description of survey results connected to user archetypes

As there is no clear, available uniform data on user behaviour connected to space heating in residential setting for all of the real and virtual demo countries (France, Spain, Germany, Lithuania, Czech Republic, Italy, Hungary, Belgium), thus conducting a targeted survey provides valuable insight on occupant behaviour in relevant buildings. Furthermore, information extracted from this survey can also help defining and segment end users who are potentially willing to implement BIO4EEB solutions.

Below the most important results of the survey conducted in Hungary (one of the virtual demo cases) is presented, with particular focus on aspects that might have an effect on socio-economic user segmentation or development of user archetypes describing prominent occupant behaviour.

Similar survey is distributed in all of the remaining real and virtual demo countries, and document is planned to be updated at a later date based on the outcomes of those survey results.

4.1.1 Patterns of energy demand

4.1.1.1 Insulation of dwelling, heating systems, and smart meters

Regarding the insulation of the dwellings, we found that insulated windows (68.9%) and insulated doors (52.2%) were the most common. External or internal insulation of the walls was carried out in almost half of the dwellings (46%). Insulation of the roof was reported in about one third of the houses (34%), and of the attic in 28.1%. The insulated basement was mentioned least often (11.9%).

Modern cooling and heating systems are found in only a few households. 5.3% of the houses have solar panels, another 2.6% had solar collectors and 3.7% had heat pumps installed.

The most common method of optimising energy consumption is the use of energy-saving light bulbs. It is used by 86.6% of households.

In terms of heating appliances, portable electric heaters have the largest share (44.3%). 41.9% of the radiators in the households are equipped with adjustable valves.

Among the control devices, the wall-mounted room thermostat is the most common (25.7%). One tenth of households (9.9%) have a portable thermostat. Almost as high is the share of users of other smart devices that control cooling or heating (9.7%).

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In another question, we specifically asked about the existence of individual smart meters. The smart electricity meter was mentioned in the largest proportion (10.6%). This was followed in order by the smart heating meter (7.6%), then the smart gas meter (5.1%).

Two percent of the dwelling cannot be heated. Of the heating appliances, the most common are those used for space heating (38.4%), including individual heaters powered by gas, electricity, oil or solid fuels. This is followed by boilers and radiators installed in the dwelling (32.3%). District heating is used by 20.8% and boilers and radiators by 8.9% supplying several apartments. 12.2% of the dwellings also use air conditioning for space heating. Underfloor or in-floor heating was reported in 6.4% of the dwellings.

Among the energy sources used for heating, piped natural gas is the most common (50.9%). LPG gas in a container was mentioned by 0.8%. In addition, a significant proportion of solid fuel (wood, coaler coke, pellets) is used by 29.8%. District heating serves 21% of the dwelling, while electricity is used for heating in 21.5%. The use of geothermal energy is still very low (1.2%). 2.4% of the respondents indicated that they also use waste for heating.

4.1.1.2 Sunshine and shading

Before exploring the heating habits and techniques of the rooms occupied we revealed which rooms receive direct sunlight.

The rooms receive less sunlight in winter than in summer. Even in winter, most sunlight reaches bedrooms (65.3%), living rooms (63.6%) and American kitchens (63.4%). Study rooms (57.6%) and dining rooms (50.9%) have a slightly lower share of sunlight. Kitchens receive the least amount of sunlight (43%).

Most of the respondents leaves the shading open during winter in specific rooms. In all of the room types (i.e., study, kitchen, living room, bedroom, dining room) between 79.7-87.3% of the respondents leaves the shading open.

4.1.1.3 Heating habits

As for the habits of heating slightly more than half of the respondents heat all rooms to the same temperature (52.8%), but the rest of the respondents (47.2%) adjust the temperature of the rooms according to use (Figure 3).

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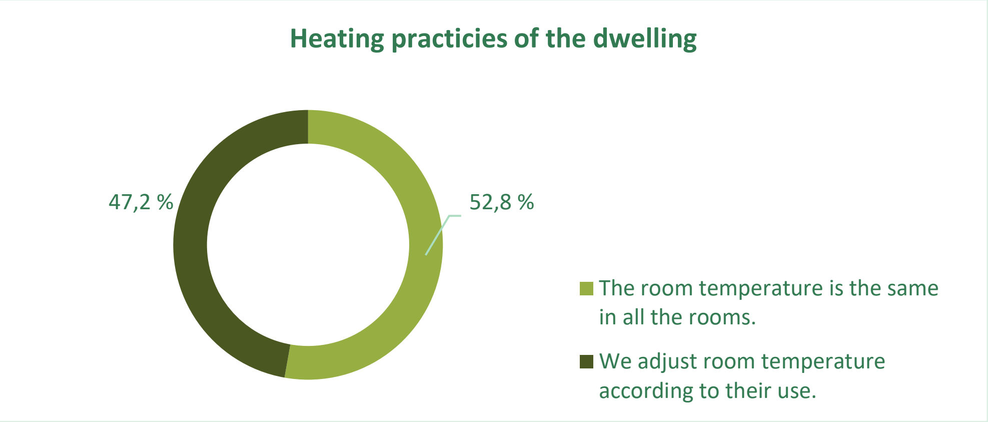

Figure 3 Which of the following best describes the way you heat your dwelling?

It would be very important that everyone has the possibility to control the heating in their home. In Hungary, the percentage of people who cannot control it is very small (2.5%). However, those who can control it have reported different habits. 15% of the households set the heating to certain temperature and leave it that way regardless of the time of the day. One tenth (9.8%) of the respondents set the thermostat to a temperature and let it adjust the heating during day and night. There are several households (15.6%) that control the heating manually and adjust the temperature that way during the day (Figure 4).

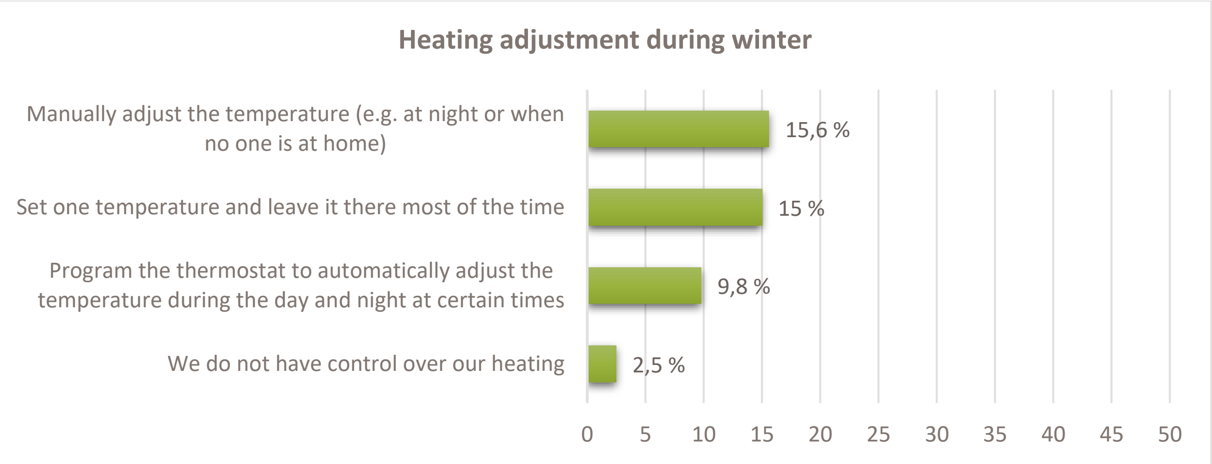

Figure 4 Which of the following best describes how your household controls your main heating equipment most of the time?

The average heating temperature in the occupied and unoccupied rooms of the flat does not differ significantly (Figure 6). The average temperature in the occupied rooms is 22 °C, while the average temperature in the unoccupied rooms is 20 °C.

When no one is at home, most people lower the heating temperature in the home (72.2%) or do so only in some rooms (70.2%). 42.5% of the respondents leave the heating temperature as if someone was at home. Almost one third of the respondents (31.7%) turn off the heating in some rooms when no one is at home and 24.5% of them turn off the heating completely (Figure 5).

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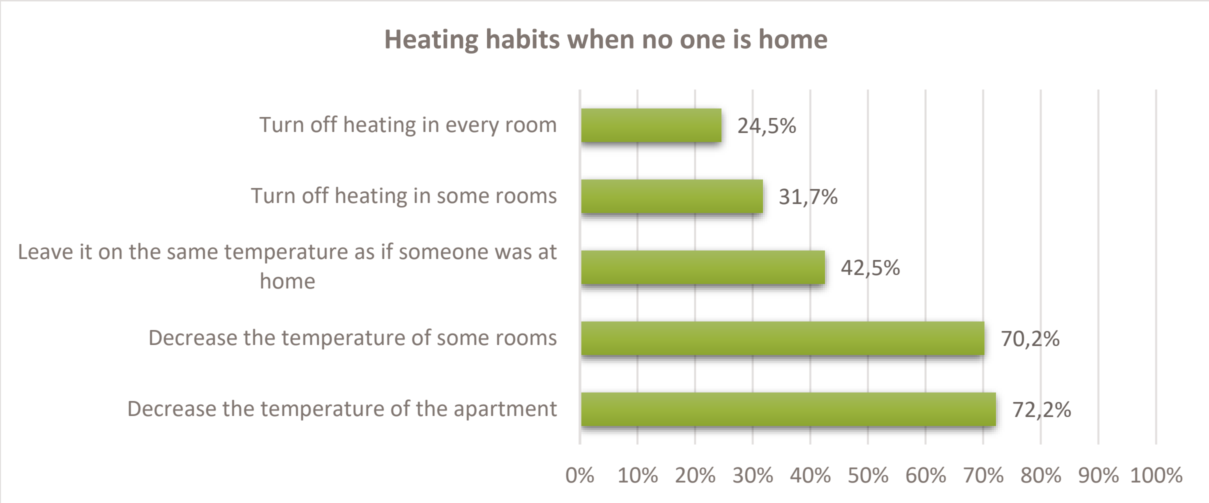

Figure 5 What would you do when no one would be at home?

According to the respondents on average day of December (when no one of the household members are on vacation and they are doing their daily tasks) at 4 pm the mean temperature of the occupied rooms would be 22 °C while the mean temperature of the unoccupied rooms would be 20 °C (Figure 6).

4.1.1.4 Temperature and preferences

Most of the Hungarian respondents (85%) are able to measure the temperature in their apartment, almost 60% in every room, another 25% in specific rooms. Those who cannot measure the temperature in their apartment represent only 15% in the sample. The most common device to measure the temperature among the respondents is the thermometer (analogue or digital) (83.9%), which is followed by the room thermostat for 19.4%. Measuring the temperature by a cooling device (e.g., air-conditioner) applies for 11.8% of the cases. Less common device to measure the temperature is the appliance thermostat (portable) for 10.5%. Other answers then the listed ones were given by only 1%. These answers include for example a weather station or an air purifier.

When it comes to changing the temperature in the apartment in any way most people consider how hot or cold, they themselves feel (59.7%). About one third (33.4%) of the sample considers how hot or cold other members of the household feel when they change the temperature. The temperature measured by a device is the determining factor for 28.6% of the respondents to change the temperature and for only 24.9%, the information they consider when changing the temperature is saving. A small part of the respondents (9.9%) cannot change the temperature.

The usual temperature in the dwelling during winter on an average day of December when no one at the household is on holiday and everyone carries out his/her everyday activities has been investigated for three cases: 1. At daytime, when household members are at home; 2. At daytime, when no one is at home; 3. At night, when household members are at home. Most Hungarians heat their flats between 20°C and 22°C when they are at home: 25.6% of respondents reported a temperature of 22°C, 15.7% reported 21°C and 18.7% reported 20°C. The temperature somewhat differentiates at night: 20.4% of respondents heat their home to 20°C. However, many people still prefer 21-

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22°C (31.8%). At daytime, when no one is at home 41.7% of users heat their home between 17-19°C and 20% to 20°C (Figure 6).

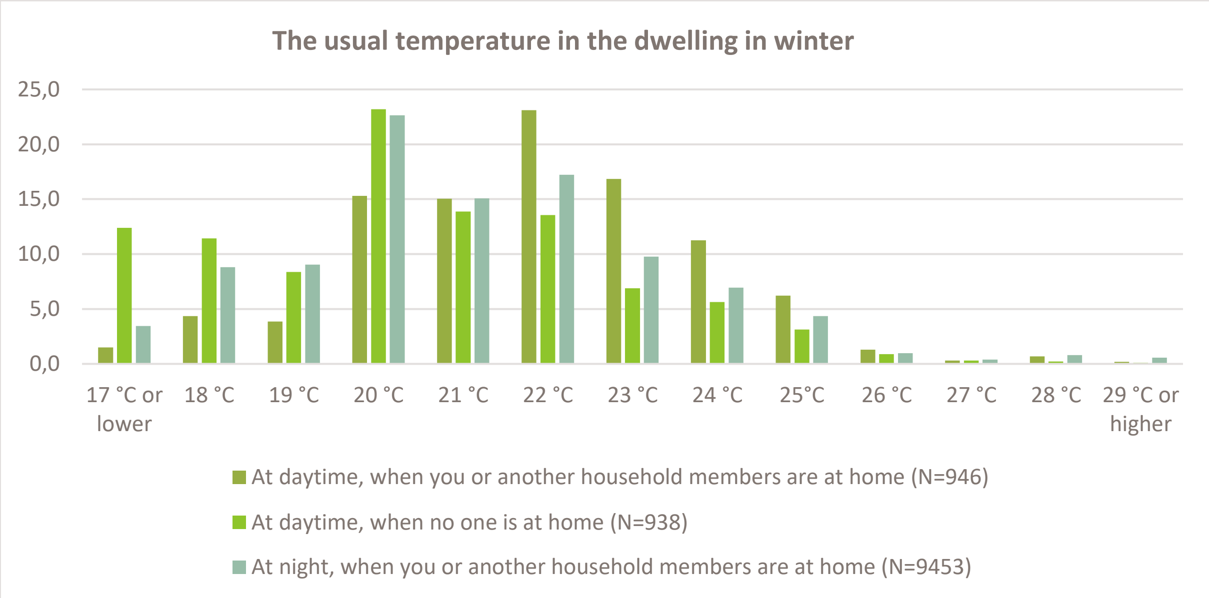

Figure 6 What is the usual temperature in your dwelling during winter on an average day of December?

Respondents were also asked about their preference regarding the temperature in their dwelling during winter on an average day of December in the abovementioned three cases. 23.1% of respondents would prefer 22 °C in their home and a relatively large number, 34.4%, would prefer 23-25 °C. This shows that Hungarians prefer warmer flats (Figure 7).

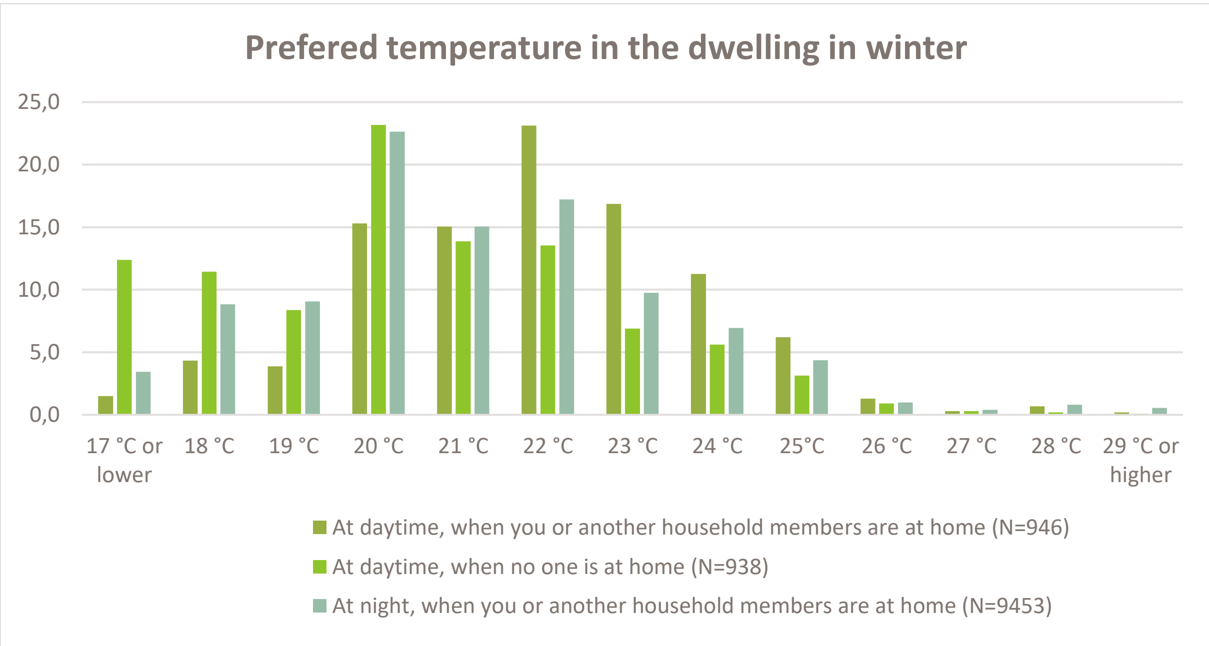

Figure 7 What temperature would you prefer in your dwelling during winter on an average day of December?

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In terms of preferred and actual temperature of the apartment during winter there are no big differences (Table 3). At daytime when the apartment is occupied, someone stays at home the usual average temperature is 21 °C, while the preferred temperature is 22°C (Figure 7 ; Table 3). On the other hand, when no one stays at home the usual and also the preferred average temperature is 20 °C. At night, the usual and the preferred average temperature is also the same, 21°C. People tend to set their heating one degree colder than the preferred average temperature when they are at home. When no one is at home, people like to heat differently and set the temperature a little lower, which can also be done for energy efficiency reasons.

Table 3 Mean of the usual and preferred heating temperature during an average day of December at different occasions

Mean temperature at daytime when someone is home		Mean temperature at daytime when no one is home		Mean temperature at night	
Usual	Preferred	Usual	Preferred	Usual	Preferred
21°C	22°C	20°C	20°C	21°C	21°C

The temperature has been considered very cold by 3.3% of the sample. Altogether 21.9% told that they felt rather cold (frequency of value 5 and 6) about the temperature in their dwelling in December. Neither warm nor cold (value 4) has been chosen by 47.2% of the respondents. Less than 27.6% considered the temperature in their dwelling in December rather warm or very warm (values 1-3).

The next question investigated how comfortable people found the average temperature in their dwelling in December. Answers were given on a five-point scale (1=very uncomfortable, 5= very comfortable). The biggest part of the sample found the temperature neither comfortable nor uncomfortable (frequency of value 3-48.9 %). Altogether 12.3% of the respondents found the temperature rather uncomfortable or very uncomfortable. 27.1% considered the temperature rather comfortable and only 11.7% answered that they found the temperature in their dwelling during winter very comfortable.

When comparing the feelings about the average temperature in the dwelling in December with the feelings of comfortability about it, a positive correlation outlines. A significant number of respondents (63.6%) feel that their home is cold in winter and they find it very uncomfortable. Also, 52.6% of respondents who found their home very warm on an average winter day found it very cosy (Figure 8). In conclusion 38.9% of the respondents are feeling rather comfortable during winter in their dwellings and only 12.2% of the respondents are feeling rather uncomfortable.

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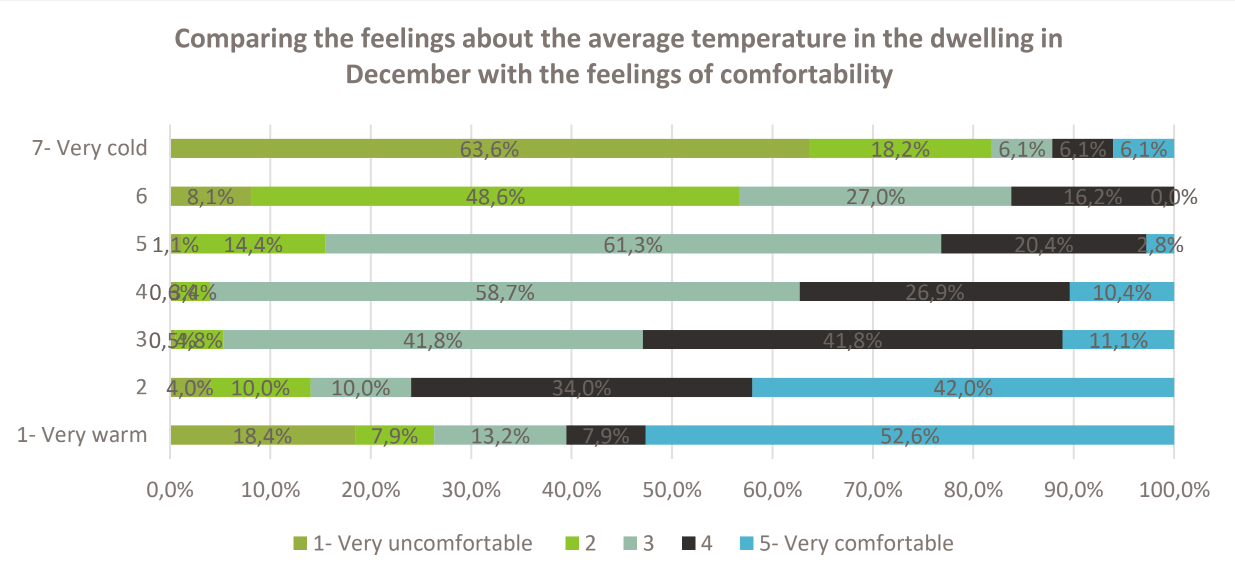

Figure 8 What temperature would you prefer in your dwelling during winter on an average day of December?

4.1.1.5 Schedules of occupancy

In order to more accurately quantify how many people there are at home in the households during the different periods on an average weekday in winter in December (when no one at the household is on vacation and everyone carries out his/her everyday activities) the mean values have been analysed but measured as percentage values of the overall size of the households (mean = 2.27)[1].

Following are the results for the eight-item version of the question on the number of household members staying at home on weekdays:

Weekday all day/all the time option- no valid answer;

Weekday early mornings (6:00-8:00) 75.76% (1.99 person on average),

Weekday mornings (8:00-12:00) 48.89 % (1.28 person on average),

Weekday lunchtime (12:00-14:00) 49.35 % (1.29 person on average),

Weekday afternoons (14:00-17:00) 69.09% (1.81 person on average),

Weekday late afternoon (17:00-19:00) 84.79 % (2.24 person on average),

Weekday evening (19:00-22:00) 90.36 % (2.37 person on average),

[1] In order to compute these proportional values for every day-period the overall household member mean value has been applied, as the differences compared to the variable-level shares have been insignificant, approximately 2 percentage points on average.

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Weekday later at night (22:00-06:00) 90.97% (2.36 person on average) are at home.

On weekends, most household members can be found at home all day.

Weekend early mornings (6:00-8:00) 92.30% (2.42 person on average),

Weekend later in the morning (8:00-12:00) 87.54% (2.31 person on average),

Weekend afternoon (12:00-19:00) 88.11% (2.31 person on average),

Weekend after 19 o'clock there is a slight increase, 92.11% (2.41 person on average),

Weekend night (22:00-06:00) 94.21% (2.46 person on average) are at home.

To explore the temporal resolution of occupation and practices regarding heating, the respondents were asked to think of a cold winter day in December, Wednesday, at 4:00 P.M. when household members are not on holiday and carry out their daily activities.

On average 2.3 household members are at home on such a winter day. In a case of 4.2% no one would be at home. 80.2% said that 1-3 household members would be at home and 15.6% of the respondents said that 4 or more people would be at home.

The next question focused on the possible activities the household members do at home in December on a Wednesday, at 4:00 P.M. They mostly do household chores (68.3%), nonphysical leisure activities (e.g. watching TV, browsing the Internet) (59.2%) and/or take a sleep/rest (47.5%) based on the multiple activity options included in the survey. The 15.8% of the household members study, 15.2% do some physical work, 28.6% do some nonphysical work (e. g. working on the computer) and 7.3% doing exercises (Figure 9).

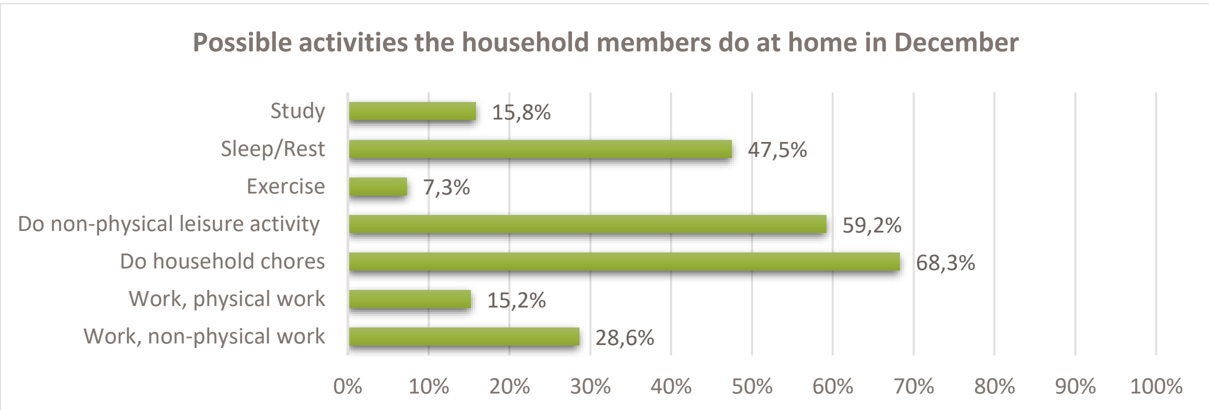

Figure 9 What temperature would you prefer in your dwelling during winter on an average day of December?

As for the rooms occupied by the household members during the nominated period in December the American kitchen (81.3%); and the kitchen (80.7%); living room (in a separated room) (85.2%); dining room (74.7%); bedroom (76.8%); study (in a separated room) (71.7%) have the highest shares according to the multiple answer data.

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4.1.1.6 Practices during the heating period

Regarding practices during the heating season, most people wear warmer clothes on cold days (76%) to avoid an increase in heating costs. There are also some ventilation techniques that many of the respondents use: 78.8% of the respondents lets the window wide open for a short amount of time and 39.6% opens the window narrowly and lets it open for a longer time period. However just 55.1% turns the heating off while airing. About two third of the respondents (66.3%) turns off the heating when they are not at home and 58.7% uses heating only in rooms that are in use (Figure 10).

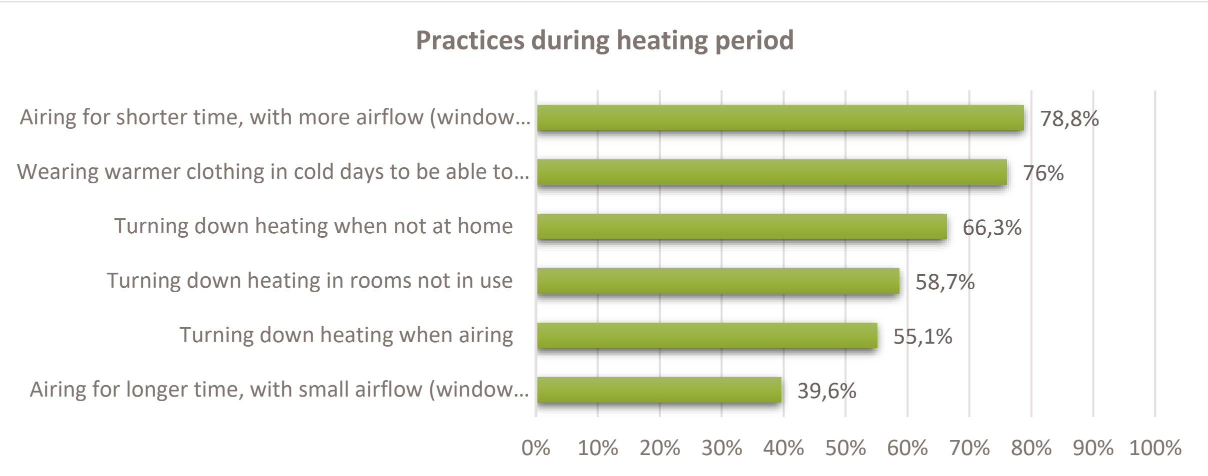

Figure 10 Do you practice the following?

As for the techniques described in the survey to warm themselves up on cold winter days, when feeling cold in the dwelling it is common to wear warmer clothes in order to stay warm (81.3%) and drink hot beverages (52.3%). It is also common to raise the heating temperature (48.1%). It is less popular to leave the shading open (30.3%) in order to let he sunlight make the apartment warmer and only 15.1% of the respondents prefer to do some physical activities to stay warm (Figure 11).

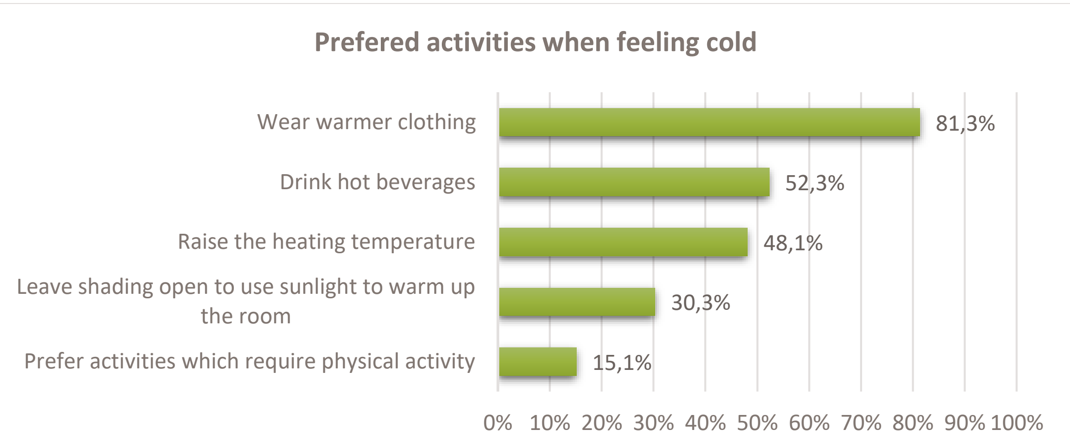

Figure 11 Do you apply any of the following when you are cold in the apartment?

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4.1.1.7 *Household composition, tenure, home office*

After the Covid-19 pandemic, the home office is becoming commonplace in more and more households. 19.3% of households work from home four or more days a week, 6.4% 2-3 days and 3.4% one day. However, in 70.9 % of households this is only occasionally or never the case.

The ownership structure of the dwellings reflects the character of the Hungarian residential property market. A significant proportion of the flats are privately owned (84.7%). The share of private rentals is modest (11.5%) and the share of public rentals is low (3.1%). Only 0.7% mentioned another legal form (e.g. housing co-operative, etc.) (Figure 12).

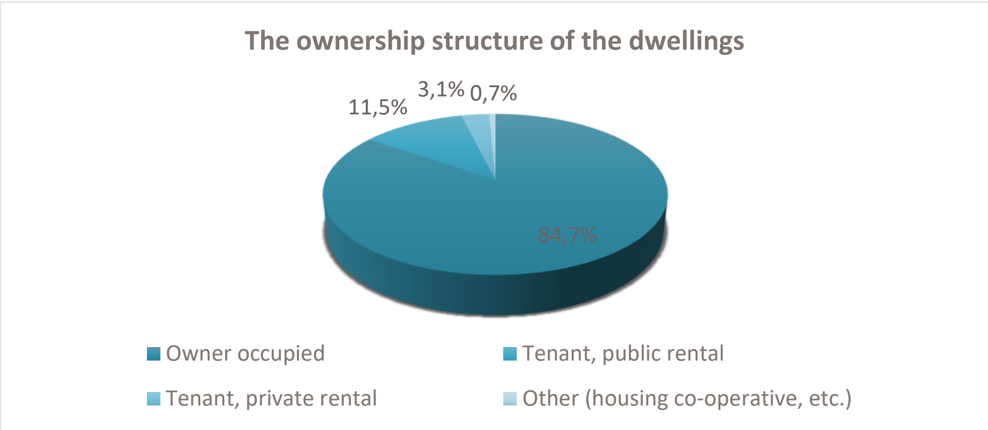

Figure 12 What is the tenure of your apartment?

Looking at the number of occupants of the dwellings, we find that households with 2 persons accounted for the largest share (38.2%) in the sample. This was followed by households with 3 persons (22.6%) and households with 4 or more persons (22%). The share of one-person households was the lowest (17.3%).

Composition of the household members by age: Children aged 3 years or younger lived in 11.4% and aged 4-17 years in 20.2% of households. Adult residents (18-64 years) of employable age lived in 85.6% of the households. People aged 65 and older lived in 32.7% of the dwellings.

4.1.1.8 *Characteristics of respondents*

The breakdown by gender reflects the gender ratio in Hungary: 46.6% of respondents are men and 53.4% are women.

The youngest age group (18-29 years) account for 18.1% of the sample. The share of 30-39 year olds is 19.4% and that of 40-49 year olds is 16.2%. Among the older age groups, 17.7% of 50-59 year olds and 14.5% of 60-69 year olds are represented in the sample. The share of the oldest (over 70 years) is 14.2%.

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In terms of education, 51% of the sample have at most primary education (no formal education or below primary education); 31.3% have secondary and post-secondary non-tertiary education and 17.7% have tertiary education.

Looking at the current employment status of the respondents, we find that the largest proportion (44.6%) reported full-time employment. The share of part-time employees is 6.2%, that of employees in their own company is 2.9%. The second largest group was pensioners with 28%. Among the inactive, the proportion of those at home with small children is 5.7%; the proportion of students is 2.2%. The share of unemployed is 5.9%, that of public employees (employed for no longer than 3 months) is 1%. The remaining 3.5% of the sample placed themselves in other categories.

A relatively large proportion (26%) of households have a person who spends a lot of time at home for health reasons. Household members who take care of small children or other family members at home were reported by 14.7% of the respondents.

In the last two decades, fewer and fewer people in Hungary have answered questions about income. Therefore, the question was asked in different ways.

For the questions on the income situation of the household, 43.8% of the respondents answered the open question. Another 34.3% answered on the basis of the predefined income categories. A relatively large proportion of respondents (21.9%) did not answer this question. Using this data, we sorted the answers into the predefined categories and arrived at the following result: The percentage of households with an income of less than 200,000 HUF is 19.7%, with an income of 201,000-300,000 HUF is 17.3% and 15% have an income of 301,000-400,000 HUF. The proportion of respondents with an income of HUF 401,000-500,000 was 9.4%, while an income between HUF 500,000 and 1 million was typical for 13.3%. 3.5% of the respondents had a household income of more than 1 million HUF.

According to the households' subjective assessment of their income situation, the relative majority (45.2%) get by on their current income. A quarter of households (25.5 %) have difficulties, while 12.1% often have difficulties. However, 17.2 %of the sample live comfortably on their current income (Figure 13).

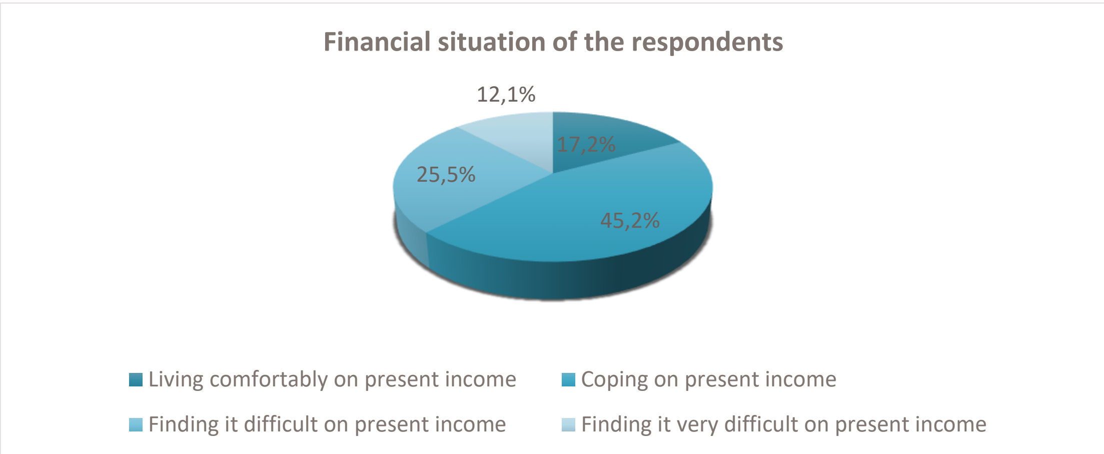

Figure 13 Which describes best your financial situation?

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In order to be able to pay their energy bills, 12.8% of the surveyed households received some kind of financial support from public institutions (including so-called social tariffs) in the last 12 months.

4.2 Socio-economic segmentation of end users

This section focuses on covering the socio-economic segmentation and general characterization of populations and potential end users or in this case more specifically buyers (investors, building owners) for the BIO4EEB project and product portfolio. The project aims to offer pertinent renovation approaches and products that comply not only with technical performance expectations but also at a cost that is attainable to different socio-economic categories. To do so, this report will provide an overview of the different socio-economic categories in the main geographic markets represented and tackled in the consortium (France, Spain, Germany, Czech Republic) characterizing them in terms of certain economic indicators of interest such as disposable income, savings and ownership rates and cross referencing this information with the building typologies they most commonly correspond to.

4.2.1 France

This section provides on the one hand the socio-economic segmentation and economic characterization of the French population as well as the segmentation of these identified categories amongst the main building typologies.

- **Socio professional segmentation**

The following figure provides an overview of the segmentation of the French active population by main socio-professional categories and age.

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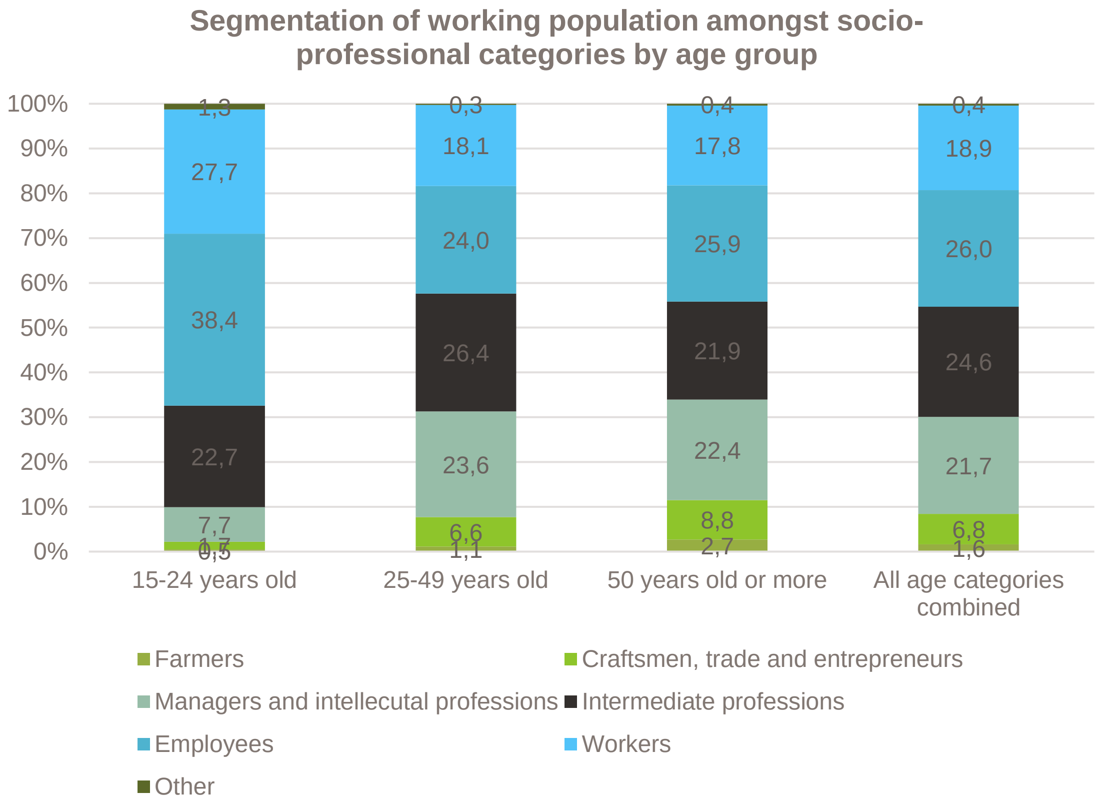

Figure 14 Segmentation of working population amongst socio-professional categories by age group 2022

Unsurprisingly, the main observation that can be made are a higher proportion of salaried employees at younger ages and more managers through middle age categories reflecting the effects of experience and time working. One of the main elements of interest here will be determining income levels for each category and their occupancy status in terms of residences.

- **Income/ wealth segmentation**

To understand whether solutions and retrofits are economically viable for a population, it is important to get an idea of their level of life and disposable income. To do so, the equivalized disposable income has been used. This is the total income of a household, after tax and other deductions, that is available for spending or saving, divided by the number of household members converted into equalized adults; household members are equalized or made equivalent by weighting each according to their age, using the so-called modified OECD equivalence scale.

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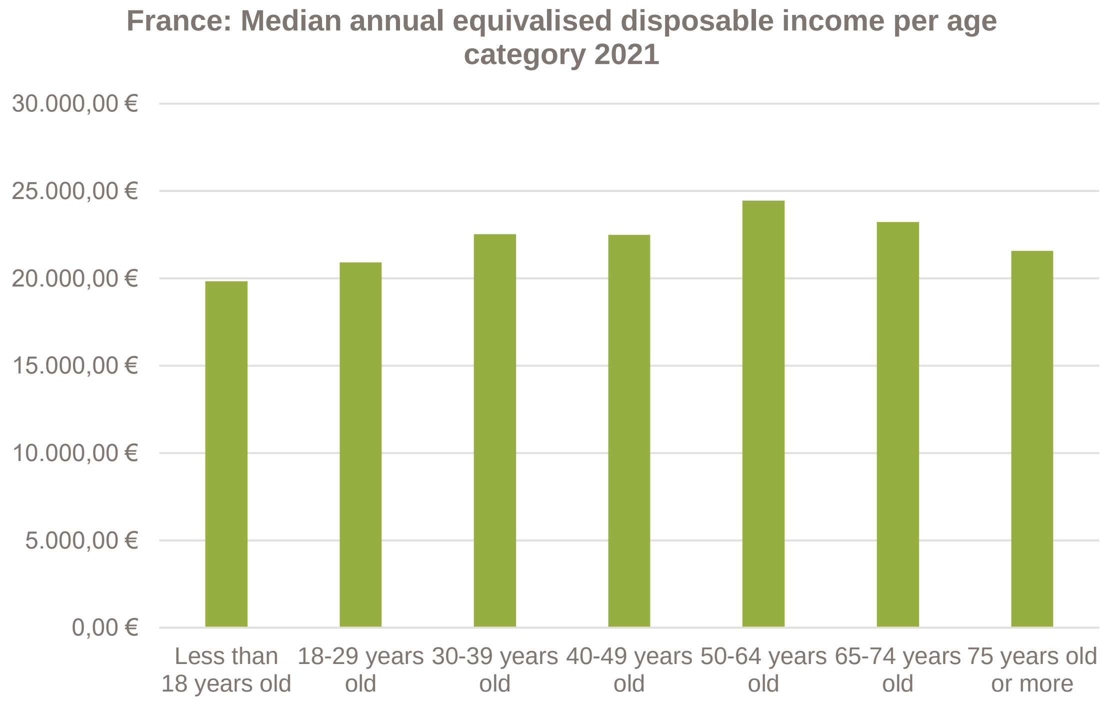

Figure 15 Median equivalized disposable income per age category 2021

Peak income in French households is reached within the 50-64 years of age reflecting the later years of one's career and potential opportunities for income aside of simply wages at a median of 24.450€ adjusted to amount of people in the household.

Nevertheless, given the above figure (Figure 15) presents averages of age categories which could have much lower medians due to high inequalities of wealth it is important to observe figures breaking down disposable income distribution. If looking at the distribution by deciles we are faced with the following figure (split in deciles).

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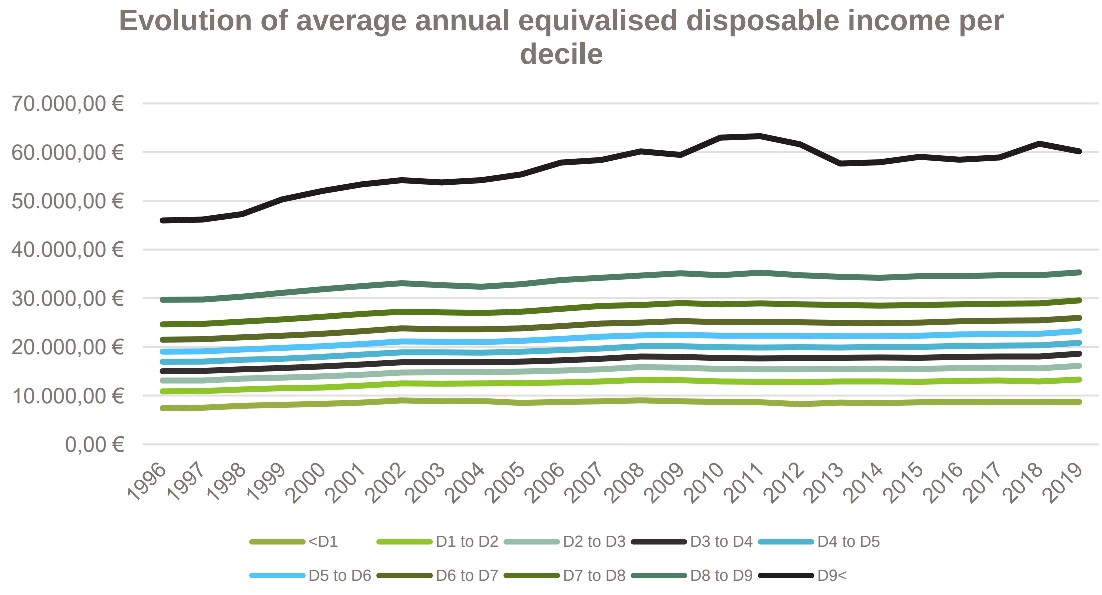

Figure 16 Evolution of average annual equivalized disposable income per decile

Clearly a gap is present between D9< and other deciles. From a socio-professional point of view, the following figures provide a breakdown for the prior identified categories.

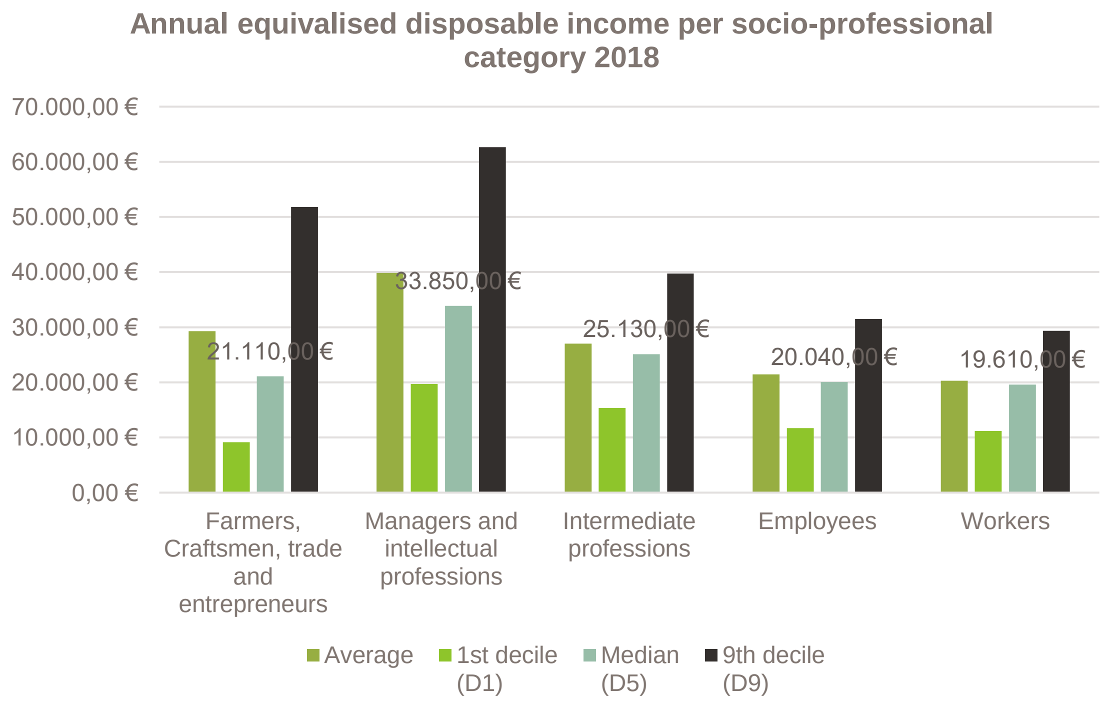

Figure 17 Disposable income per socio-professional category 2018

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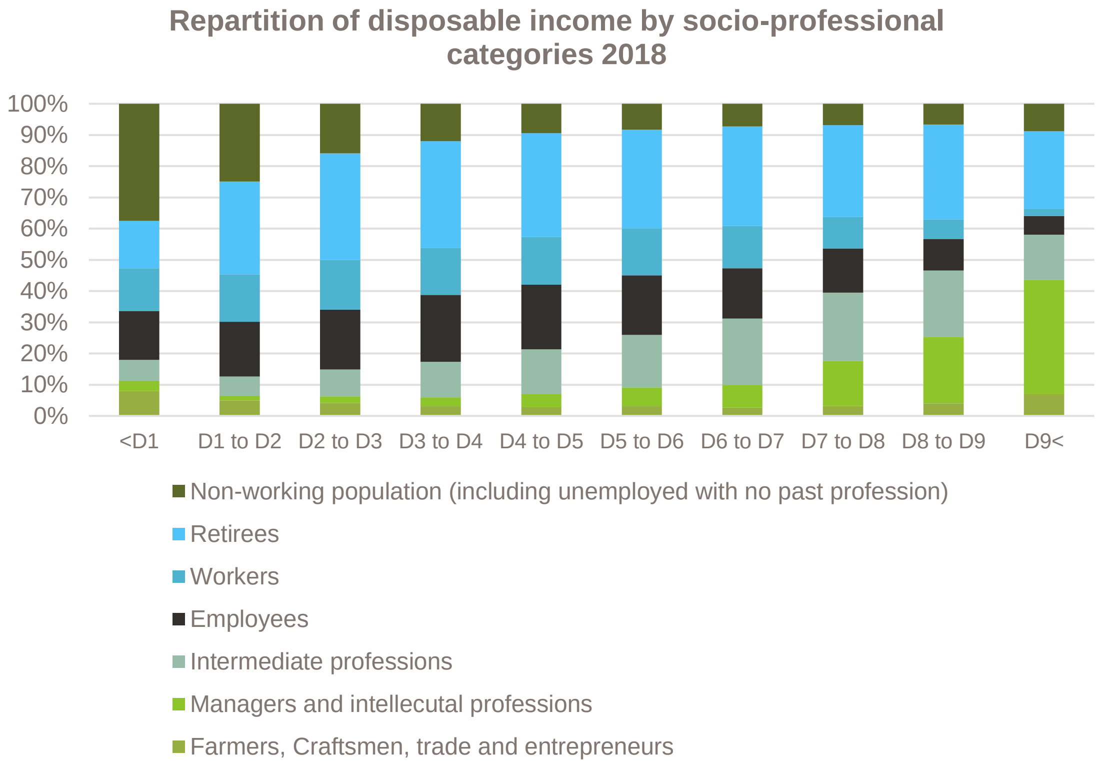

Figure 18 Repartition of disposable income by socio-professional categories 2018 (only including population over 18 within households)

In 2018 the equivalised disposable income was at a general average of 26.570€ with the lowest average for workers at 20.310€ and the highest for managers and intellectual professions at an almost double (39.860€). Unsurprisingly, lower deciles are represented in majority by the non-working population, middle deciles see an increase in workers, employees and intermediate professions while high deciles see a drastic increase in managers and intellectual professions. Retirees remain relatively stable in their representation throughout most deciles.

- **Characterizing socio economic segments: home ownership, savings, investment and spending**

It is important to put the prior data in context with related economic KPIs that inform us on the actual habits and behaviours of potential segments. Elements of focus will be brought on home ownership due to the fact that home owners are the main agents choosing to renovate a particular building asset along with investment, savings and spending habits in order to understand the amount dedicated towards real estate, the expected returns that might be expected in certain investments and the potential minimal returns that have to be yielded by a certain retrofit or renovation to comply with market expectancies and also understand the burden that housing costs and utility bills may have spurring additional incentives for renovation.

The savings rate in France is rising sharply as it reaches 20.9% in 2020 and 18.7% in 2021. Generally, this rate has of course varied according to the socio professional category of the population and the resulting position within the distribution of disposable income. Recent data suggests the 1st quintile of the population in disposable income have a savings rate average

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of 2.71% while the fifth quintile have a savings rate average of about 28.37% in 2017 as shown in the following graph.

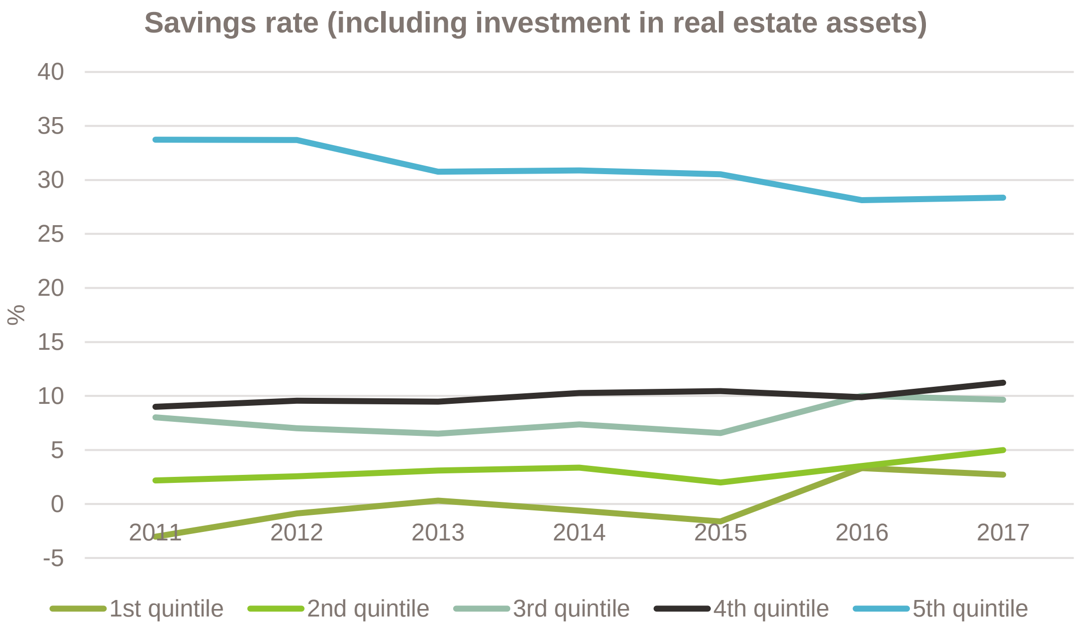

Figure 19 Savings rate (including investment in real estate assets)

From an investment and savings point of view, the French are very cautious investors preferring risk free asset classes and investments. Risk-free savings accounts providing interest payments and in particular life insurance investments in euros are by far the most sought-after.

More than 80% of households have at least a Livret A, which is a savings account product providing tax free interest returns at a historic low of 0.52% for 2020. Conversely, investments in shares of French households remain low. But the indirect holding of shares, via collective funds invested in shares, tends to increase, particularly through unit-linked life insurance contracts, employee savings and retirement savings.

Real estate investment occupies a major place in French investments. In 2018, more than 60% of the total savings of the French which reached around 11,500 billion euros was invested in real estate. From 2005 to 2009, households allocated more than 10% of their disposable income to home ownership. Since then, the rate of housing investment declined until 2015 and has increased slightly since then. It reaches, again, 10% in 2021. Moreover, in 2019, 33.2% of French households hold mortgages with 24.5% being for the purchase of their primary residence. This figure even goes up to 50% for ages between 40 and 49 holding a mortgage and 47% for ages between 30 and 39 holding a mortgage.

All of this data shows that France as a whole is a country characterized by high rates of home ownership with real estate being one of the preferred asset classes on the side of placements and standing for a majority of the country's total savings along with important portions of disposable income dedicated to the latter. Indeed, in 2021 57.7% of French households are owners of their main home.

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The following figures (Figure 20, Figure 21) present home ownership in age segments and socio professional segments, with logical results reflecting increasing ownership as age increases and higher rates of ownership for categories with higher disposable incomes or having retired.

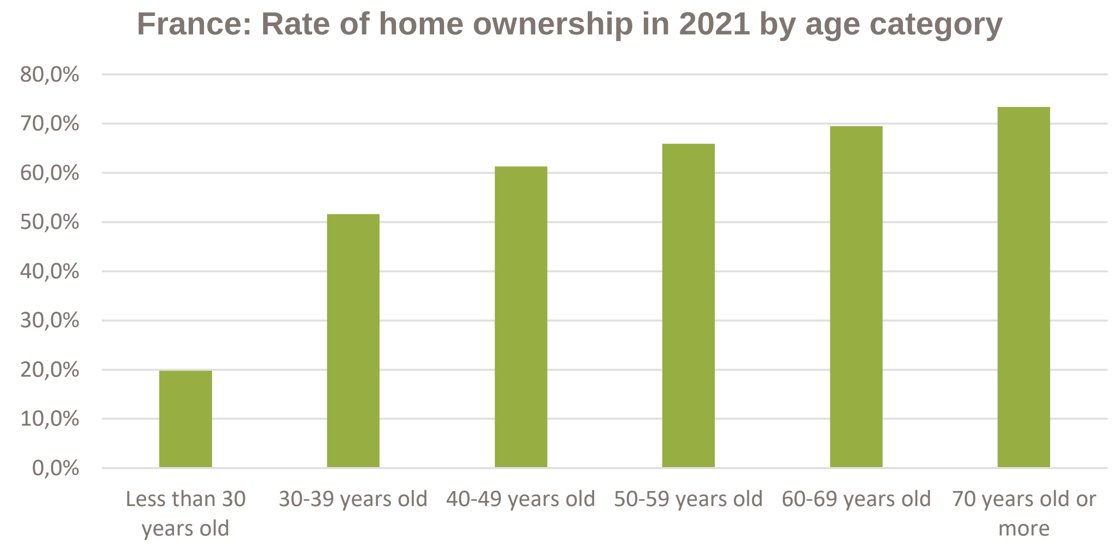

Figure 20 Rate of home ownership in 2021 by age category

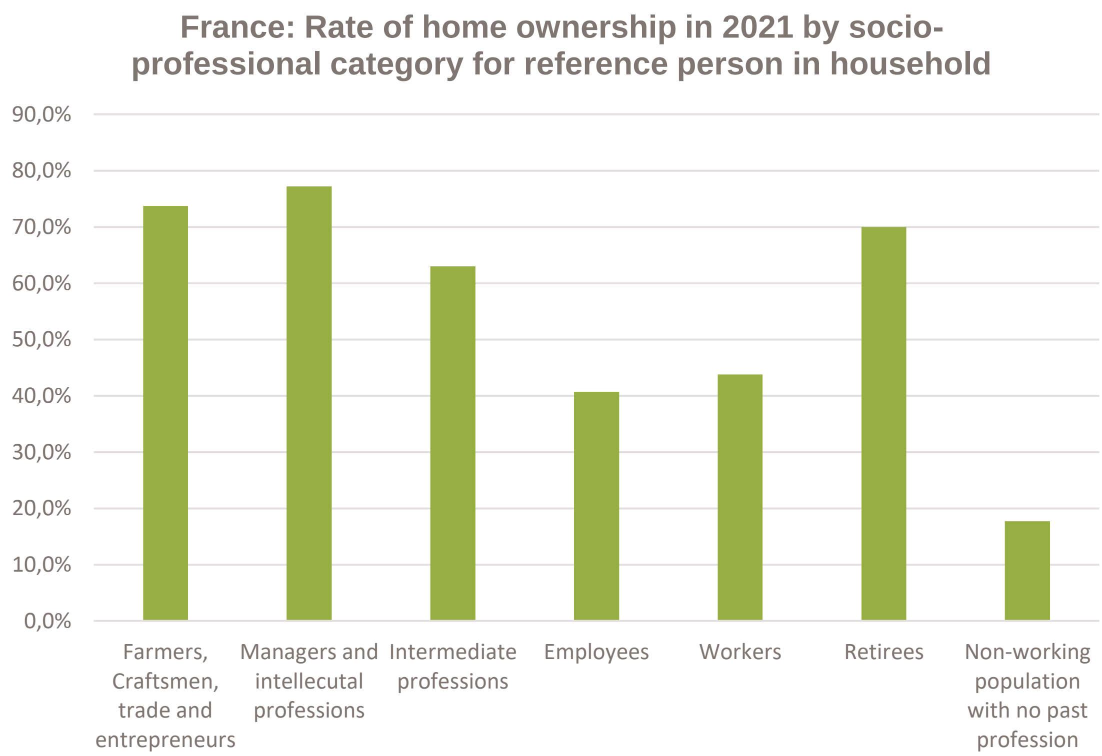

Figure 21 Rate of home ownership in 2021 by socio-professional category for reference person in household

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On the side of savings and investments, looking at general household spending and consumption, we can see that households dedicate an important part of their budget towards housing, heating, lighting and other housing items and equipment and that over the years this percentage has increased. Indeed, as demonstrated in the bottom figure, it has gone from 20.4% of total household spending and consumption to 32.74% from 1961 to 2021 driven in part by increasing energy costs and appreciating rent and real estate.

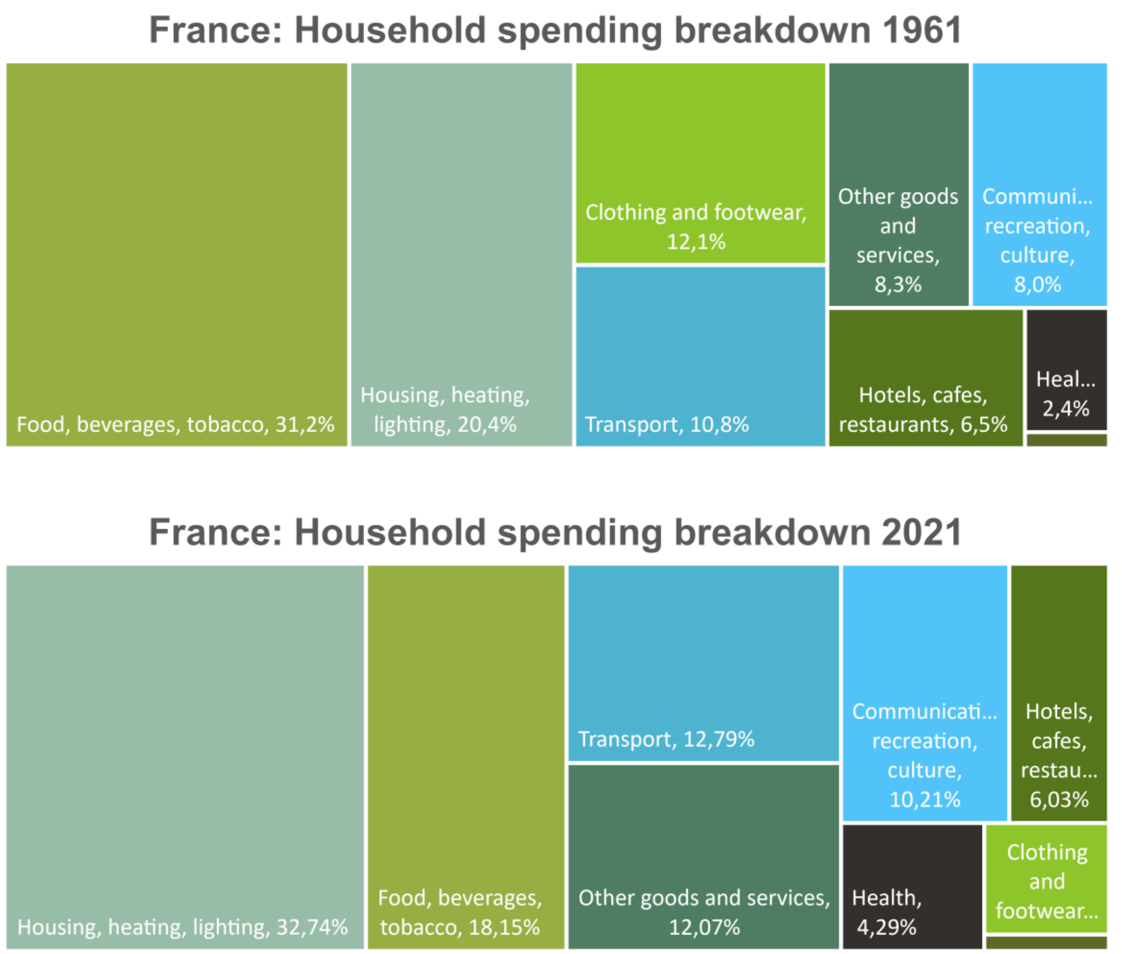

Figure 22 France: Household spending breakdown

This may translate in a drive to reduce such expenses through renovations and retrofits, given sustained inflation on energy costs and high national levels of home ownership potentially reducing split incentive issues. An important element is also the fact that all quintiles spend about the same percentage of their disposable income in housing heating and lighting as demonstrated by INSEE data.

Of course, this hypothesis is subject to the financial ability of households to improve thermal insulation and heating and cooling systems, regardless of the financial aids at their disposal for performing such renovations. Indeed, 20% of French people say they have suffered from the cold during the winter of 2020-2021, for at least 24 hours and that 40% believe that it is because of poor thermal insulation of their home and 36% for financial reasons. Thermal comfort deficiencies are mainly a problem that lower income categories are faced with. Energy

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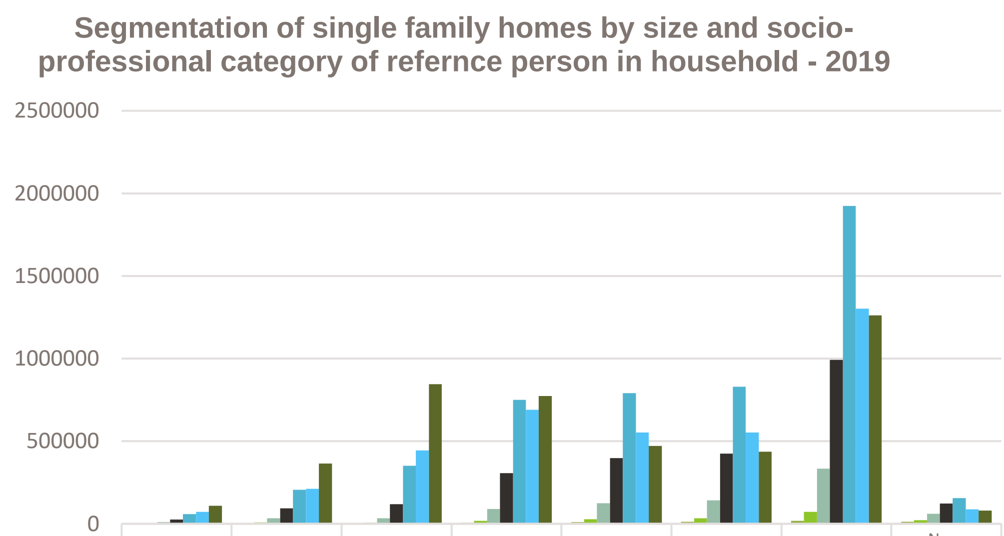
poverty, which occurs when energy bills represent a high percentage of consumers' income, or when they must reduce their household's energy consumption to a degree that negatively impacts their health and well-being, is defined in France as a household with energy expenditures greater than 8% of disposable income per consumption unit, with the adjusted income per consumption unit being less than the 3rd decile (see figures above).

As a result of this qualification, In France in 2020, 10.5% of the population, equivalent to 3 million households, spent more than 8% of their income to pay the energy bills of their home, and are below the third decile in adjusted disposable income.

Moreover, 6% of households renting private housing and 36% of households in social housing are faced with energy poverty; young people are increasingly vulnerable with 30% of 18-34 year olds saying they suffered from the cold in 2021 and 46% of them saying they have difficulty paying their bills in 2021. Finally, 62% of households faced with energy poverty are the owners of their own residence.

- **Building typologies per identified socio-economic segments.**

The following figures present the segmentation of different socio professional categories amongst different building typologies with one figure focusing on multifamily homes (Figure 24) and the other on single family homes (Figure 23).



	Farmers	Craftsmen, trade and entrepreneurs	Managers	Intermediate professions	Employees	Workers	Retirees	Non-working population with no past profession
Less than 30 m²	782	3039	2893	6148	9294	12334	18917	11534
From 30 to 40 m²	2251	7565	6502	17315	26914	34232	72847	21195
From 40 to 60 m²	9551	32643	33023	89874	123805	142888	332848	60751
From 60 to 80 m²	25755	93416	119474	307405	398546	425637	991835	123040
From 80 to 100 m²	59274	205727	351181	749263	791654	830389	1923353	155493
From 100 to 120 m²	71291	212220	444146	690226	551987	552014	1301956	87474
120 m² or more	108084	364852	845963	773224	471993	436026	1261227	79627

Figure 23 Segmentation of single family homes by size and socio-professional category of reference person in household - 2019

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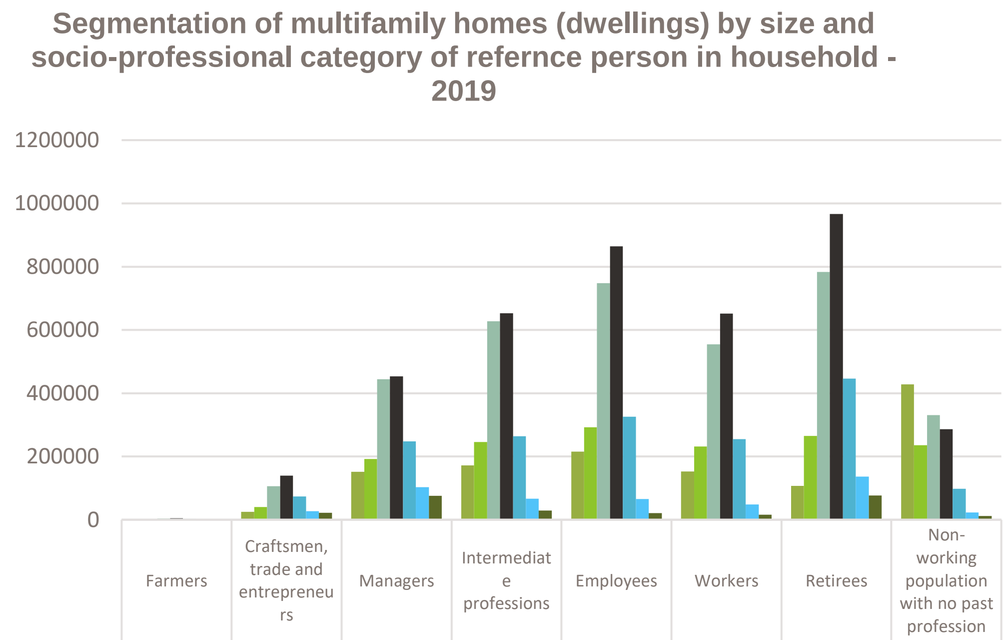
Unsurprisingly, single family homes tend to be of larger size then multifamily dwellings with a total of over 18 million dwellings being over 80 square meters in area. Single family homes between 80 square meters and 100 square meters are the most common including multifamily dwellings at over 5 million while single family homes in the 100 square meters to 120 square meters and the over 120 square meter range are respectively around the 4 million mark.

Retirees are with a significant difference the socio-professional category that live in single family homes the most with a total of over 8 million near doubling other segments.



	Farmers	Craftsmen, trade and entrepreneurs	Managers	Intermediate professions	Employees	Workers	Retirees	Non-working population with no past profession
Less than 30 m²	684	25206	151450	172164	215445	152856	106522	427735
From 30 to 40 m²	1345	40175	192370	246059	292138	231312	264471	235315
From 40 to 60 m²	4125	105640	444132	627794	747902	554144	783452	331171
From 60 to 80 m²	4930	139206	453634	653114	864536	651234	966107	286070
From 80 to 100 m²	2672	73477	247577	263506	326099	254342	446644	97909
From 100 to 120 m²	950	27467	102950	66933	65862	48468	136608	23126
120 m² or more	703	22317	76067	28693	21403	15420	76278	12246

Figure 24 Segmentation of multi-family homes by size and socio-professional category of reference person in household - 2019

For multifamily dwellings, the most common size is between 40 square meters and 80 square meters for all categories except unemployed and non-working population. In total, over 3.6 million multifamily dwellings are between 40 and 60 square meters and over 4 million are between 60 and 80 square meters. This is not surprising given that multifamily buildings will generally be more common in metropolitan areas with less space and more expensive real estate and rent. Again, retirees are the most represented category with over 2.7 million households living in multifamily dwellings.

One surprising piece of information presented by these figures is the fact that not many managers and intellectual professions live in single family homes or the largest sized multifamily dwellings given their higher disposable income. Nevertheless, this is in part explained by geographic repartition in comparison to other socio-professional categories.

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Indeed, they are closer to metropolitan areas where rent and real estate prices are significantly higher per square meter and generally dwellings are smaller in size than in less populated areas.

- **Building Stock characteristics and common building typologies**

In order to contextualize the above figures, the following section will provide an overview of the main breakdown in France.

The stock of residential buildings can be divided into 4 main periods:

1. Old buildings built before 1850: characterized by a great disparity in construction methods and materials used, varying according to the region.
2. Old buildings built between 1850 and 1948: characterized by an industrialization of building materials and the generalization of construction methods throughout France.
3. Recent non-insulated buildings built between 1949 and 1974: characterized by a rationalization of construction to meet the high demand for housing during the reconstruction and the Trente Glorieuses period of post war economic growth.
4. Recent insulated buildings: characterized by the first thermal regulation in 1974 and its various updates all the way up to RE2020 which sets heavy emphasis on life cycle aspects of new buildings rather than simply emissions during use and operation.

In the following figure you can see a segmentation of the single-family homes (including detached house on parcels, no joint ownership and semi-detached house on one or two sides) and the multifamily homes (including small multifamily apartment building with less than 10 units, semi-detached or isolated and large multifamily housing building with more than 9 units).

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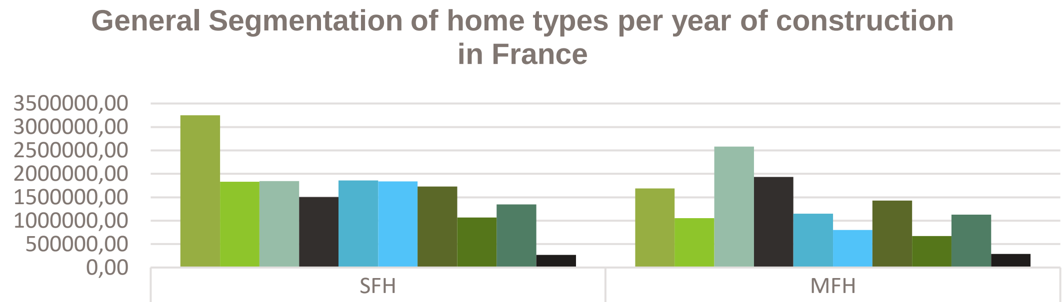

	SFH	MFH
Pre- 1915	3251076,00	1687024,00
1915 - 1944	1829370,00	1056480,00
1945 - 1967	1843286,00	2578495,00
1968 - 1975	1503633,00	1932209,00
1976 - 1981	1860309,00	1151928,00
1982 - 1989	1838635,00	801666,00
1990 - 2000	1731161,00	1428335,00
2001 - 2005	1068034,00	672601,00
2006 - 2012	1349881,00	1130946,00
>2012	271925,00	291471,00

Figure 25 General Segmentation of home types per year of construction in France

Old buildings and recent non-insulated buildings each represent about 1/4 of the existing stock and isolated buildings built since 1974 constitute almost half

4.2.2 Spain

This section provides on the one hand the socio-economic segmentation and economic characterization of the Spanish population as well as the segmentation of these identified categories amongst the main building typologies.

- **Socio professional segmentation**

The total number of unemployed in Spain is 3,127,999.97 people in the first quarter of 2023, which is 3.44% more than in the previous quarter. The unemployment rate is 13.27%, 0.39 percentage points higher than three months ago, according to the Labour Force Survey compiled by the National Statistics Institute (INE).

The following figure provides an overview of the segmentation of the Spanish active population by main socio-professional categories.

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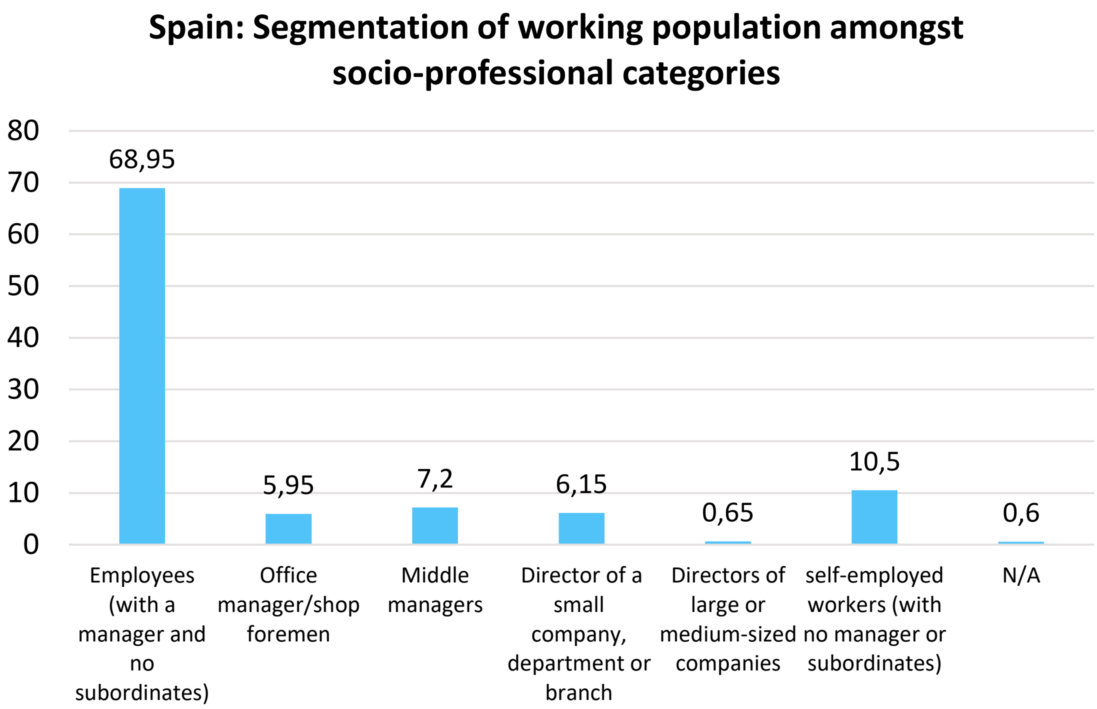

Figure 26 Segmentation of working population amongst socio-professional categories in Spain 2021

The main observation that can be made are a higher proportion of salaried employees mostly at younger ages and lower directors of large or medium sized companies through middle age categories reflecting the effects of experience and time working.

- **Income/ wealth segmentation**

To understand that solutions and retrofits are economically viable for a population, it is important to get an idea of their level of life and disposable income. The average annual wage by age group.

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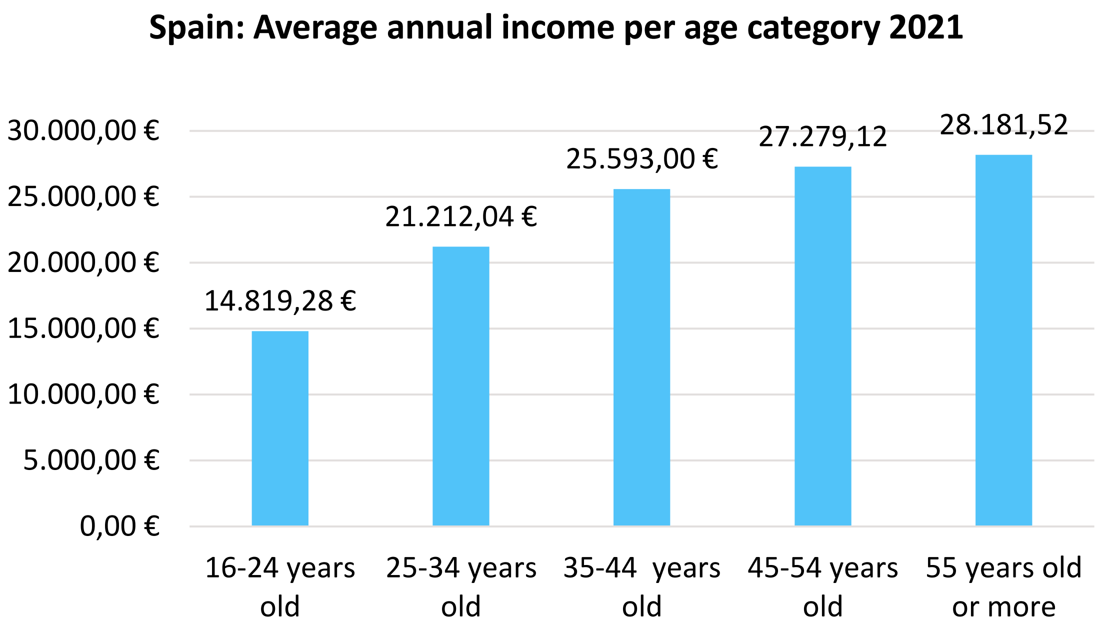

Figure 27 Average annual income per age category in Spain 2021

Peak income in Spanish households is reached within the 50 years old or more reflecting the later years of one's career and potential opportunities for income aside of simply wages at a median of 27.279€ adjusted to amount of people in the household. Nevertheless, given the above figure presents averages of age categories which could have much lower medians due to high inequalities of wealth it is important to observe figures breaking down disposable income distribution. If looking at the distribution by deciles we are faced with the following figure (split in deciles).

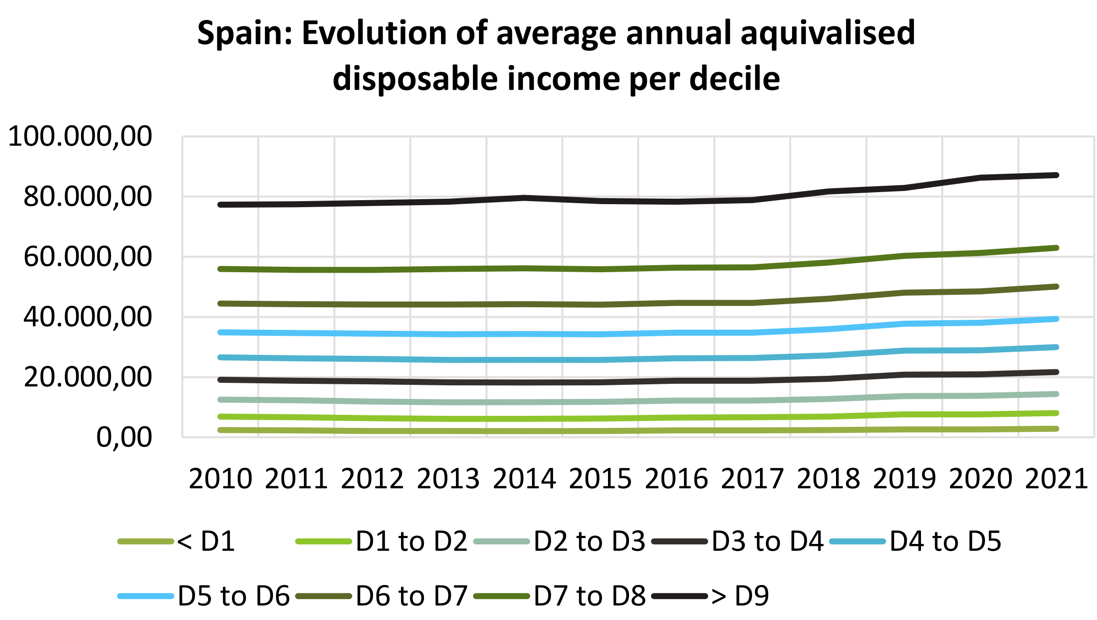

Figure 28 Evolution of average annual equivalized disposable income per decile in Spain

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A gap is present between D9< and other deciles.

From a socio-professional point of view, the following figure provide a breakdown for the socio-professional identified categories.

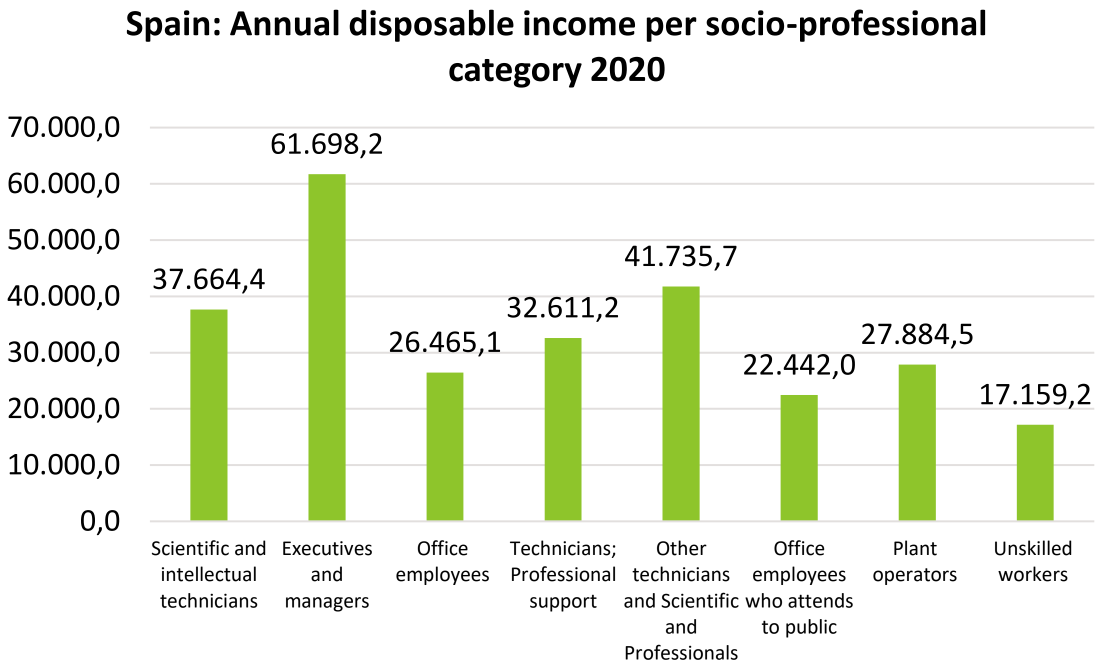

Figure 29 Disposable income per socio-professional category in Spain 2020

In 2020 the lowest average for unskilled workers is at 17.159€ and the highest for executive and managers at 61.698€. Unsurprisingly, lower disposal income is represented in majority by the unskilled workers population.

- **Characterizing socio economic segments: home ownership, savings, investment and spending**

It is important to put the prior data in context with related economic KPIs that inform us on the actual habits and behaviours of potential segments. Elements of focus will be brought on home ownership due to the fact that homeowners are the main agents choosing to renovate a particular building asset along with investment, savings and spending habits.

The savings rate of households and non-profit institutions stood at -3.2% of their disposable income in quarter 3 of 2022, according to INE. This figure represents a variation of -9.6% points from the same quarter of the previous year.

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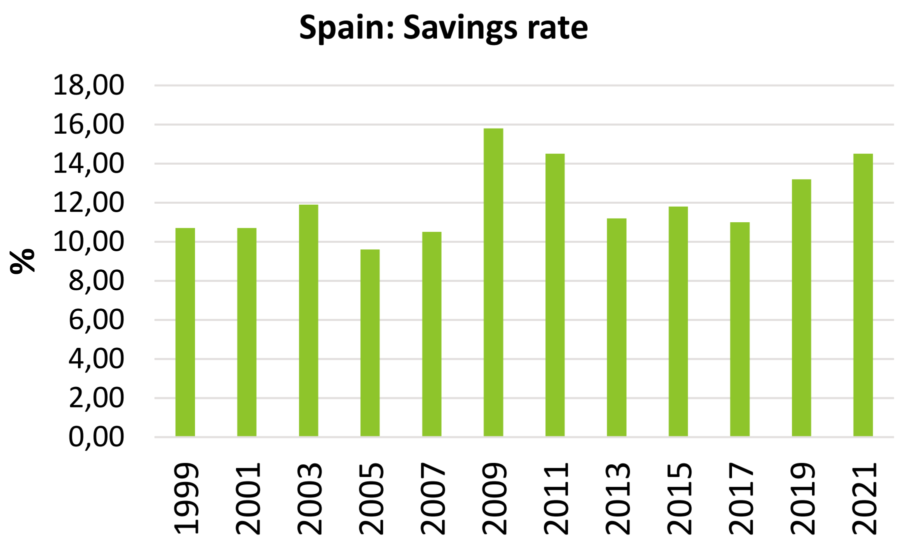

Figure 30 Savings rate of households in Spain

The INE calculates the saving rate by dividing gross saving by the gross disposable income of households and non-profit institutions, data found in the Quarterly Non-Financial Accounts of Institutional Sectors. In the case of the gross disposable income of households, these institutions obtained a total disposable income of 186.6 billion euros, up 1.65% year-on-year.

The following figures present home ownership in age segments and socio professional segments, with logical results reflecting increasing ownership as age increases and higher rates of ownership for categories with higher disposable incomes or having retired.

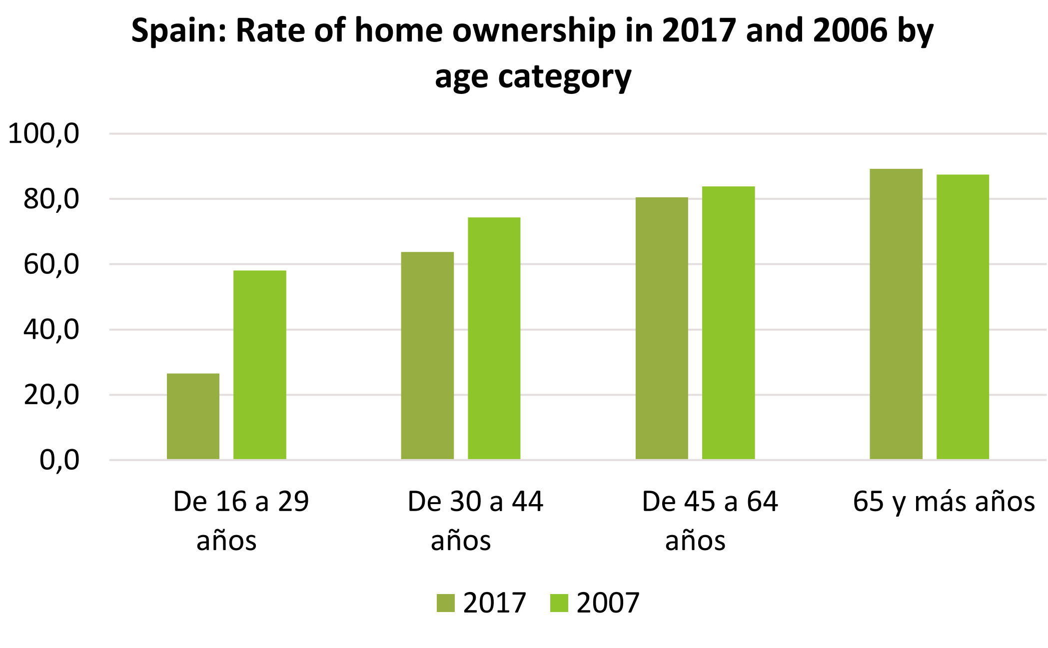

Figure 31 Rate of home ownership in Spain 2007 and 2017 by age category

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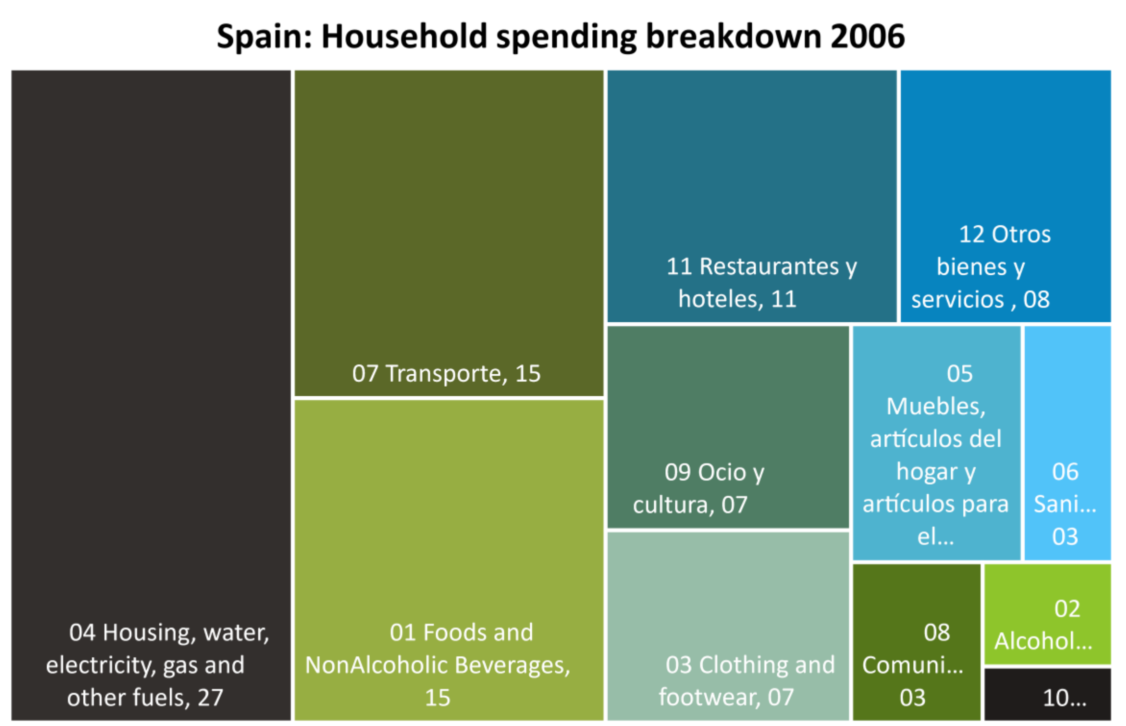
On the side of savings and investments, looking at general household spending and consumption, we can see that households dedicate an important part of their budget towards housing, water, electricity, gas lighting and other fuels that over the years this percentage has increased. Indeed, as demonstrated in the bottom figures, it has gone from 26.89% of total household spending and consumption to 33.83% from 20061 to 2021 driven in part by increasing energy costs and appreciating rent and real estate.



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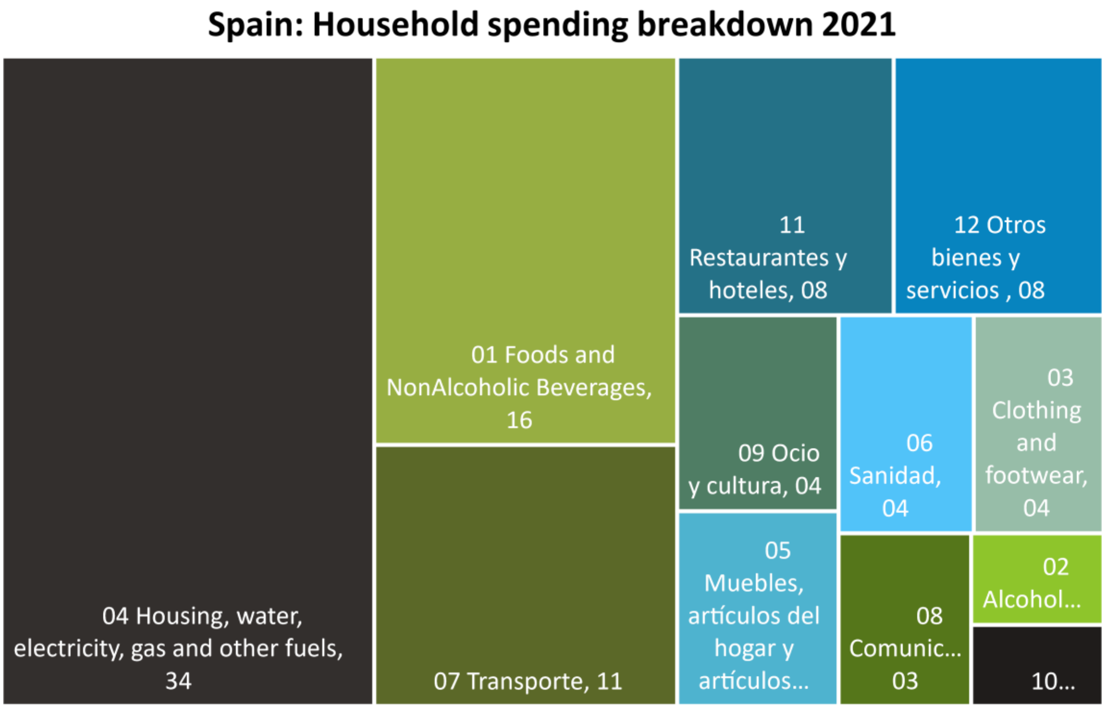

Figure 32 Spain: Household spending breakdown

This may translate in a drive to reduce such expenses through renovations and retrofits, given sustained inflation on energy costs and high national levels of home ownership potentially reducing split incentive issues. This hypothesis is subject to the financial ability of households to improve thermal insulation and heating and cooling systems, regardless of the financial aids at their disposal for performing such renovations.

- **Building Stock characteristics and common building typologies**

From a basic building typology perspective, the building stock of residential buildings can be divided into 4 main periods:

1. Buildings built before 1921: characterized by a great disparity in construction methods and materials used. The prevailing tendency was detached and semi-detached house.
2. Buildings built between 1940 and 1960: characterized by the growth of multifamily buildings, notably buildings with more than 10 dwellings in 1960.
3. Buildings built between 1960´s and 2000: This period is characterised by important growth in large multi family buildings containing more than ten dwellings. This is a product of sustained demographic growth and urban sprawl.
4. Buildings built since 2000: Continued growth although more moderate of large multi family buildings containing more than 10 dwellings until 2010 which coincides with flattening of population growth curve. Increase in terraced or semi-detached housing.

In the following figure you can see a segmentation of the single-family homes (including detached house on parcels, no joint ownership and semi-detached house on one or two sides)

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and the multifamily homes (including small multi-family apartment building with less than 10 units, semi-detached or isolated and large multi-family housing building with more than 9 units).

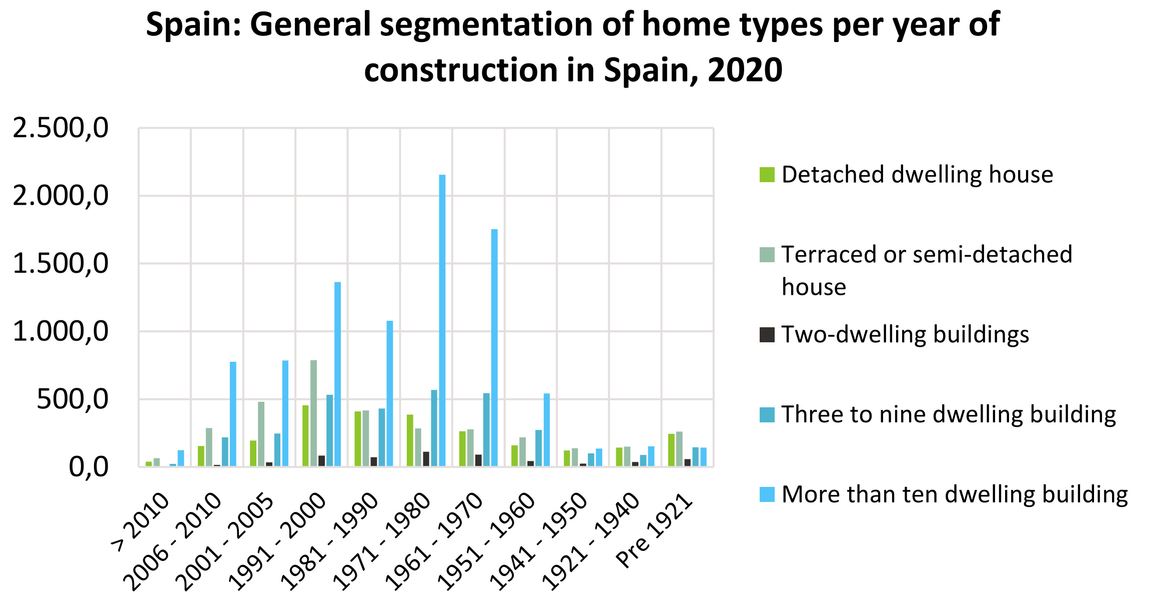

Figure 33 Spain: General Segmentation of home types per year of construction in Spain

In terms of actual insulation levels and build quality, only since 1981 is the laying of thermal insulation mandatory. In 1981 the first Spanish law was enacted in which minimum thermal insulation was set, which is well below current standards. Incomprehensibly this regulation was in force for 25 years and was only updated in 2006, when the CTE 2006 (Technical Building Code) was published.

The delay in improving the energy efficiency of buildings was so important that in 2014 the regulations were updated again, which is why homes built between 2006 and 2013 also have insufficient insulation. The regulations require greater insulation thickness in buildings located in places of rigorous climate, such as in inland areas with harsh winters or in homes located higher above sea level.

Thermal insulation also protects from excessive heat in summer. In Spain, the ambient temperature can reach 40 degrees Celsius, but the roof materials exposed to the sun throughout the day can reach 70. To protect users from this extreme heat, the thickness of the insulation on the roof must be almost twice that applied on the façade.

The following figure provides an overview of the regulations related to insulation and their year of application and insulation thickness.

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Year of construction	Period/regulation	Insulation thickness (cm)
Until 1940	pre-war	0
1941-1980	post-war	0
1981-1990	post NBE-AT-79	1,5-2,5
1991-2006	post NRE-AT-87	2,0-2,5
2007-2014	CTE 2006	3,0-6,0
starting in 2014	CTE 2013	6,0-13,0

Table 4 Regulations and insulation thickness for buildings in Spain

Please note that insulation thickness in the above table vary by climate region.

More recently, with respect to thermal insulation, the CTE received important updates in 2019.
In the case of new construction, in this new update of the regulation the requirements in the necessary thicknesses are increased. In this sense, for example, considering a thermal conductivity of the insulating material of 0.035 W / mK, such as Extruded Polystyrene (XPS), for walls and floors in contact with outside air, the recommended thicknesses would range from 5 to 14 centimeters. For the insulation of roofs, the new CTE would recommend reaching thicknesses of between 5 and 17 centimeters.
The requirement also increases in the field of rehabilitation, for which the CTE foresees thicknesses similar to those of new construction. This implies doubling the insulation thicknesses established for certain areas in the previous regulation. All this means that thicknesses of 3 or 4 cm, which were the most common a few years ago, are relegated to exceptional cases in which it is not possible to use larger thicknesses due to construction conditions.

These laws, their chronology and the prior table on building typologies and years of construction enable us to cross reference the information and obtain an understanding of the building stock landscape for the residential sector in Spain.

Buildings used mainly or exclusively for residential purposes and number of buildings by year of construction by building status is presented in Figure 34.

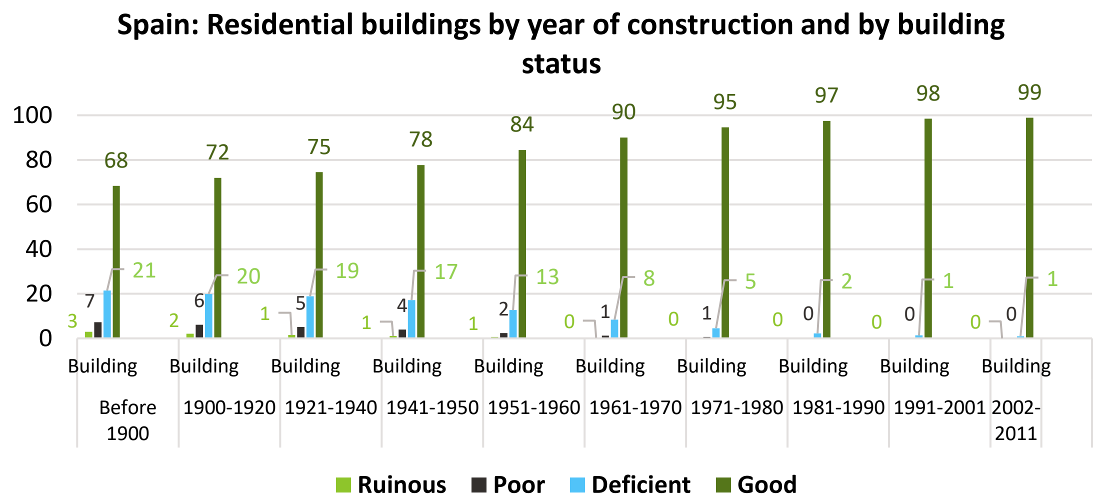

Figure 34 Spain: Residential buildings by year of construction and by building status

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4.2.3 Germany

This section provides on the one hand the socio-economic segmentation and economic characterization of the German population as well as the segmentation of these identified categories amongst the main building typologies.

- **Socio professional segmentation**

In 2023, an average of 3,918,281 employable people in Germany received citizen income. On January 1, 2023, unemployment benefit II (ALG II) was replaced by citizen benefit. The number of employable recipients of ALG II benefits has tended to decline since 2017.

The unemployment rate was 5.5 percent in May 2023. The number of unemployed fell by 41,934 in May compared to the previous month, compared to the same month last year (May 2022) the number of unemployed was around 284,095 higher.

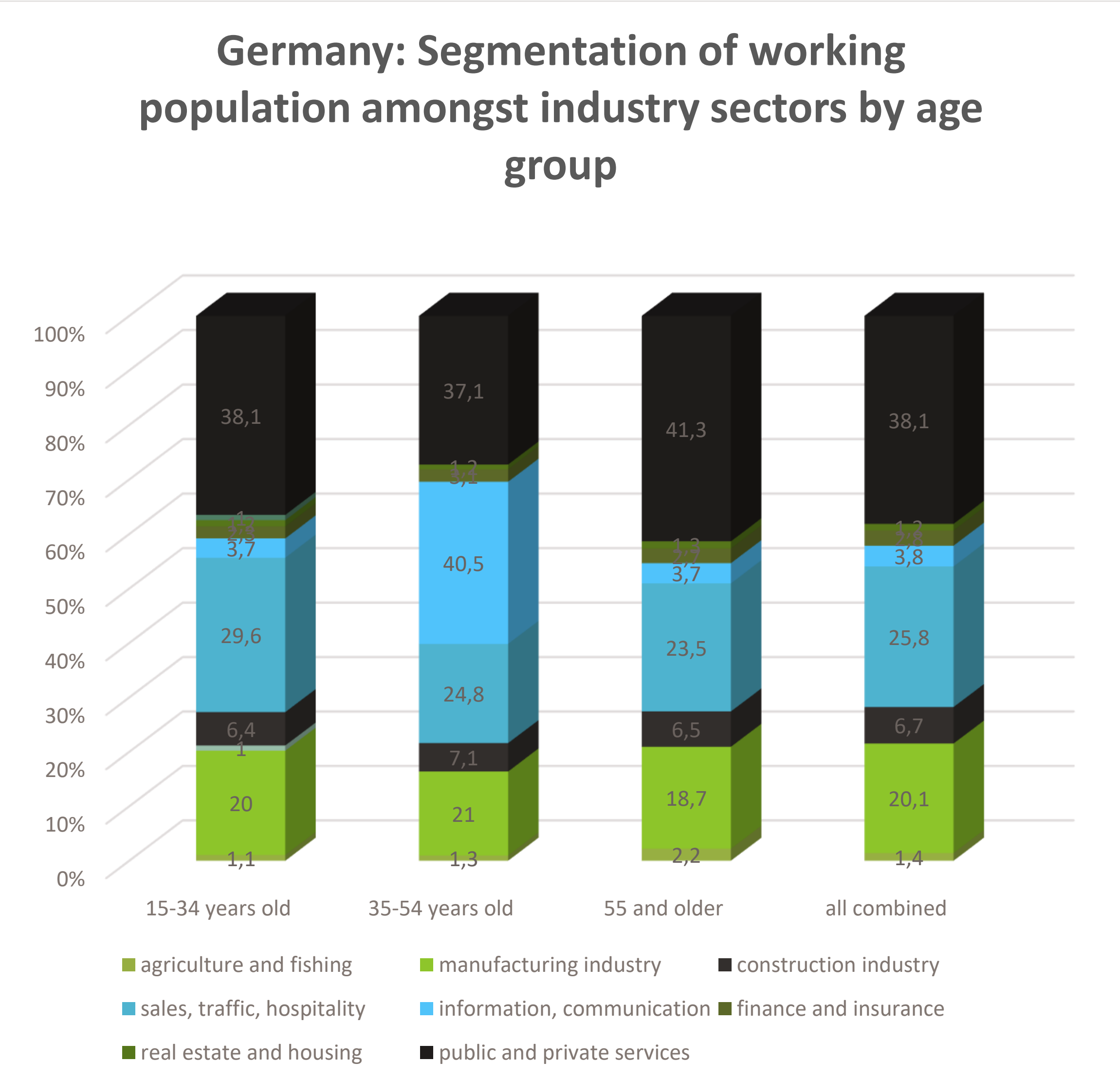

Figure 35 Segmentation of working population amongst employment sectors by age group in Germany 2017

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In view of demographic change, the question arises to what extent economic sectors are also experiencing age-related changes. On the one hand, certain activities are easier or more difficult to carry out in old age, depending on the work requirements. On the other hand, the career choice of young school graduates influences which economic sectors will be affected by a lack of young people and an aging population. In 2017, 30% of all employed persons in Germany were younger than 35 years, about half between 35 and 55 years (48%) and about every fifth person was at least 55 years old (22%). Differences according to economic sectors show that in agriculture, forestry and fisheries the average age of employees is significantly higher. While the age group 55 years and older makes up one third (34%), only 23% of the labour force there are under 35 years. The "second oldest" branch of the economy is public administration, in which an above-average number of older people work at 25% and a below-average number of younger people at 27%.

The "youngest" branch of the economy, on the other hand, is the "trade, repair of motor vehicles and hospitality industry". Here, the employed break down by age structure as follows: 34% under 35 year olds, 46% 35 to under 55 year olds and 20% 55 year olds and older. In second place is "mining and manufacturing" (excluding construction and energy supply) with 30% younger, 50% in the middle age group and 21% older.

- **Income/ wealth segmentation**

To understand that solutions and retrofits are economically viable for a population, it is important to get an idea of their level of life and disposable income. The average annual wage by age group.

Figure 36 Average annual income per age category among professionals and executives in Germany 2021

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Anyone working in Germany as a specialist or manager can look forward to a steadily increasing salary up to the age of 45, as the Statista chart shows. For its 2017 salary report, the salary comparison platform Salary.de evaluated the data of almost 218,000 specialists and executives in Germany. For skilled workers, the gross annual salary increases continuously up to the age of 40, executives can even count on an increase up to the age of 60. However, differences are not only evident in the position, the gender pay gap, i.e., lower pay for female workers, is also clearly evident. Women earn less even when they start their careers. This gap then continues to grow in the course of professional life and is particularly evident in executives. In addition, the academic degree is important for earnings. According to content.de, academics with a master's degree in particular have above-average salary prospects.

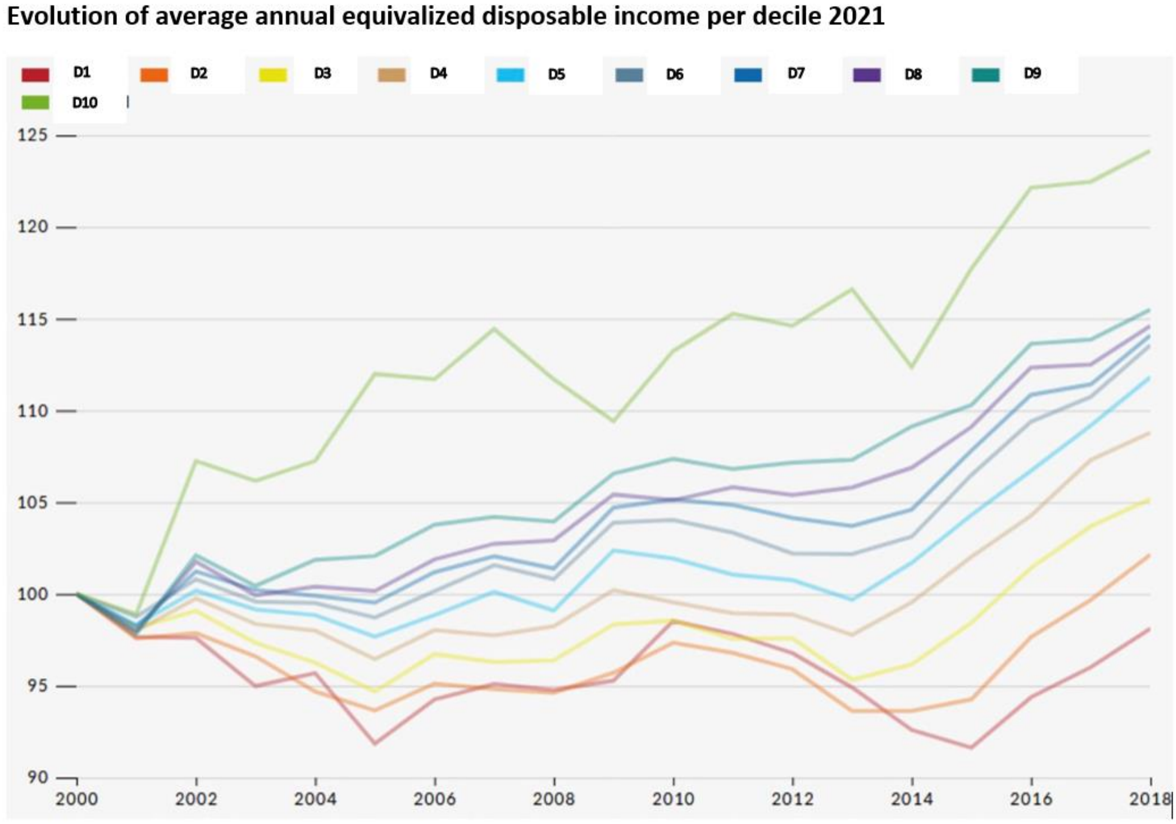

Figure 37 Evolution of average annual equivalized disposable income per decile in Germany from 2000 to 2018

A gap is present between D9 and other deciles.

From a socio-professional point of view, the following figure provide a breakdown for the socio-professional identified categories.

Germany: Annual equivalized disposable income per socio-professional category 2018

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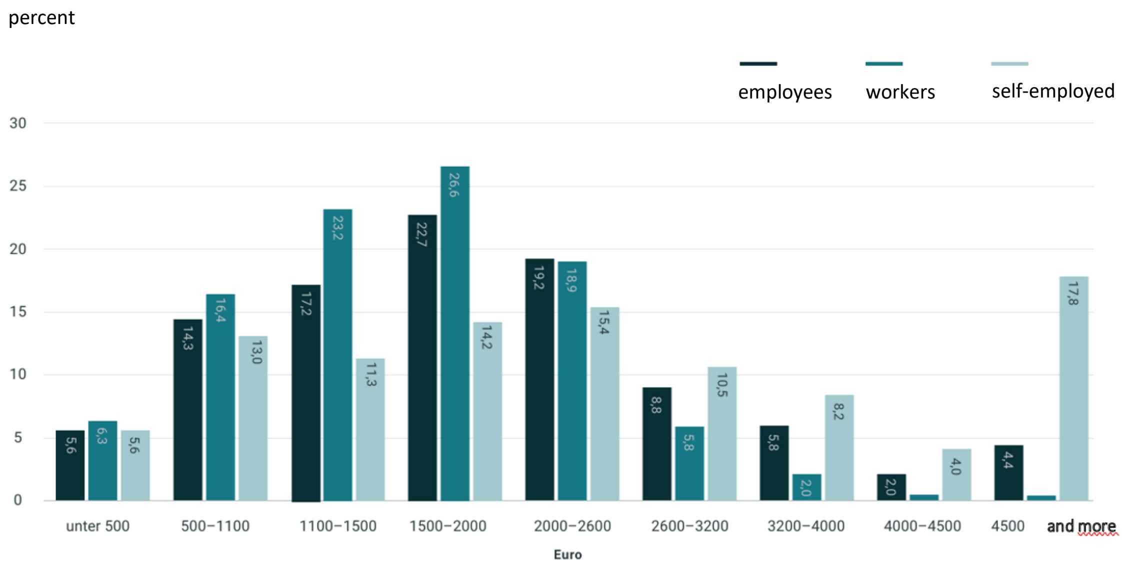

Figure 38 Annual equivalized disposable income per socio-professional category in Germany 2018

The high incomes end at the limit of 4,500 euros and more (17.8 percent of the self-employed). It is therefore not clear how large the proportion of the self-employed is who achieve higher or top incomes. It also needs to be asked whether top earners are actually willing to state their income correctly - whether in surveys or in tax returns.

Solo self-employed are people who work on their own and at their own risk and do not have any employees. To a large extent, this group of people has special problems in the labour market. In addition, the risks of low income and inadequate social security are increasing here.

(Solo) self-employment is not subject to any legal regulations with regard to the duration, location and distribution of working hours or occupational health and safety. "Self-exploitation" is therefore easily possible. Income (receipts minus operating expenses) develops on the market and depends on many influencing factors that can only be actively influenced in part. Sales are subject to seasonal and economic fluctuations and revenues can only be low in the event of low demand, increased competition and/or high costs. In this respect, (solo) self-employment is probably mostly a risky form of employment. It should not be overlooked that there is also a non-quantifiable proportion of self-employed people who "rely on" basic security in old age in favour of a high present income. The situation of liberal professions organized in chambers is different. Their fees are usually regulated by fee schedules. Your social security is provided by the respective pension schemes. However, there are only rarely purely solo self-employed people here, since employees work in the offices, practices, law firms, etc.

The exclusion of the solo self-employed from labour law and health protection creates incentives to create self-employed forms of employment for cost reasons, in which there are no entitlements to continued payment of wages, vacation, minimum wage, protection against dismissal, working time regulations, etc. Whether this is actual self-employment or employee-like self-employment or bogus self-employment must be determined on a case-by-case basis and with legal effort. Solo self-employment is also heterogeneous. There is a considerable spread in terms of income: the range extends from above-average incomes to the low-income sector. This is highly dependent on the industry or professional group. It is not surprising that

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there is also a considerable gender income gap here. Findings show that the proportion of people with a gross income of less than EUR 8.50 per hour fell slightly between 2011 and 2013 (price-adjusted), but is still around a quarter of the solo self-employed. On the other hand, around a quarter of those surveyed also earn 25 euros and more.

In not uncommon cases, the income must be supplemented by benefits under SGB II, since the household income is still below the requirement threshold for basic security. In August 2019, this applied to around 72,000 self-employed, which corresponds to 7% of all employed ALG II recipients. However, the data does not reveal whether these are solo self-employed or self-employed with employees.

Self-employment, which does not pay off economically, since the income is not even sufficient to cover the socio-cultural subsistence level, is therefore subsidized. At the same time, such forms of employment lead to increased pressure on the labour market, also and especially in comparison to employees subject to social security contributions. They are - "bought" by a work contract - significantly cheaper for a company and can trigger displacement processes. The same applies if those affected feel unable to pay contributions for private old-age provision or occupational/disability insurance from their low gross income. In old age there is a risk of poverty and dependency on basic security benefits, which must be financed from general tax revenue. Formerly self-employed already make up a large part of the recipients of basic security.

Germany: Repartition of disposable income by socio-professional categories 2021

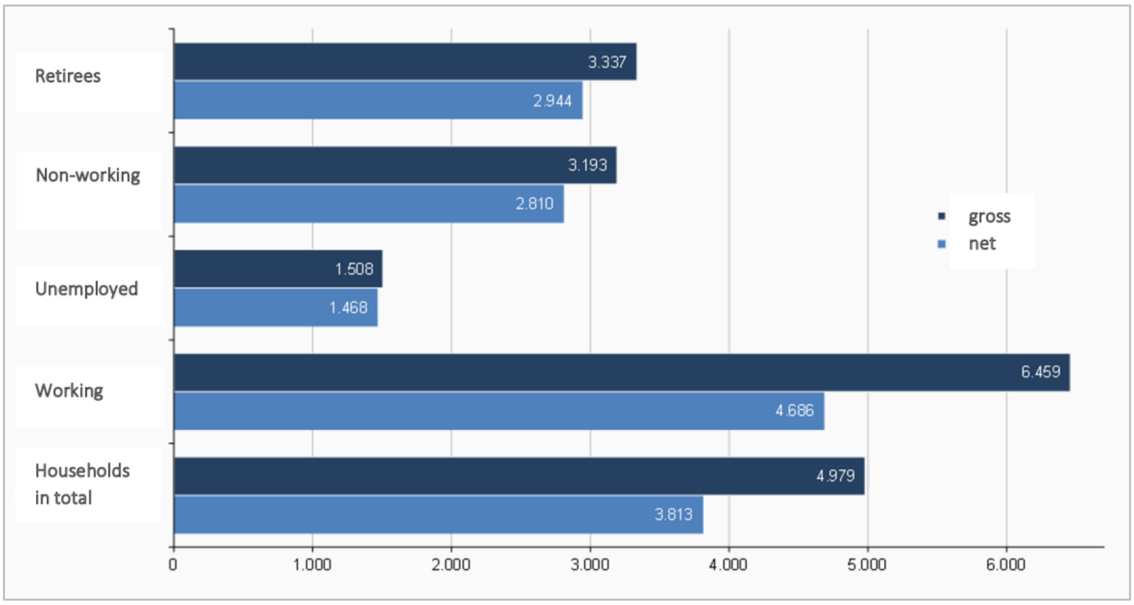

Figure 39 Annual Repartition of disposable income by socio-professional categories 2021

The average monthly household income varies greatly depending on the household type. Couple households have high gross and net incomes, while single people and single parents are at the bottom of the hierarchy. However, the number of household members is not taken into account.

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- **Characterizing socio economic segments: home ownership, savings, investment and spending**

It is important to put the prior data in context with related economic KPIs that inform us on the actual habits and behaviours of potential segments. Elements of focus will be brought on home ownership due to the fact that homeowners are the main agents choosing to renovate a particular building asset along with investment, savings and spending habits.

Germany: Development of savings rate (including investment in real estate assets)

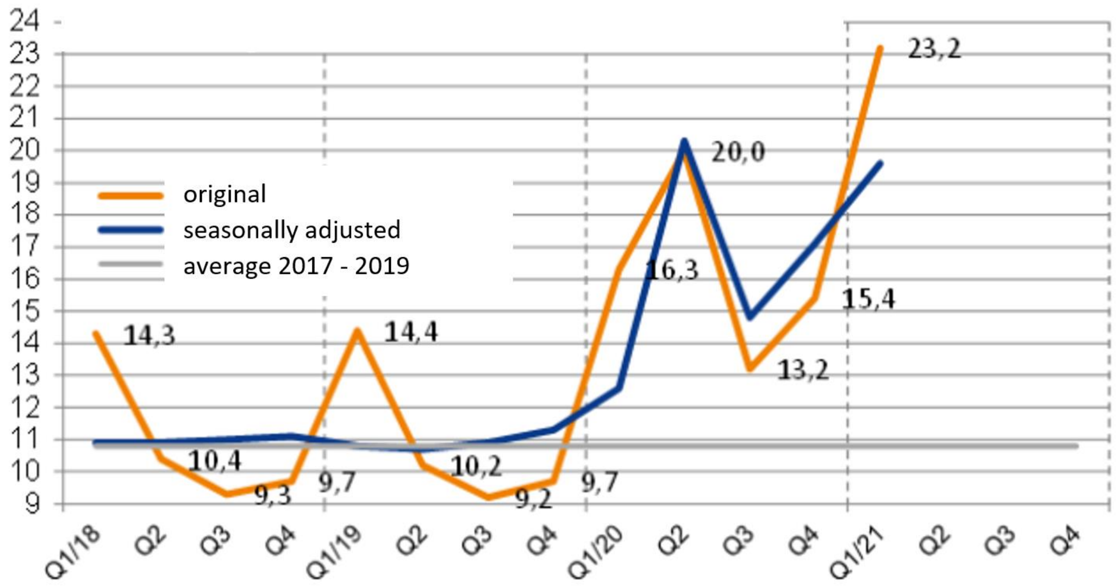

Figure 40 Development of savings rate of households in Germany

The savings rate of private households in Germany continues its roller coaster ride. Driven by the Corona crisis, this shot up to 20% in the second quarter of the previous year and thus to by far the highest value since reunification. In the rest of the year, the proportion of income that households save was significantly lower, but it remained well above the average of previous years. According to the latest figures from the Federal Statistical Office, the savings rate in the first quarter of 2021 then reached a historic record of 23.2%. The savings rate, which fluctuates strongly seasonally, is always high in the first quarter anyway, and this year the tough lockdown was added to this.

Even if the current quarter is characterized by the gradual easing of the corona measures, citizens are still saving a lot. However, this is likely to change when, with the progress in vaccination, shopping, gastronomy, culture and holidays are possible again without major restrictions. In the course of the second half of the year, the savings rate is likely to fall well below the long-term average. The means for vigorous consumption are available. After all, private households saved more than 150 billion euros more than usual in 2020 and in the first quarter of 2021 and mostly parked them temporarily in current accounts. A significant part of this additional savings should be used to catch up on lost consumption and thus push the

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economic upswing after the Corona crisis. Only in the course of the next year is the private savings ratio likely to return to the normal level.

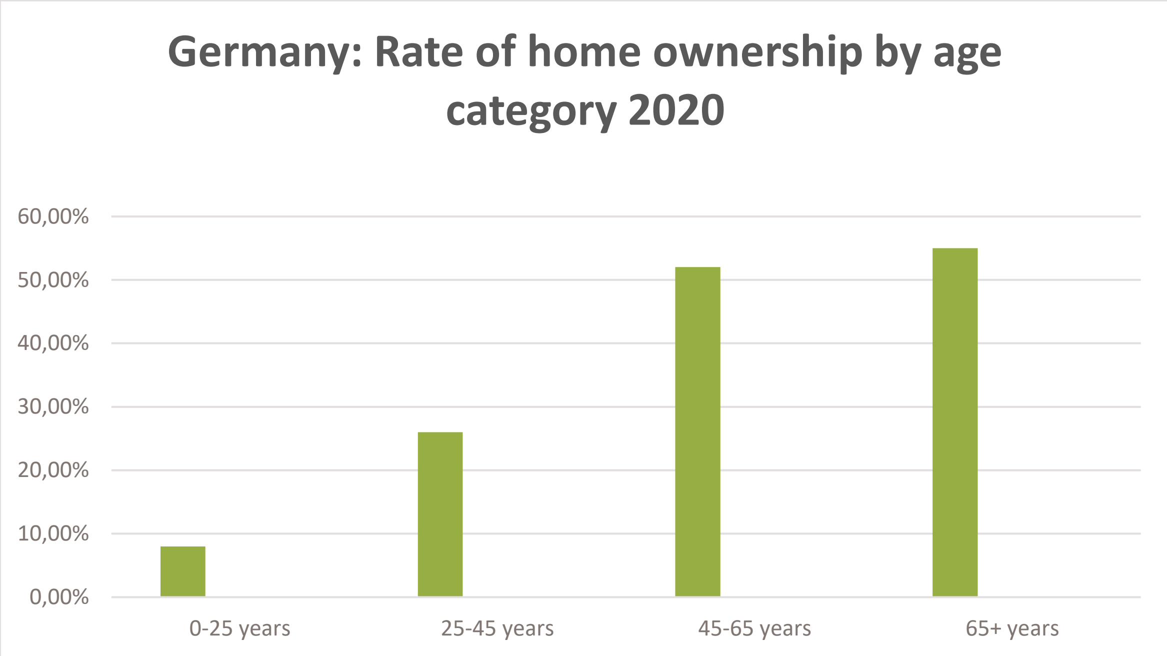

Figure 41 Rate of home ownership in Germany 2020 by age category

At around 45 percent, the home ownership rate here is well below the EU average. However, it cannot be deduced from this per se that the German housing market is afflicted with deficiencies. On the contrary: Germany is often envied for its high-quality rental housing market. However, thanks to better availability of internationally comparable household data, we now know that more home ownership is not only associated with higher total wealth, but also with lower wealth inequality in the population often assess things more positively, get involved socially and politically more often than average and are mentally healthier. In addition to financial advantages for the individual, home ownership offers tangible social advantages.

It is noteworthy that home ownership among younger households has been declining significantly since the beginning of the real estate boom in Germany. According to the latest available data from the Socio-Economic Panel (SOEP), there are almost 2.6 million owner households among the approximately 10 million households with a main income earner between the ages of 25 and 45. The proportion of homeowners in this age group is around 26%. This means that the home ownership rate in this group is a fifth lower than before the start of the real estate boom in 2008. If the home ownership rate among younger households had remained constant over the past decade, 625,000 more of these households would be homeowners today.

Declining home ownership rates among younger people would be of little concern if there were a discernible shift in these people's preferences away from home ownership. However, this is by no means the case: According to representative surveys, having your own home is still the ideal for many people – especially young people. The erosion of home ownership among younger households is therefore a socio-politically explosive consequence of the long-standing real estate boom, which has so far hardly been discussed in public.

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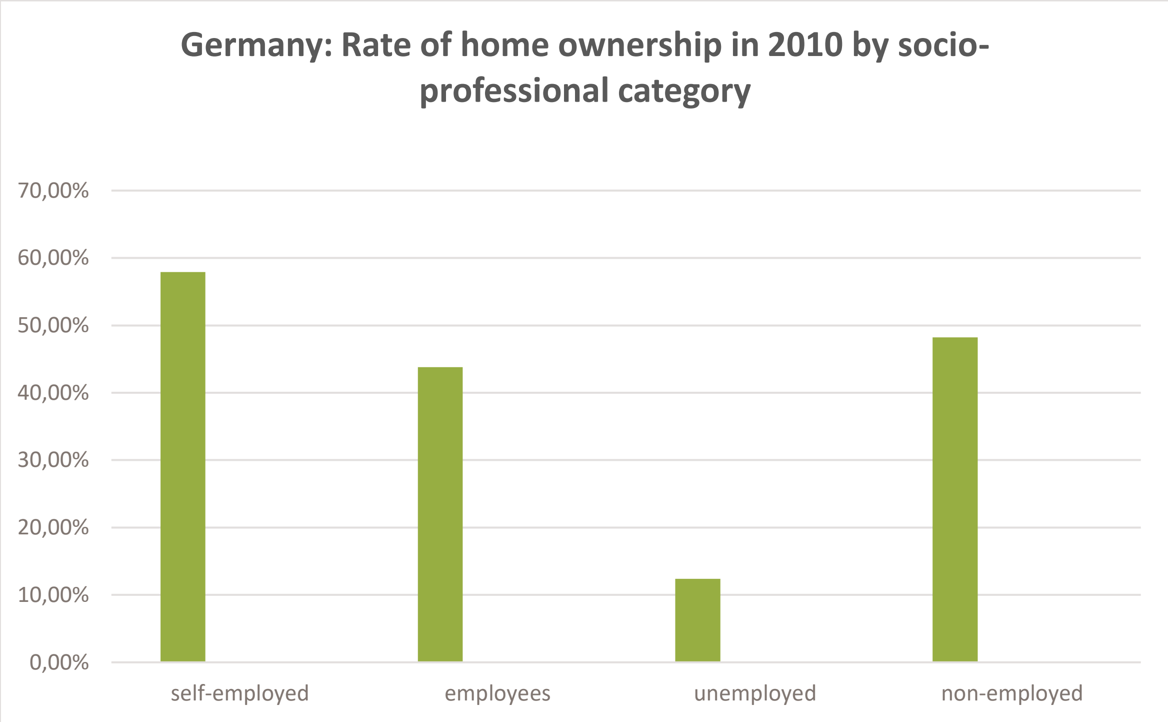

Figure 42 Rate of home ownership in Germany 2010 by socio-professional

The statistic shows the home ownership rate in Germany in 2010, broken down by social status (Figure 42). The household-related home ownership rate is shown, which is the ratio of households that own their own home to all households. Households are groups of people who are related or otherwise personally connected who live together. A single person living alone with his own income can also form a household.

In 2010, the share of owner-occupied homes in all households in Germany was around 44.2%. If the household members were unemployed, the home ownership rate was 12.4%.

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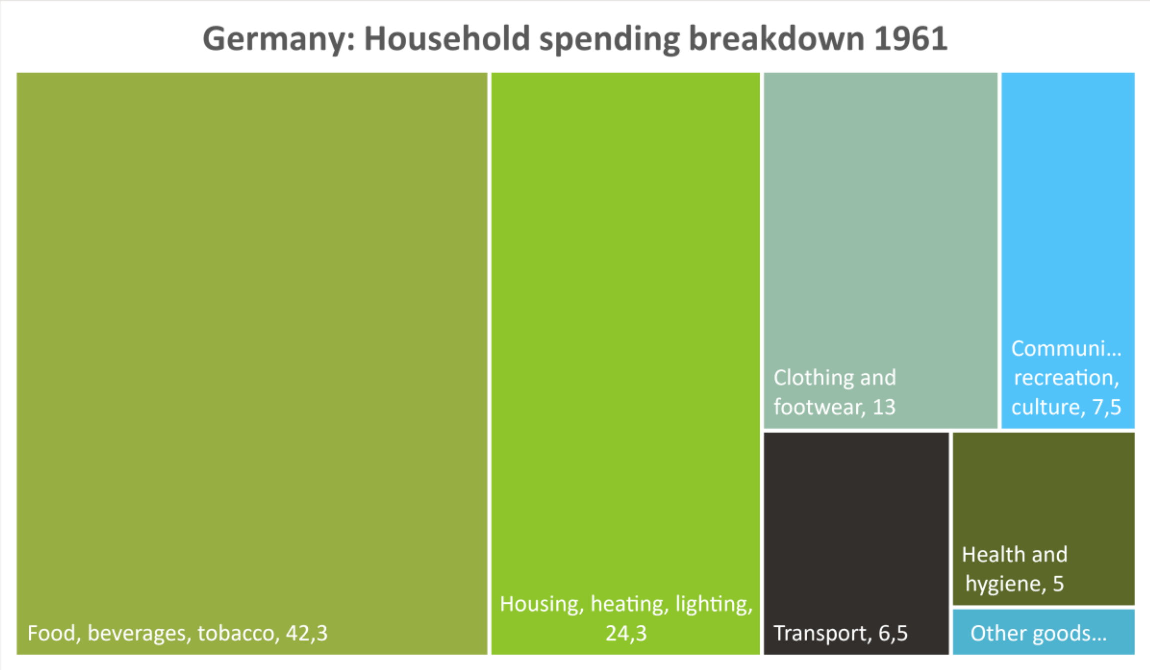

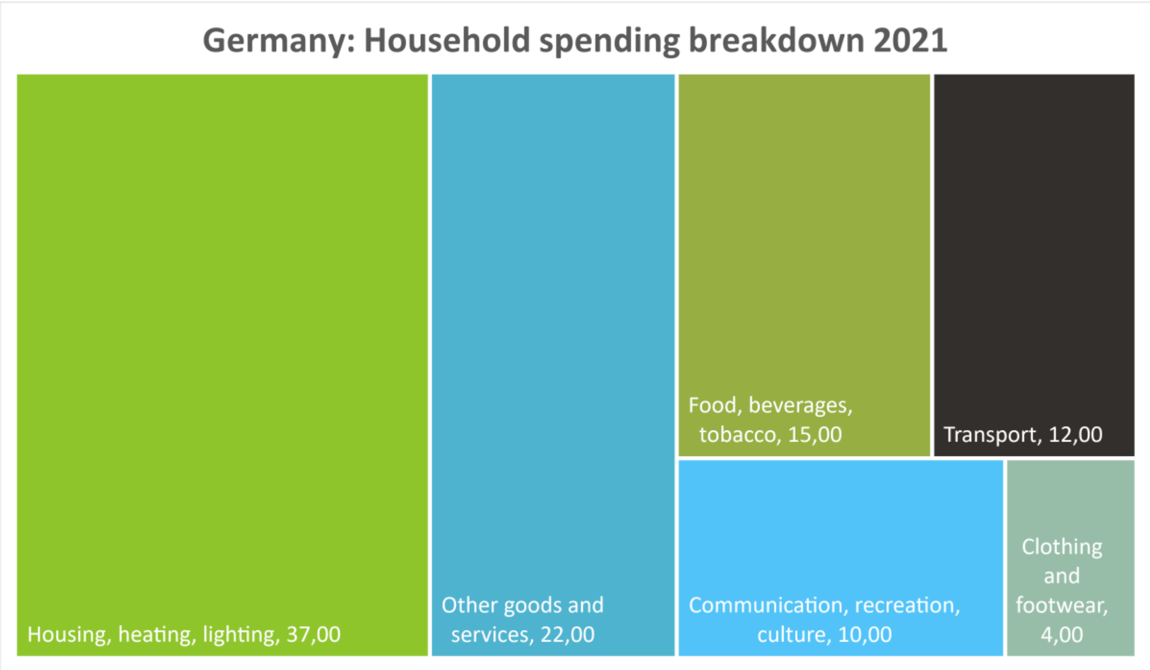

Figure 43 Germany: Household spending breakdown 1961 and 2021

In 2018, private households in Germany used a good 51% of their consumer budget to cover expenses for housing, food and clothing. As the Federal Statistical Office (Destatis) also reports, that was an average of 1,390 euros per household per month. Overall, household consumer spending was EUR 2,704 per month. That is around 10.5% more than in the last survey in 2013 (2,448 euros) and 31.2% more than in 1998 (2,061 euros).

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Households spent an average of just under 34% (908 euros per month) on housing alone. As in previous years, this item accounted for the largest share of consumer spending. In 1998 the proportion was 32%. In the sample survey of income and consumption (EVS), expenditure on living includes not only rent (including operating costs) but also expenditure on energy and maintenance. A good 13% (360 euros) was spent on food. On average, just under 5% (122 euros) was spent on clothing. In 1998 these shares were 14% and 6% respectively.

On average, private households spent 14% (379 euros) of their consumer budget on transport. This includes, among other things, spending on public transport services and your own vehicle. Spending on leisure, entertainment and culture averaged a good 11% (304 euros). The remaining 23% (630 euros) of consumer spending was in the areas of interior design, catering and accommodation services, health, post and telecommunications, education and other goods and services.

In addition to consumer spending, households also have non-consumer spending such as insurance premiums and interest on loans. Households nationwide spent an average of 484 euros per month on this in 2018.

- **Housing stock by building age class at the end of 2022**

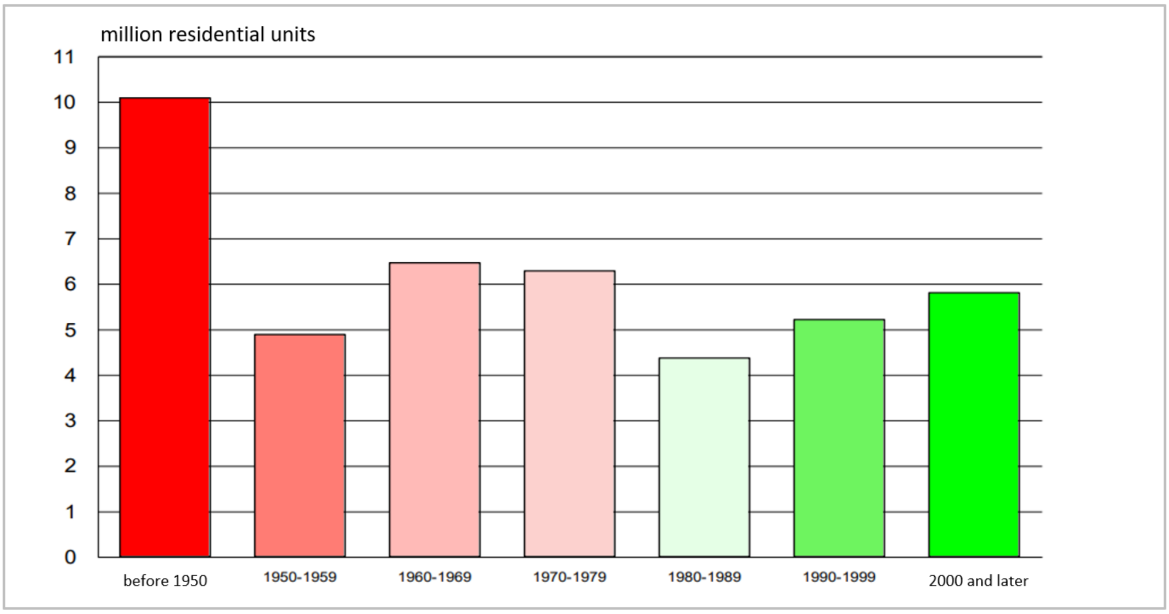

Figure 44 Germany: Housing stock by building age class at the end of 2022

In addition to the demographic need for housing, there is also a qualitative need to continuously adapt the housing stock to current standards. In 2021, the Federal Statistical Office recorded the disposal of 18,470 apartments.

Compared to the previous year's housing stock of 42.8 million, this corresponded to a departure rate of 0.043%. The calculated lifespan of our apartments would be a good 2,300 years if this rate of consumption remained constant. However, a qualitative upgrading of the stock can hardly be achieved with this. The building sector should reduce greenhouse gas emissions by around 43% by 2030 compared to 2020 and achieve climate neutrality by 2045. However, around 10% of the housing stock has been valid for many years – approx. 4.3 million

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apartments - as technically/economically not refurbishable. In purely quantitative terms, however, these apartments will also be needed in the future, because the immigrants from other countries should live in apartments and not in accommodation in Germany. In this respect, the aim should be to replace these apartments by 2045. This also allows the construction industry and offer the building material manufacturers a perspective of continuous construction activity. As can be seen from the figure above (Figure 44), the majority of homes in Germany were built at a time when saving energy was a secondary goal.

4.2.4 Czech Republic

This section provides on the one hand the socio-economic segmentation and economic characterization of the Czech population as well as the segmentation of these identified categories amongst the main building typologies.

- **Socio professional segmentation**

The proportion of employed persons in the number of all persons aged 15–64 years reached 75.5% in December 2022. The total number of employed persons is 5,012, 000. The percentage of the unemployed in the labour force, that is in the total number of the employed and the unemployed (that means economically active persons), reached 2.2% in December 2022. It decreased by 0.1 percentage point, year-on-year.

The following chart (Figure 45) provides an overview of the segmentation of the Czech active population according to the main socio-professional categories.

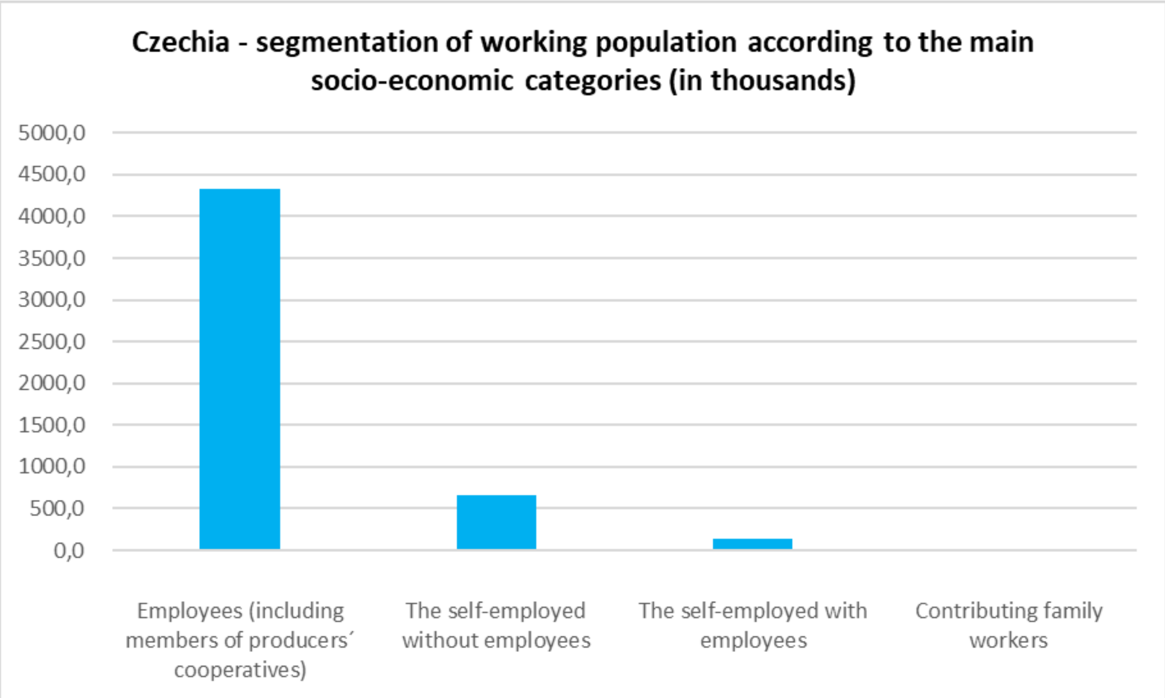

Figure 45 Segmentation of working population amongst socio-professional categories in Czechia 2022

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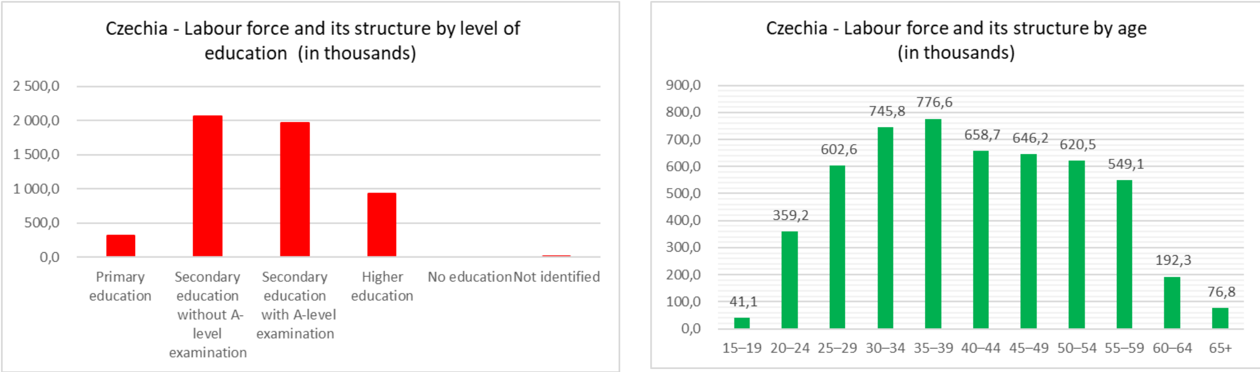

Figure 46 Structure of labour force in Czech Republic by age and education

The main observation that can be made is that the number of self-employed persons is relatively low. There is a high proportion of individuals with secondary education among the employees. The strongest age categories are 30-34 yrs and 35-39 yrs.

- **Income/ wealth segmentation**

To understand that solutions and retrofits are economically viable for a population, it is important to get an idea of their level of life and disposable income. The median annual earnings are ranging from 12 152 EUR to 20 253 EUR.

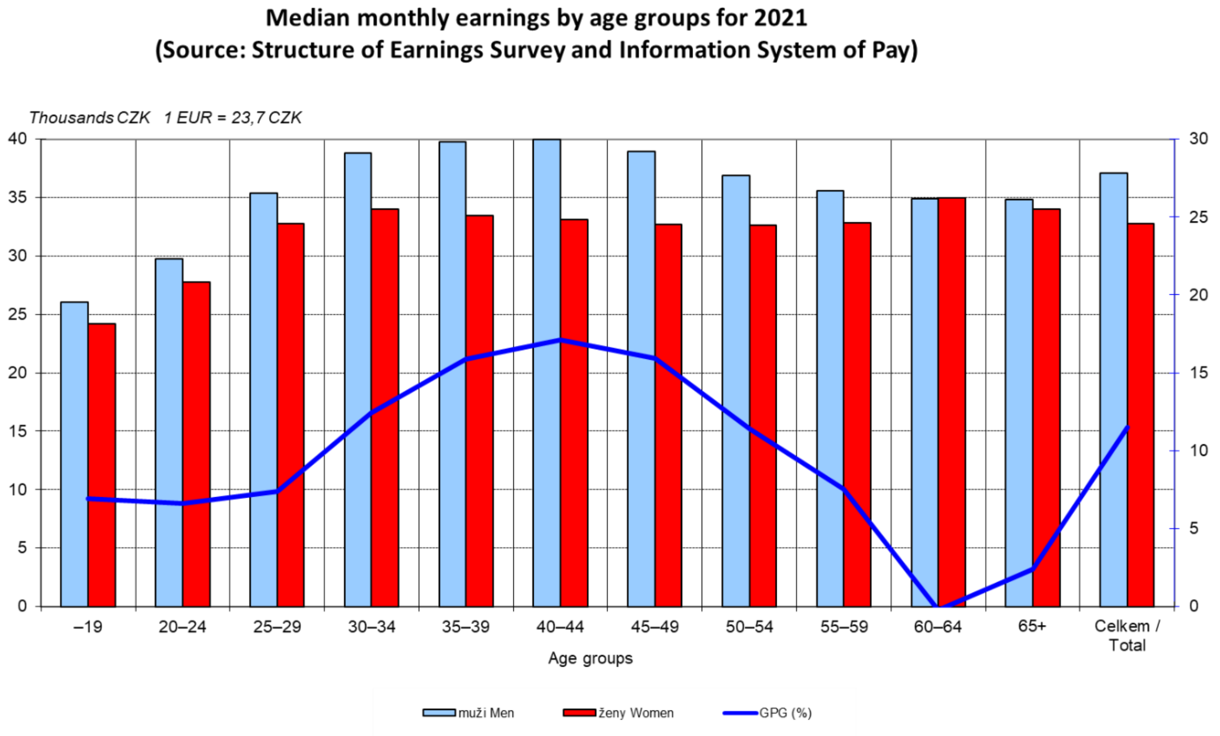

Figure 47 Monthly income per age category in the Czech Republic 2021

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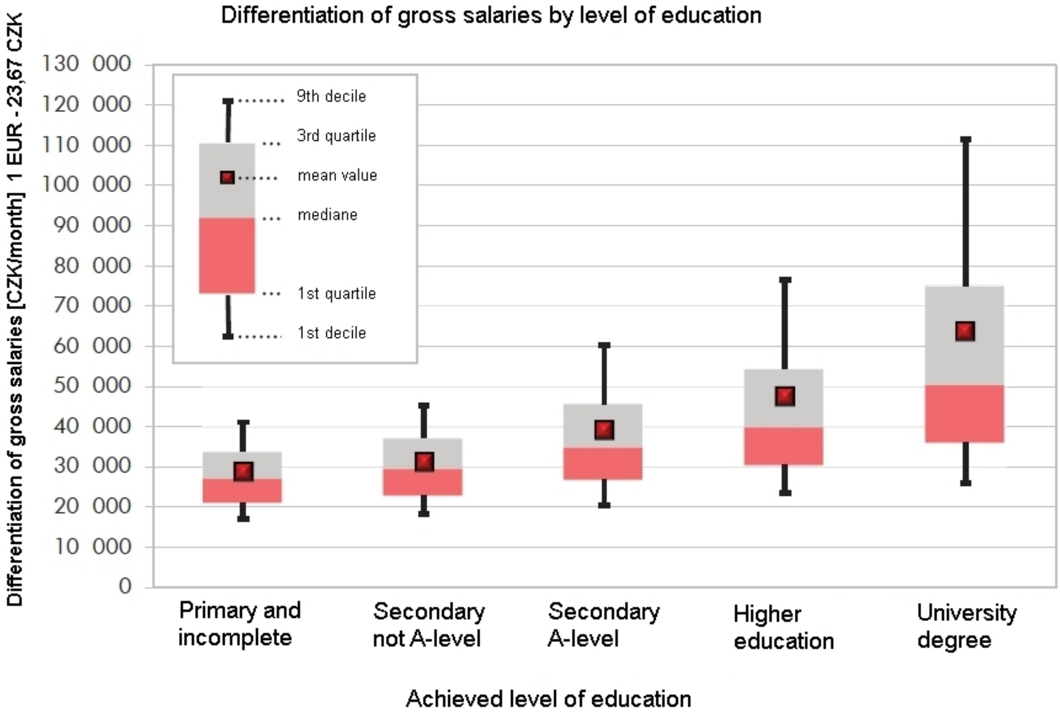

Figure 48 Monthly income per achieved level of education in the Czech Republic 2021

Peak income in the Czech households is reached between the age 35-50 years due to acquired experience and professional skills. Unsurprisingly the achieved level of education and experience strongly affect salary. The spread of salaries in the university degree category is much bigger than in other education levels. It is also obvious that especially in this category the mean value is much higher than the median.

With regards to the above-mentioned facts, it is important to observe figures breaking down disposable income distribution per member of the household. The distribution of disposable income by deciles per member of the household is shown on the chart below (split in deciles):

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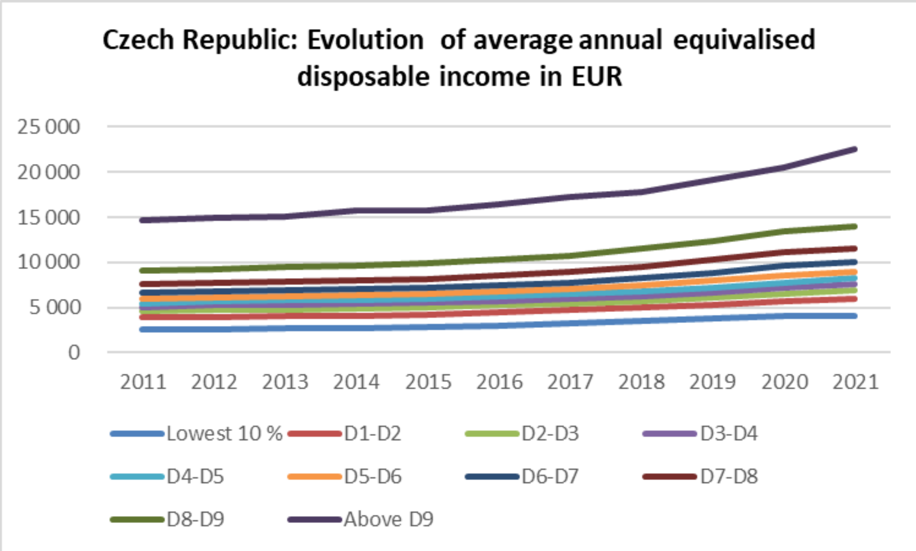

Figure 49 Evolution of average annual equivalized disposable income per decile in Czech Republic

A gap is present between D9< and other deciles.

The following chart provides a breakdown of annual disposable income for socio-professional categories as defined by ISCO classification.

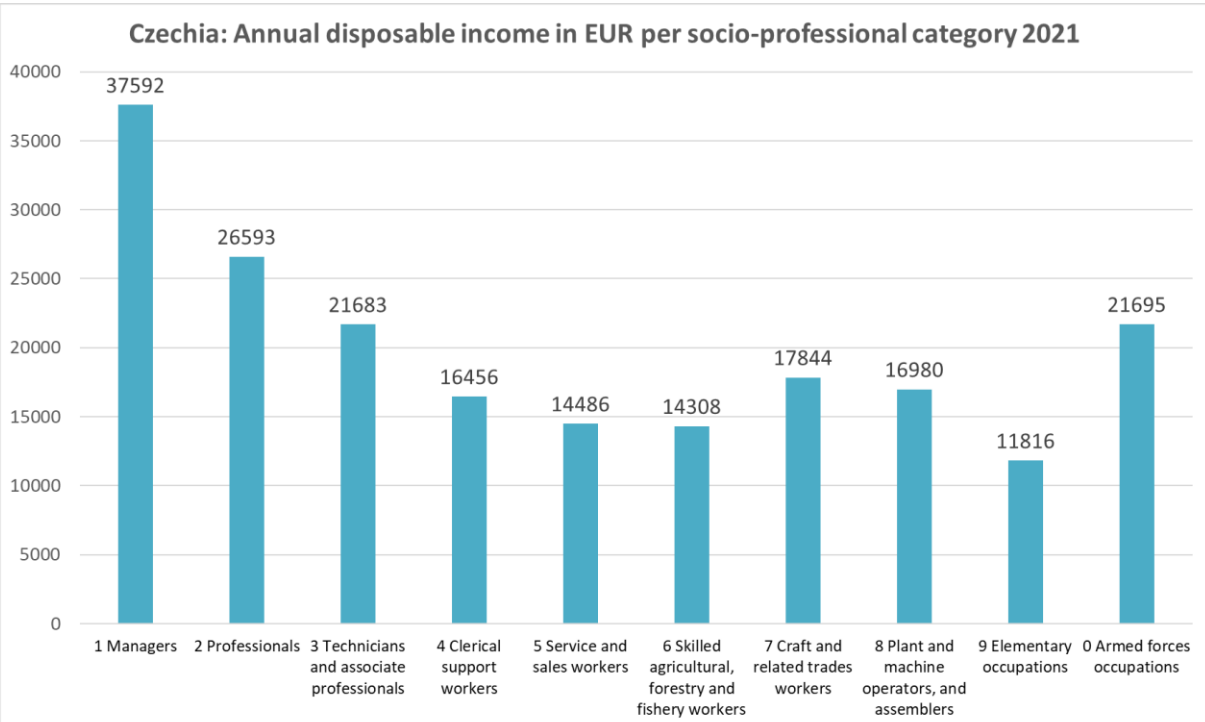

Figure 50 Disposable income per socio-professional category in the Czech Republic 2021

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In 2021 the lowest median income for unskilled workers was at 11.816 € and the highest for executive and managers at 37.592 €.

- **Characterizing socio economic segments: home ownership, savings, investments, and expenditures**

It is important to put the prior data in context with related economic KPIs that provide an information on the actual behavioural trends in potential segments.

The main housing tenure types in focus are owner-occupied and private rented because the house or dwelling owners are the main decision makers regarding the investments, spendings and renovations of their assets. According to Eurostat data the Household Saving Rate in the Czech Republic increased to 20.67% in the fourth quarter of 2022 from 17.01% in the third quarter of 2022.

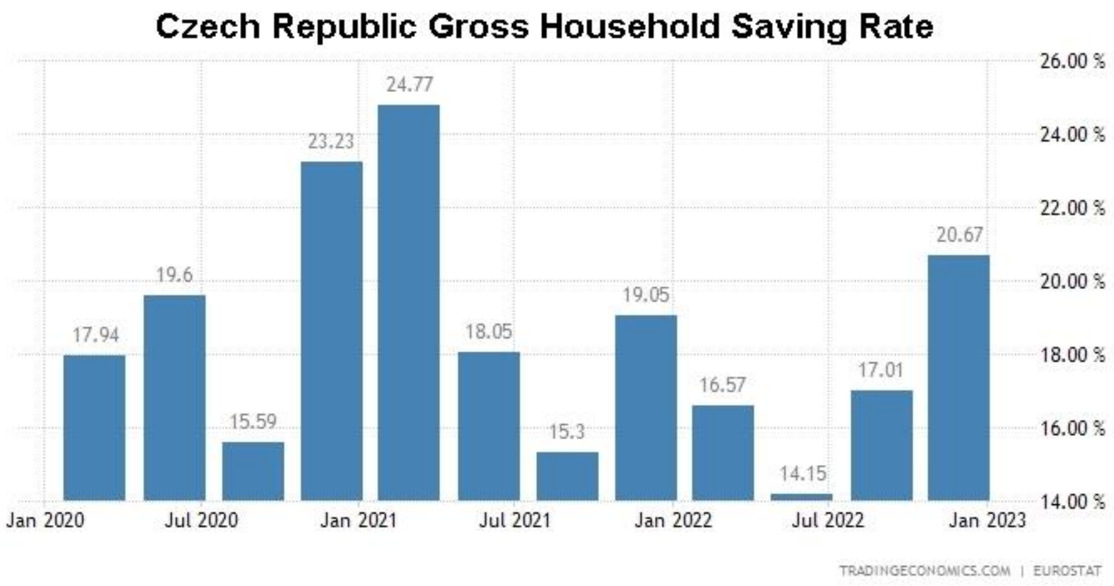

Figure 51 Saving rate of households in the Czech Republic

The gross saving rate of households (household saving rate) is defined as gross saving divided by gross disposable income, with the latter including the change in the net equity of households in pension funds reserves.

The following chart (Figure 52) shows the home ownership rate evolution in the Czech Republic. This rate is relatively high compared to other EU countries. The rate of home

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ownership by age of the owners is not available.

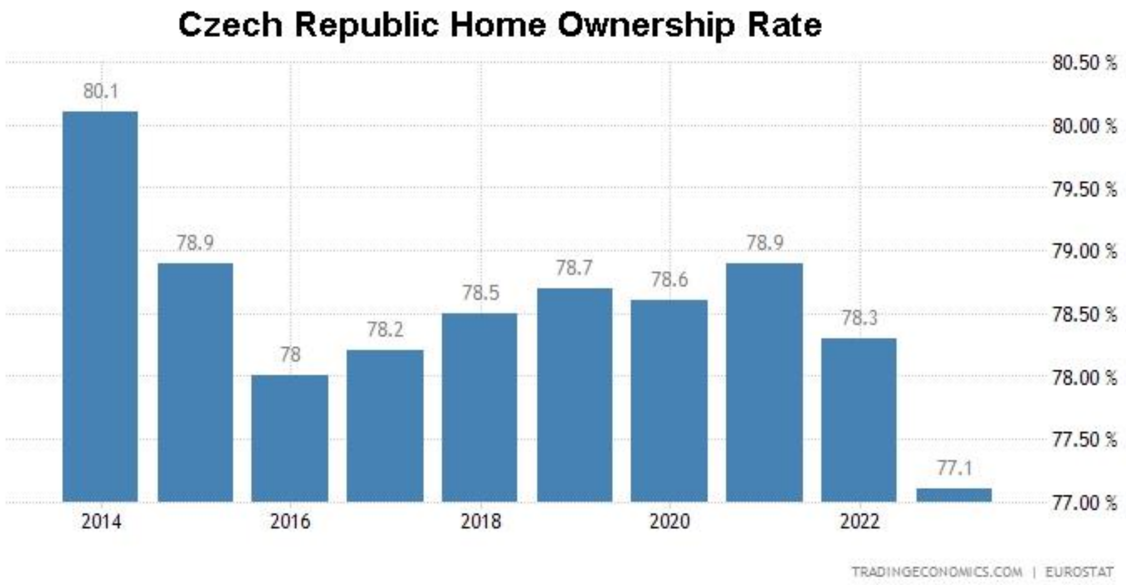

Figure 52 Home ownership rate in the Czech Republic

On the side of savings and investments, looking at general household expenditures and consumption, it is obvious that the Czech households spend an important part of their budget for housing, water, electricity, gas and other fuels (in average about 25% of the total household budget).

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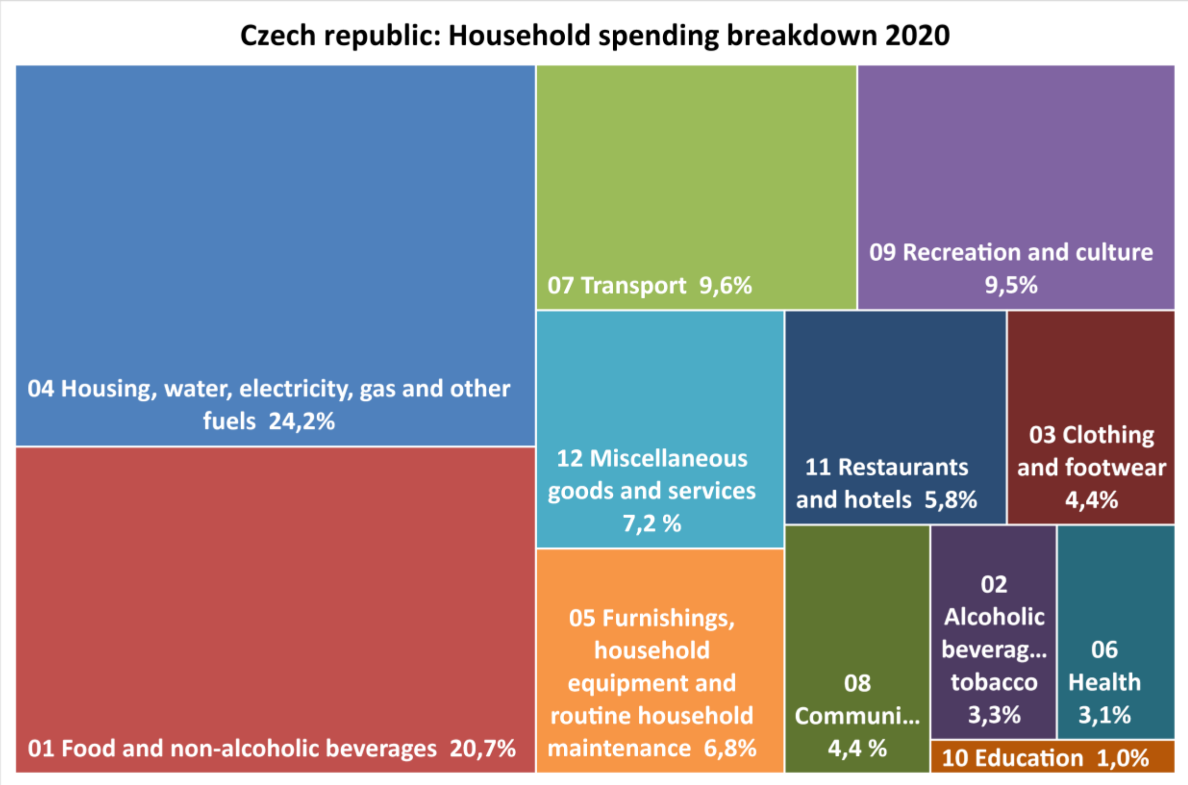

Figure 53 Household spending breakdown in the year 2020

Strong growth in energy prices is currently a major inflation factor in Czechia. The period of low electricity and gas prices ended around mid-2021, and energy prices started to surge at the end of that year. In 2022, the energy crisis was exacerbated by Russia's military aggression in Ukraine and the related sharp rise in energy prices on commodity exchanges, which is gradually being reflected in rising retail prices. This situation has changed behaviour of most of the households. The house owners also started to consider various options for energy saving measures, mainly through improvement of thermal properties of the building envelope and installation of PV cells and heat pumps.

- **Building Stock characteristics and common building typologies**

The stock of residential buildings can be divided into 4 main periods:

1. Old buildings built before 1921: characterized by a great disparity in construction methods and materials used. The prevailing tendency was detached and semi-detached house.
2. Old buildings built between 1940 and 1960: characterized by the growth of multi-family buildings, notably buildings with more than 10 dwellings in 1960.
3. Buildings built between 1961 and 1990 with a huge share of dwellings in prefabricated apartment blocks (1.16 million dwellings in 80 000 prefabricated houses). Due to issue of new energy efficiency standards in 1978, the buildings from the period 1980-90 have already improved energy performance.

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4. Buildings from the period 1991 onwards with a big share of family houses. These buildings comply with more and more challenging energy performance requirements. During the past few years only NZEB or even better energy performance standards are allowed for the new constructions.

In the following figure you can see a segmentation of the single-family homes (including detached house on parcels, no joint ownership and semi-detached house on one or two sides) and the multifamily homes (including small multi-family apartment building with less than 10 units, semi-detached or isolated and large multi-family housing building with more than 9 units).

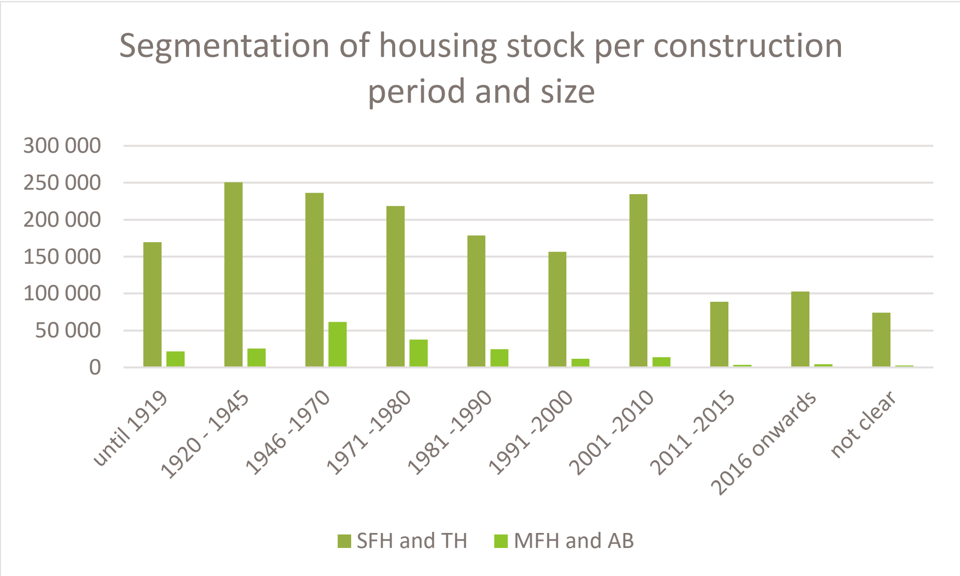

Figure 54 Household spending breakdown in the year 2020

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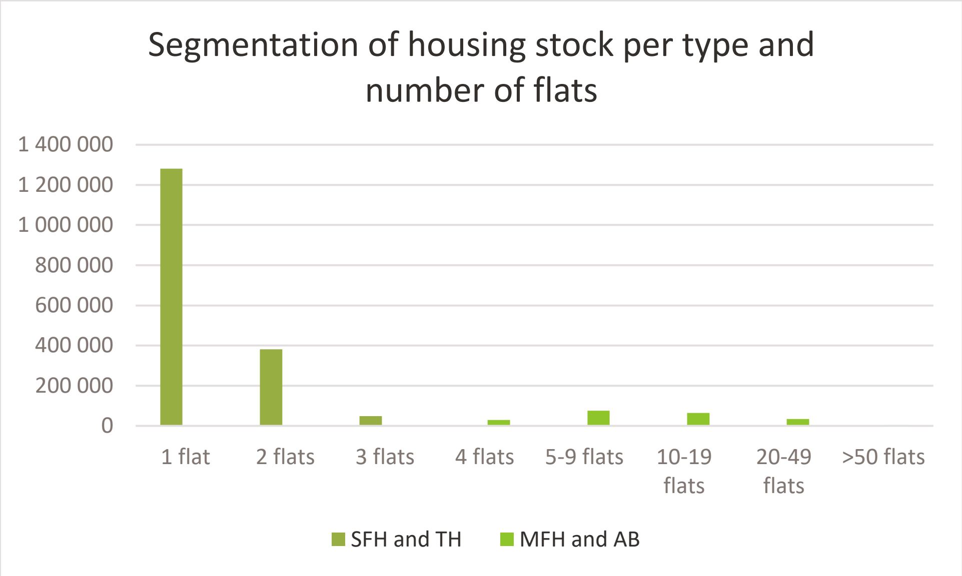

Figure 55 Housing stock breakdown per number of flats

4.3 User archetypes for energy modelling

In alignment with the literature review, it is established that occupant behaviour substantially influences energy consumption patterns. For an accurate simulation of a building's energy performance, specialized software endeavours to mimic this occupant behaviour as accurately as possible. It is necessary to evaluate the impact of user behaviour on heating performance to construct user archetypes.

The objective of this segment is to convert the prior findings into user archetypes that can be incorporated into comprehensive building energy modelling. This section will recapitulate insights gleaned from existing literature and provide recommendations based on the survey results.

Significant factors and contextual events affecting occupant behaviour in buildings have been assembled and condensed in scholarly sources, like the work of Stazi et al. (Stazi et al., 2017).

Their research emphasizes the numerous, independent, and intricate factors directly influencing specific actions and building usage. The effects are principally arranged around the following phenomena:

- Occupant presence and usage of equipment;
- Window and door usage trends;
- Setpoints and utilization of heating appliances;
- Patterns in shading usage.

On the other hand influencing factors can be collected based on what the alterable options are in different energy modelling softwares for occupant behaviour aspects. For example, in

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recent developments in software implementation of occupant behaviour models (specifically in EnergyPlus(Bandurski, 2015; Gunay & O'brien, 2018), the following critical characteristics have been considered:

- Occupancy;
- Lighting activation schedules;
- Shading timelines;
- Window usage schedules;
- Equipment plug-load schedules;
- Thermostat adjustment habits.

While standards and regulations guide the design of buildings and HVAC systems, a gap still exists between the anticipated and actual performance of a building. This discrepancy is often termed the "performance gap" in the literature. A more precise portrayal of occupant behaviour can potentially shrink this performance gap considerably (Bandurski, 2015).

Prominent user archetypes are identified based on actual responses from the administered survey. To illustrate this, a survey was carried out in one of the virtual demo countries, specifically Hungary, with a representative sample size of 1,000 participants, as outlined in section 4.1.1.

Based on the survey, an input excel collecting relevant occupant behaviour data is developed for future simulations conducted under Task 4.3 in virtual demo-cases. Out of the above mentioned six categories, based on survey data information could be extracted on Occupancy, Shading, Window usage and Thermostat adjustment habits.

Firstly, based on all responses, a general user archetype is constructed considering the most important aspects for energy modelling. Furthermore, as the Hungarian virtual demo takes into account a certain type of single-family house, typical usage is also described with only using responses from people living in single family houses. As the sample size for this survey was set for 1,000, and for the second user archetypes a pool of 579 houses was utilized, the adequacy of this dataset needs to be further evaluated.

These user archetypes can be found in

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Annexes 1 and 2 respectively.

5 Introduction to stakeholder mapping and engagement

The following sections aim to identify the stakeholders of the value chain for residential buildings' renovation or construction that are the leading promoters and beneficiaries of the energy efficiency measures implemented. They focus on stakeholder mapping and engagement in the renovation/ construction process. A stakeholder refers to 'any group or individual who can affect or is affected by the achievement of the organisation's objectives' (Freeman, 1984). For mapping of the stakeholders, we adopt the 'Hubs of Activity' model (N. Dunphy et al., 2014), which is a helpful tool for identifying stakeholders in an energy retrofit. It breaks down the project into stages and assesses the interactions between stakeholders for each respective stage. It can also provide information about the contribution of the stakeholders to generating value.

Zedan and Miller introduced the time/energy efficiency influence curve as a scale to determine the time factor, which influences the total effect of stakeholders on energy efficiency depending on when they get involved in the project (Figure 56). When compared to the time/cost influence curve, the reduction in decrease of influence with time is visible for energy efficiency. This is due to the fact that changes in costs/expenditures are more rigid than implementing energy efficiency. For instance, adding insulation in the construction stage or utilising energy-efficient appliances during occupancy can substantially influence energy efficiency. However, there might be a margin depending on how adaptable stakeholders are to the changes in the later stages of procurement (e.g. owners prohibit any modifications after the design stage, time factor should be zero to exclude the influence of stakeholders joining after the design stage) (Zedan & Miller, 2018). Hence, necessity of identifying stakeholders needs and drivers and addressing them through stakeholder engagement will be addressed in sections 7 and 8, respectively.

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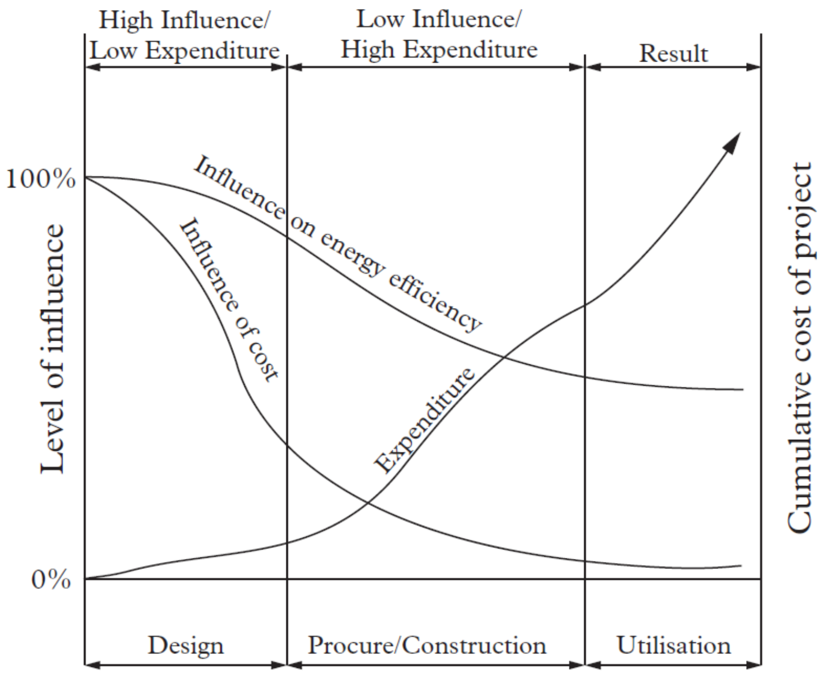

Figure 56 Time/energy efficiency influence curve (Zedan & Miller, 2018)

6 Stakeholder analysis/mapping

Construction supply chains cover all businesses and other organizations taking part in the process (i.e. from the extraction of the raw materials to the end-of-life) (N. P. Dunphy et al., 2013). Based on their dynamic and transitional character while focusing on a particular project, they can be specified as temporary multi-firm configurations. The value approach for modelling supply chains of the construction industry was recognised as adequate for capturing the dynamic nature and complexity (Sabri, 2015). A conventional approach to understanding markets based on value chains originated from business management literature (N. P. Dunphy et al., 2013). Porter conceived the value chain concept in his book "The Competitive Advantage: Creating and Sustaining Superior Performance". 'The value chain displays total value and includes value activities and margin. Value activities are physically and technologically distinct activities, while margin is the difference between the total value and the cost of performing the activities. The activities can be categorized into primary and support activities. Primary activities consist of inbound and outbound logistics, operations, marketing and sales and service, while support activities cover firm infrastructure, human resource management, technology development and procurement (Porter, 1998).

Porter and Kramer later updated this concept of the value chain with the concept of shared value which is related to policies and operating practices that at the same time are beneficial both for the company and the community (Porter & Kramer, 2011). However, it has been recognized that the value chain could 'include additional perspectives which incorporate shared value and look beyond the chain's stakeholders, with collaboration as a means to sustainable competitive advantage' (Fearne et al., 2012). Moreover, value chain analysis is used for assessing activities inside the value chain to identify areas for improvement (i.e. production of the product until final sale) (Stobierski, 2020).

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The construction value chain comprises many actors that dynamically interact and make decisions at various stages of the process. However, they do not cooperate continuously throughout the process resulting in difficulties in the circular economy adoption (Dewagoda et al., 2022). For management and improvement of the value creation and project flow, closer collaboration and integration between the project team members and stakeholders is essential. In construction projects, there are several levels of integration of teams and stakeholders, namely fully, partially or hardly integrated. It has been recognized that in the industry, customer value creation is needed for success. This could be 'achieved by early identification, involvement and integration of the diverse stakeholders and practices' (Aapaoja, Haapasalo, et al., 2013). In the case of the renovation project, the uncertainties (i.e. unknown pre-existing conditions) are typically more prevalent than in the new construction. However, this can offer a good ground for stakeholder integration and collaboration (Aapaoja, Herrala, et al., 2013).

The stakeholders' requirements are usually the basis for the solutions and decisions in the project (Aapaoja, 2014). Stakeholder theory is based on two core questions:

- What is the purpose of the firm?
- What responsibility does management have to stakeholders? (Freeman et al., 2004)

Participation of the stakeholders throughout all stages of the process offers the following benefits:

- Increased attention paid to the findings;
- Assisting in the assurance that all relevant questions are asked;
- Raised stakeholders' understanding of the organization and the evaluation;
- Promoting a participatory and collaborative relationship;
- Increased validity of the evaluation of findings (Geist, 2010).

Relational multiparty contacts and methods have been proposed to increase value creation for all project stakeholders. Additionally, it has been noticed that developing integrated project teams has improved project results. The interest in such an approach has been increasing substantially especially in the case of renovation projects due to unsettled and fragmented modus operandi. Early stakeholder involvement is one of the milestones of value creation. However, it is essential to identify the involved stakeholders and employ a manageable number of key stakeholders (i.e., a number of stakeholders raise complexity) (Aapaoja, Haapasalo, et al., 2013). Moreover, to maximize long-term capacity and increase uptake, it is essential to understand the material and monetary flows within the sector and the value relationships between stakeholders (N. P. Dunphy et al., 2013). Hence, the stakeholder mapping exercise was conducted taking into account the stakeholder roles and positions as well as their interactions.

For identifying the stakeholders in an energy retrofit, it is helpful to categorize the generic stages of a project and define the activities for each stage. This approach is followed by 'Hubs

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of activity' (HoA) model developed in UMBRELLA[2] F7 project. The life cycle of a generic building was clustered into six stages based on a cradle-to-cradle approach (Table 5). The model structures the value creation process along the supply chain as well as networks and relationships between the stakeholders (N. P. Dunphy & Morrissey, 2015). Although the activities are highly interdependent, they also can be executed in substantially different timespans (N. P. Dunphy et al., 2013). The model is a helpful tool for providing the analytical framework of stakeholder interaction and value flows (Morrissey et al., 2014).

Table 5 Stages of a generic project (N. P. Dunphy & Morrissey, 2015)

Hub	Example of Activity
1. Upstream activities	Extraction of raw materials, manufacturing, transport, etc.
2. Initiation & viability check	Original proposal, making business case, etc.
3. Design & planning	Designs, building plans, project plans, etc.
4. Construction and/or installation	All site activities
5. Operation and maintenance	Use and upkeep
6. End of life/downstream activities	Deconstruction, reuse, recycling, disposal, etc.

However, understanding the value based on the type of stakeholder is crucial. For instance, for specific stakeholders, it can be based on lower utility and running costs, while for another, thermal comfort. Hence, it is vital that stakeholders identified in the stages of HoA take out satisfactory value based on their involvement (Dunphy & Morrissey, 2015). In general, stakeholders of a project might be classified as internal and external; primary and secondary; and participating and non-participating. In energy retrofit projects, classification based on the power in corporate decision-making (i.e., participating and non-participating) has been recognized as the most suitable (Fasna & Gunatilake, 2020). Participating stakeholders have the power to decide, while non-participating does not have a voice in the decision-making (Arnstein, 1969).

Based on the stages defined in Table 5, the generic list of stakeholders was specified for a typical energy efficiency retrofit project (Table 6) as a part of the UMBRELLA project. The stakeholders' identification was based on a thorough literature review and a series of brainstorming workshops. Additionally, techniques such as mind-maps and spider diagrams were used to assess the relationships between stakeholders (N. P. Dunphy & Morrissey, 2015).

[2] UMBRELLA (Business Model Innovation for High Performance Buildings Supported by Whole Life Optimisation) project was based on developing a web-based decision support application for recognition of the implementation and incentivization of building energy efficiency solutions.
http://www.umbrella-project.eu

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While the stakeholder groups are defined to cover as many potential stakeholders as possible, the list is not all-embracing (O'Connor, P, MacSweeney, R., Dunphy, 2017).

Table 6 Generic list of stakeholders (N. P. Dunphy et al., 2013)

Hub of Activity	Key Stakeholders (i.e. 'players')	Other Stakeholders (i.e. 'context setters', 'crowd', 'subjects')
1. Upstream activities	Manufacturers; Policy Makers; Legislators; Statutory Regulators; Investors	Primary Producers; Material Processors; Financiers; Standard Bodies; R&D Institutions; Retailers and Distributors; Logistics; End-users.
2. Initiation & viability check	Owners; Investors; Solution Providers; Designers	Occupants; End Users; NGOs; Neighbours; Municipalities; Insurance Companies; Utility Companies; Financiers; Policy Makers, Legislators; Public
3. Design & planning	Designers; Owners; Project Managers; Investors; Solution Providers; Planning Authorities; Building control	Occupants; Public; NGOs; Neighbours; Financiers; Third Party Product Certification; Infrastructure providers, Utility companies
4. Construction and/or installation	Designers; Owners; Project Managers; Neighbours; Solution Providers	Occupants; Public; NGOs; Investors; Infrastructure providers; utility companies; Policy Makers; Legislators; Financiers
5. Operation and maintenance	Owners; Project managers, Occupants, Utilities companies	Designers; Investors; Solution Providers; R&D Institutions; Public; NGOs; Financiers; Retailers and Distributors; Logistics
6. End of life and downstream activities	Owner; Planning Authorities; Waste Authorities; Local authorities	Environmental Protection Agencies; Service Providers; Contractors; Public; Retailers and Distributors; NGOs; Infrastructure providers; Utility companies.

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6.1 Types of stakeholders

For identifying types of stakeholders first 6-stage HoA model was cross-referenced with the 11-stage BIO4EEB model. This approach was adopted from NewTREND[3] project (O'Connor, P, MacSweeney, R., Dunphy, 2017). Categorising the activities in this way is helpful for the identification of the key stakeholders. Additionally, it offers a framework for analysing stakeholder relationships, power dynamics, drivers, conflicts and possible synergies. After identifying the stages of the model, the value mapping exercise can be conducted for each lifecycle stage for identifying the stakeholders. Furthermore, for more efficient allocation of the stakeholders, distinguishing between project roles and stakeholder categories was recognized as a viable approach (O'Connor, P, MacSweeney, R., Dunphy, 2017).

Table 7 6-stage HoA cross-referenced with 11-stage BIO4EEB model

6 stage UMBRELLA HoA model	11-stage BIO4EEB model
Upstream activities	Securing raw materials R&D of new materials and components Manufacturing
Initiation & viability check	Initiation & viability check
Design & planning	Design & preparation
Construction and/or installation	Deployment & installation Applicability & replicability Education & training
Operation & maintenance	Monitoring Evaluation
Downstream & End-of-Life	Downstream & End-of-Life

Four roles were recognized as present in any building refurbishment project but can be fulfilled by various stakeholders (Table 8). On the other hand, stakeholder categories are not

[3] NewTREND (New integrated methodology and Tools for Retrofit design towards a next generation of ENergy efficient and sustainable buildings and Districts) aimed at improving energy efficiency of the existing European building stock and renovation rate. The tool developed is used for collaborative design enabling assessment of various design options at both building and district level.
http://newtrend-project.eu/

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responsible for project delivery. However, they either impact it or are impacted by it (Table 9) (O'Connor, P, MacSweeney, R., Dunphy, 2017).

Table 8 Project roles (Aapaoja, Haapasalo, et al., 2013; O'Connor, P, MacSweeney, R., Dunphy, 2017)

Project role	Description	Possible stakeholders
Client	Initiator of the project and contracts with the designer and contractors. Final decision maker with either legal ownership or possessing control of the building throughout the project.	Owner, landlord, developer, municipality, state agency, housing association, etc.
Design team	Converting the client's specifications into a final project design.	Architect, engineer (civil, electrical, mechanical, structural...), quantity surveyor, energy consultant, ESCO, energy certification consultant, etc.
Project manager	The building project executor in accordance with the design. An important link between the client and other stakeholder groups.	Architect, engineer, main contractor, representative of the client, etc.
Building contractor	Practical project's executor. Main and subcontractors' responsibilities can be distinguished, where the main contractor carries out all the construction work and subcontractors execute specialised tasks.	Main contractor, sub-contractor, specialists, etc.

Table 9 Stakeholder categories (Aapaoja, Haapasalo, et al., 2013; O'Connor, P, MacSweeney, R., Dunphy, 2017)

Stakeholder category	Description	Possible stakeholders
Financiers	External parties providing capital for the project's implementation (e.g., investment funds, loans, grants).	Shareholders, investors, banks, national and local governments, public grant programmes, energy supplier schemes, etc.

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Public and Statutory Bodies	All regulatory and public authorities affecting the project's design and implementation.	Local authority, planning bodies, environmental protection agencies, standards bodies, EU, national and local legislators, etc.
End-user	Everyone who will use the building, so it can cover different categories of users in a single project.	Occupants, staff, tourists, students, service users, customers, etc.
Occupants	Class of users referring to a resident of the building irrespective of duration (i.e., long or short term).	Owner-occupier, commercial tenants, residential tenants, subtenants, student residents, hotel guests, etc.
Building management	Operating the building and the energy system.	Facility manager, maintenance staff, ESCO, etc.
Community and civic society	Influenced by the project or are affecting it due to either their physical proximity (i.e., residence) or particular interest (e.g. NGOs).	Neighbours, NGOs, general public, businesses, local business groups, special interest and campaign groups, etc.
Third parties /Market support agents	Not directly related to the design or implementation but possess consultants' capacity based on a specific area of expertise.	Insurers, property valuators, media, marketing, planning consultant, auctioneer, etc.
Materials and solution providers	Involved in producing either traditional or innovative building products and technical solutions.	Primary producers, material processors, manufacturers, R&D institutions, solution providers, education and training institutions, etc.
Infrastructure providers	Engaged in providing infrastructure, i.e., roads, sewerage, electricity, telecommunication, etc.	Logistics, utilities, infrastructure providers, waste contractors, distributors, recycling firms, etc.

6.2 Power-interest analysis

After recognizing the generic groups of stakeholders, the types of actors vital for the specific context under the study can be defined as the next step (Dunphy Niall P. et al., 2014). By cross-referencing the 6-stage HoA model with the 11-stage BIO4EEB model, all the stages of the HoA model can be characterized as applicable to the BIO4EEB model. Hence, the first step was to consider all the key stakeholders identified by Dunphy et al. for a generic energy efficiency retrofit project. In a method proposed by Dunphy et al. mapping of stakeholders was done on a 2x2 (high&low) power versus interest matrix (Figure 57). Four types of

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stakeholders based on the matrix are: 'players', 'subjects', 'context setters' and 'crowd'. Interest, in this case, refers to the vested interest/stake in a building. Besides, power is the ability of individuals or organizations to impose their will, whether or not they are in positions of formal hierarchical authority (Dunphy Niall P. et al., 2014). The level of power and interest also shows how much the project manager should pay attention to specific stakeholders, e.g. 'players' ought to be managed closely. Hence, it is a valuable tool for deciding on a plan of action for the management of stakeholder groups (O'Connor, P, MacSweeney, R., Dunphy, 2017).

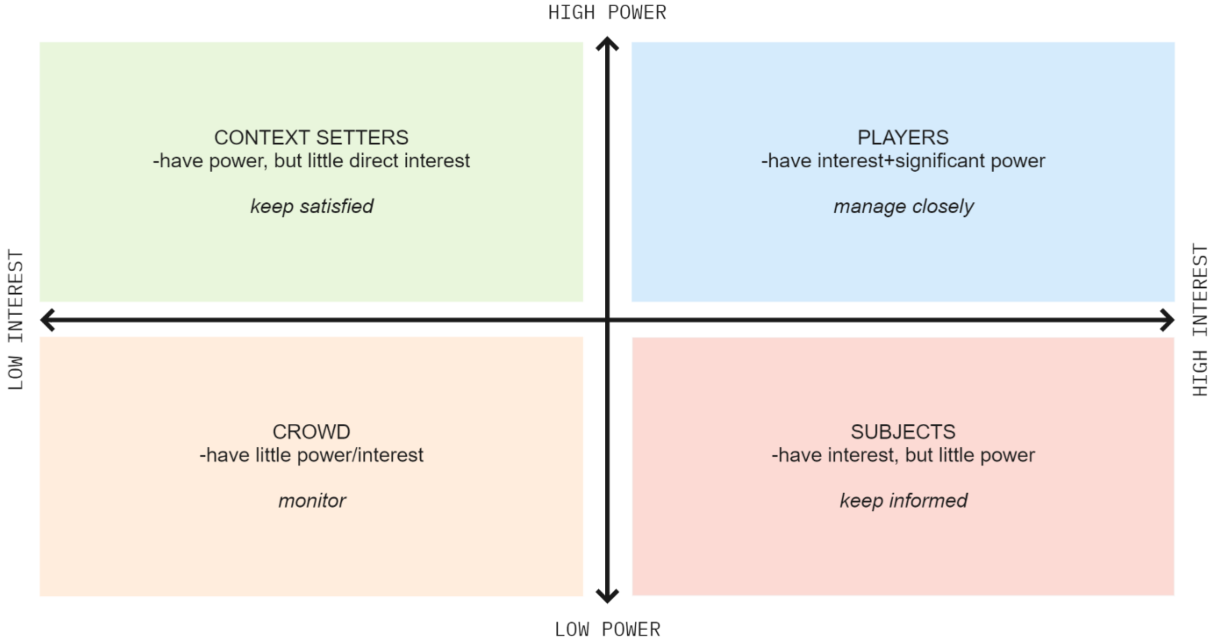

Figure 57 2x2 power vs interest matrix (Dunphy Niall P. et al., 2014)

Table 6 was the basis for the identification of the stakeholders in the BIO4EEB model. 'Players' and other stakeholders which were frequently repeated are considered for further evaluation. Moreover, it is expected that 'players' would cover project roles presented in Table 8 with possible additional stakeholder types based on the new technologies and tools developed by BIO4EEB project. Furthermore, BIO4EEB model was separated into two sets of phases for a more detailed assessment of key stakeholders. The first set starts with securing raw materials (i.e., upstream activities) to preparation (i.e., design & planning). The second one corresponds to phases between deployment & installation (i.e., construction/installation) and downstream & end-of-life. Respective stakeholders were placed on two power vs interest matrices representing two identified sets of phases. After an interactive workshop between the project partners, key stakeholders were identified.

The final list of stakeholders was generated by joining the results of both sets of phases (Table 10

). Some stakeholders are merged compared to the initial list proposed by Dunphy et al. since they are typically positioned the same and refer to a similar type of activity (N. P. Dunphy et al., 2013). Moreover, in the BIO4EEB model, the end-user can be either owner or occupant depending on the perspective of developed materials and components or enhancing energy performance, respectively. Hence, the end-user term will not be used but rather owner and occupant for more apparent distinction. In this case, the owner would refer to the definition of a client in Table 8 and the occupant's definition of an end-user in Table 9. It should be

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emphasized that each stakeholder's position on the power vs interest matrix will depend on the stage taken into account. Moreover, interactions between the stakeholders might be evaluated throughout different flows, such as energy, material or money flows (N. P. Dunphy et al., 2013). Additionally, depending on the characteristics of a specific project/ building (e.g., age, repair and condition, ownership) the role of the stakeholders may differ. Hence, more detailed evaluation will be provided in section 7.

Table 10 List of stakeholders for BIO4EEB model

Key stakeholders (i.e. 'players')	Other stakeholders (i.e. 'context setters', 'crowd', 'subjects')
Designers	Distributors and retailers
Contractors/construction companies	Facility managers
Materials and solution providers	Financial institutes
Community and civic society*	Community and civic society*
Owners	Third parties/Market support agents
Public and statutory bodies	Occupants
Project managers	R&D institutions
	Infrastructure providers

*depending on a stage

7 Background on stakeholders' needs and drivers

The companies may have different values, even when they are of the same type and/or activity. Their values are the key drivers of their activities. However, for a sustainable energy efficiency market, project and company values have to cover sustainability as the key element (Dunphy Niall P. et al., 2014). It has been recognized that company policy is the most significant motivation for organizations to implement green building (GB) standards. GB can be characterized as a building that considers and minimizes its impact on the environment and human health, uses significantly less water and energy than non-GB, typically has higher levels of indoor air quality, takes into account the lifecycle effects of different building materials, furnishings (Darko et al., 2017).

Achieving success can be hampered by the construction industry stakeholders having varied and conflicting opinions on the energy efficiency of the buildings. The main competing and conflicting challenges in building energy efficiency identified by the stakeholders have been competing short- and long-term goals, pursuing quality over quantity, and paying attention to cost efficiency against jobs (Adinyira et al., 2018).

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Camarasa et al. discussed drivers and barriers to energy-efficient technologies (EETs) in EU residential buildings. They recognized that despite their availability and economic feasibility EETs are not being adopted at the necessary rate to satisfy the EU's carbon reduction ambitions. A global understanding of the market-specific barriers (i.e., anything that hinders the widespread adoption of new technologies) and drivers is required to encourage the adoption of EETs. This can be especially valuable if it is supported with data from stakeholders engaged in the technology choice (e.g. architects, engineers, constructors, etc.). The drivers and barriers were categorised into environmental, technical, economic, social and legal aspects. Results differed based on the considered country (i.e. Belgium, Germany, Spain, France, Italy, Netherlands, Poland, United Kingdom) and EET (i.e. building automation & smart metering, district heating, electric storage, heat pumps, high-performance windows, insulation, photovoltaic systems, solar thermal systems, ventilation-with heat recovery). The technical and economic drivers were identified as the most influential in most countries and categories. Choosing technical and economic drivers as the most relevant was also applicable for the insulation and high-performance windows as EET. When barriers were considered, the economic aspect followed by technical were most frequent for most countries and solutions. Hence, the alleged economic feasibility of the solutions is not sufficiently acknowledged or appealing to encourage widespread deployment of EETs. However, results varied between countries, even those with the same EU climate zone (e.g., Italy and Spain). The findings highlight the importance of values and awareness for adopting EET and legislative measures that address issues on the national level (Camarasa et al., 2021).

Darko et al. identified five main categories of drivers regarding green buildings (GBs): external, corporate-, property-, project- and individual-level drivers. Government regulations and policies have attracted the most attention as a key driver in GB (Darko et al., 2017). In Figure 58 Conceptual framework of GB drivers *(Darko et al., 2017)*Figure 58 more detailed definition of possible individual drivers is provided. The outlines point to the main categories of GB drivers, while dashed lines indicate instances where a driver from one category may impact a driver from another.

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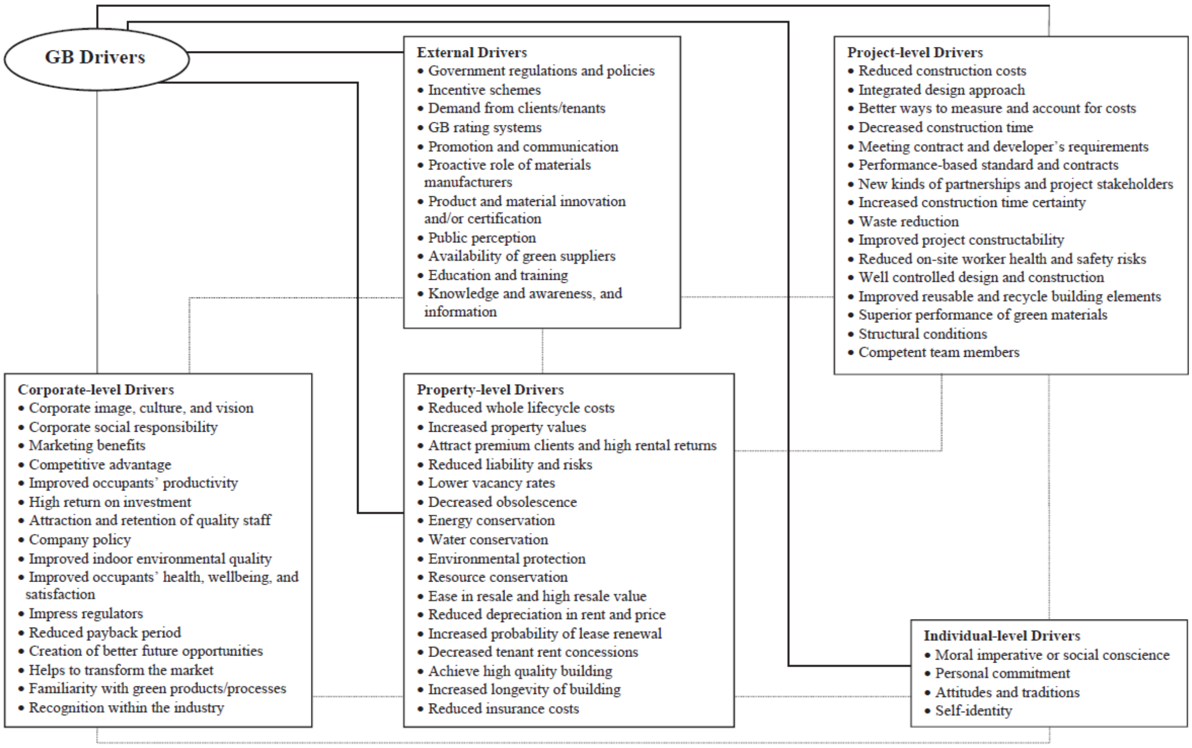

Figure 58 Conceptual framework of GB drivers (Darko et al., 2017)

As a part of NewTREND[3] project, interviews were conducted with various stakeholder categories regarding the building construction projects. One of the findings focused on the stakeholders' interests, drivers and motivations in an energy retrofit, where four categories were identified (Table 11). Moreover, the interests, drivers and motivations of the stakeholders for energy-efficient building might be divided into:

- Incentives- public policy and its impact on the market, values and attitudes of the key stakeholders, the familiarity and established property of the technologies/materials;
- Disincentives- market and financial factors, public policy;
- Variable impact (i.e. incentives or disincentives based on circumstances)- market and financial factors, the relationship of energy-efficient technologies to the wider socio-technical system (O'Connor, P, MacSweeney, R., Dunphy, 2017).

However, the strict distinction between them is not viable but should be identified in the broader socio-technical system where decisions about the energy efficiency of the buildings are made. Based on data from interviews, public policy and personal and corporate values/attitudes were recognized as critical drivers of energy-efficient building (O'Connor, P, MacSweeney, R., Dunphy, 2017).

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Table 11 Categories of stakeholders' interests, drivers and motivations (O'Connor, P, MacSweeney, R., Dunphy, 2017)

Categories	Incentives	Disincentives	Variable impact
1. Market and financial factors	Impact on property value and rental	High upfront costs Long payback times Project risk Split incentives Fossil fuel externalities	Rate of return on investment Funding source Ownership structure Fuel poverty Information
2. Regulation and policy drivers	National and EU regulations Financial and non-financial incentives Feed-in tariffs Planning system Assessment and certification schemes	Heritage restrictions	
3. Building and technology factors	Change of ownership/use Coincidence with other works/ maintenance Modernization/repairs Familiarity of technologies/ materials		Integration with other technologies
4. Socio-cultural values and attitudes	Occupant requirements Pro-environmental values Project champions Public relations and peer pressure	Non-financial costs	Autonomy and control

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Darko et al. identified that stakeholders whose opinions on the drivers for implementing GB practises were sought the most are architects, construction units, clients, engineers and developers. Architects have been recognised as key decision-makers for the materials used, but also critical players in educating clients and suggesting green materials to them. Moreover, construction units translate the green design into GB, ensuring safety and quality while minimizing resource consumption during construction (Darko et al., 2017). Based on stakeholders' interviews conducted, O'Connor et al. recognized that the client was presented most frequently as the most influential stakeholder in setting the goals of a project concerning building energy renovation. In various interviews, the success of a project was associated with the client's satisfaction as the only measure (e.g., not mentioning energy savings). Their decision-making is impacted by various interests, drivers and motivations covering market and financial, policy and regulatory, building and technology-related factors, attitudes and values (O'Connor, P, MacSweeney, R., Dunphy, 2017).

On the other hand, in the case of the energy-efficient renovation in the residential sector based on empirical findings from five EU countries (Germany, Switzerland, Italy, Spain, France) following findings are abstracted:

- Stakeholders involved in the energy-efficient refurbishment projects are not mainly and exclusively motivated by energy savings;
- There is a shortage of skilled labourers to meet the requirements of energy-efficient retrofitting;
- Public support schemes for retrofitting measures are essential;
- Local project integration is crucial (Beillan et al., 2011).

Based on the data on the abovementioned EU countries, insulation is the least common type of energy-efficiency intervention, while changing windows is the most common. Moreover, the blocks of flats that are in co-ownership have been recognized as the most challenging type in the residential sector for energy-efficient retrofit. Additionally, the motivations related directly to the energy issues varied between owner-residents of the detached houses, landlords of collective housing units or co-owners. Energy savings, better comfort and living quality, were recognized as the primary motivations for adopting energy-efficient measures for the owners of detached houses. On the other hand, most of the owners of units in collective housing aimed at raising the properties' value based on improving energy efficiency. Two additional considerations that promoted the incorporation of an ambitious energy component into renovation projects were the possibility of tighter regulations and owners' concerns for environmental protection. However, the owners' access to information frequently influenced their choice significantly, either from professionals, local advisory bodies, or their professional or personal network (Beillan et al., 2011). It seems that regulation and policy, as well as socio-cultural values and attitudes (either personal or corporate), have the ability to influence the market regarding the application of (new) EETs.

8 Strategy for engagement

Compared with stakeholder analysis, stakeholder engagement is concerned with communication, involvement and development with stakeholders, while stakeholder management is covering both stakeholder analysis and engagement (Yang et al., 2011). Zedan and Miller identified four points through which stakeholder management could lead to better implementation and development of the energy-efficient housing:

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1. Managing the complex construction industry's short-term goals, contrasting priorities and late participation of players;
2. Assisting regulators in creating rules that are based on a better comprehension of the responsibilities, interests, aims and time of involvement of the stakeholders and balancing their objectives depending on their level of impact on energy efficiency;
3. Developing strategies to encourage the stakeholders with a higher power to be more interested and/or stakeholders with high interest to be more influential;
4. Quantifying and comparing the stakeholders' impacts on decisions to include innovative sustainable technologies into housing (Zedan & Miller, 2018).

In the construction projects there are three possible approaches to stakeholder engagement:

1. Management technique-identifying which claims/persons/groups/organizations are significant for the company and to whom the management has to pay attention;
2. Ethical requirement- values participations as a democratic process and views stakeholders as citizens with the right to determine (or at least influence) the services;
3. Forum for dialogue to facilitate mutual social learning- social procedure that includes reflection and mutual learning (Mathur et al., 2008).

Although in the renovation and/or construction project the initiator's (e.g., owner) needs are the milestone for delivery of the project, there are many other stakeholders which are a part of the building life cycle. The conventional stakeholder engagement leaning solely on information sharing can result in dissatisfaction and negatively influence the project's budget and schedule. Engaging stakeholders in collaborative manner considering their needs and drivers and involving them in the decision-making process can lead to innovative solutions and mutually advantageous results. As a part of the BIO4EEB project the stakeholder centric approach is adopted, where stakeholders' needs and requirements are put at the centre from the start to an end (i.e. not as a parallel supporting activity). The objective of the stakeholder engagement of the BIO4EEB project is:

- Communication (i.e., information exchange regarding the developed bio-based solutions);
- Dissemination (i.e., spreading the bio-based solutions to the target audience using predetermined channels and strategies);
- Exploitation (i.e., enabling application of the developed bio-based solutions on a large scale).

While communication could be part of most of the stages of 11—stage BIO4EEB model (Table 7), dissemination would be mostly applicable after completion of the manufacturing process. On the other hand, exploitation is viable for the later stages (e.g., from deployment and installation).

8.1 Assessing the stakeholder engagement

It has been recognized that there is no stand-alone method, and the most helpful approach is to define the set of stakeholder engagement methods. Moreover, levels of engagement have

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been identified as useful tools to be matched with a specific method for more effective stakeholder participation. The levels of stakeholder engagement can be defined as following:

1. Inform- giving balanced and objective information to stakeholder in order to aid comprehension of the problems, alternatives, and/or solutions;
2. Consult- obtaining stakeholder feedback on analysis, alternatives and/or decision;
3. Involve- interacting with the stakeholders to ensure that their issues and concerns are acknowledged and considered;
4. Collaborate- incorporating the stakeholders in all aspects of decision-making process;
5. Empower- putting final decision-making in the hands of the stakeholder (IAP2, n.d.).

Based on findings from an empirical study in Hong Kong and Australia as well as some previous studies explained in detail in a paper by Yang et al., the comprehensive set of stakeholder engagement strategies was identified (Table 12). However, there does not exist single, most effective method. Selecting the specific methods depends on the specific situation, project and stakeholders involved. Hence, there is usually a combination of methods that are applied throughout the specific project. Each of the methods has its strengths and considerations which are not presented here but are detailly described in the above-mentioned study. (Yang et al., 2011). Based on the three objective of the stakeholder engagement for the BIO4EEB project introduced in the previous section (i.e. communication, dissemination and exploitation) set of engagement strategies for each objective was identified (Figure 59) taking into account the approaches introduced in Table 12. More detailed specifications of the chosen stakeholder engagement strategies will be introduced in the next section (8.2).

Table 12 Typology of approaches for stakeholder engagement (Yang et al., 2011)

	Inform	Consult	Involve	Collaborate	Empower
Construction advice letters	x				
Darzin (software)	x				
Displays and exhibits	x	x			
Door knocks	x	x			
Email/mail/fax/phone	x	x	x	x	x
Feedback bulletins	x				
Focus groups		x			
Forums		x	x	x	
Information hotline	x	x			
Interviews		x			
Listening post		x			
Media management	x				
Meetings	x	x	x	x	
Negotiations		x	x	x	
Newsletters/ Postcard series/ Fact sheets	x				
Open house/ day	x	x	x	x	
Professional services		x	x		

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Questionnaires and surveys	x	x			
Social contacts	x	x	x		
Social Network Analysis			x		
Walking/ site tour	x	x			
Website	x	x	x	x	
Workshops		x	x	x	x

Communication	Dissemination	Exploitation
• Feedback bulletins • Focus groups • Interviews	• Networking dinner • Presentations • Website and social media • Workshops	• Building product letters • Open days • Digital BIO4EEB platform

Figure 59 Set of stakeholder engagement strategies adopted for BIO4EEB project

8.2 Developed strategy

The BIO4EEB stakeholder engagement strategy is based on a set of engagement activities introduced below based on the methodology developed in 8.1. Although in Figure 59 the list of engagement strategies was presented, more detailed introduction of specific strategies will be introduced in this section.

8.2.1 Building product letters

Level of engagement: inform

Building product letters is an effective strategy to inform stakeholders regarding the bio-based solutions developed. They would cover the technical, economic and environmental features of the product. Highlighting the benefits of the developed bio-based solutions compared to conventional products on the market would be one of the key objectives.

8.2.2 Digital BIO4EEB platform

Level of engagement: inform, consult, involve, collaborate, empower

Digital BIO4EEB platform would enable stakeholders to connect with the developed bio-based solutions in an interactive and easily accessible way. It will be an open-source platform where bio-based materials will be featured and sold, enabling interaction with the manufacturers by end-users.

8.2.3 Feedback bulletins

Level of engagement: inform

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Feedback bulletins keep the stakeholders informed by providing updates. They might be in the form of periodic bulletins or newsletter. The main aim is to inform the relevant stakeholders about the activities, progress and achievements of the project.

8.2.4 Focus groups

Level of engagement: consult

Focus group is based on gathering a diverse group of stakeholders for obtaining their insights and knowledge. The discussion can be either guided or open. One of the essential points is to create a group which would be representative of all the relevant stakeholders. It can be a helpful tool for assessing qualitative data which can assist in decision-making processes.

8.2.5 Interviews

Level of engagement: consult

Interviews can be based on one-on-one or small group discussions with relevant stakeholders in the form of either structured or semi-structured questions. It can be a helpful tool in establishing connections with the stakeholders through conversation. It would be structured in a way to assess the stakeholders' needs and drivers for wider adoption of developed bio-based products.

8.2.6 Networking dinner

Level of engagement: inform, consult, involve

Networking dinner can be used as a strategy to establish a meeting platform where stakeholders are able to create a cooperative setting (i.e. combination of a social gathering and professional networking). It provides a safe environment for stakeholders with the possibility of information exchange and partnership building. It can be also a helpful tool in facilitating collaboration among stakeholders through identifying the shared needs and drivers.

8.2.7 Open days

Level of engagement: inform, consult, involve, collaborate

Open days can serve as events where the stakeholders will be able to visit real demo sites. It is a helpful tool for building transparency regarding the developed solutions and their possible applications. They would contribute to educating the stakeholders about bio-based solutions and raising awareness about the benefits of their wider adoption. It can be also used as a platform for gathering feedback and getting to know stakeholders' perspectives.

8.2.8 Presentations

Level of engagement: inform, consult

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Presentations can lead to effective communication and distribution of project results to the stakeholders. It can provide benefits through information sharing, audience participation and discussion among the participants. The inclusion of Q&A sessions and discussion time can contribute to interactive environment. An effective presentation can lead to wider interest in developed bio-based solutions.

8.2.9 Website and social media

Level of engagement: inform, consult, involve, collaborate

Website and social media are a helpful tool as information access points and have an advantage due the possibility to be re-visited. They should be updated regularly regarding the content and usability. They would be used as platforms for regular updates being an essential focal point for those who want to know more about the project and bio-based solutions.

8.2.10 Workshops

Level of engagement: consult, involve, collaborate, empower

Workshops provide opportunities to stakeholders for engagement in a collaborative and dynamic environment while maximizing feedback from them. They enable active participation, collaboration and contribution of various stakeholders taking into consideration their diverse perspectives and knowledge. They can also be used for addressing specific concerns, issues and challenges leading to cooperative decision-making.

The identified stakeholder engagement strategies should be detailly planned regarding the phases of the project when they will be executed as well as the relevant stakeholders which would be engaged in the specific activity. This would be determined upon consultation among the project partners.

9 Limitations

This study, while comprehensive in its scope, is not without its limitations. One of the primary constraints we encountered was the lack of time to implement questionnaires in the demo countries, including France, Spain, Germany, Lithuania and Czech Republic, and virtual demo countries like Italy, and Belgium. As a result, our data collection was limited to Hungary, which may not fully represent the diverse behavioural and environmental contexts across the European Union.

Similarly, at current stage the lack of sufficient data on Lithuania, particularly in relation to socio-economic characteristics, posed another limitation. This absence of data restricts our ability to provide a comprehensive analysis and understanding of the potential audience for new bio-based solutions in this country.

It is important to note that these limitations do not undermine the value of our research but rather highlight areas for future investigation. We recognize these gaps in our study and have plans to address them in the future. This includes the implementation of questionnaires in the aforementioned countries.

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Our intention is to update this deliverable later this year, as results from the questionnaires from demo and virtual demo countries becomes available. It is believed that this approach will allow us to further refine any analyse the EU context and gather a more accurate picture on both user behaviour connected to space heating and target audience for new bio-based solutions.

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Annexes

Annex 1

User archetype depicting user behaviour based on data from a complete representative survey in Hungary.

Country:	**Hungary**		
Building type :	**General**		
Occupancy	Weekdays	Number of people	Percentage
	early mornings (6:00-8:00)	1.99	76
	mornings (8:00-12:00)	1.28	49
	lunchtime (12:00-14:00)	1.29	49
	afternoons (14:00-17:00)	1.81	69
	late afternoon (17:00-19:00)	2.24	85
	evening (19:00-22:00)	2.37	90
	later at night (22:00-06:00)	2.36	91
	Weekends	Number of people	Percentage
	early mornings (6:00-8:00)	2.42	93
	mornings (8:00-12:00)	2.31	88
	afternoon (12:00-19:00)	2.31	88
	evening(19:00-22:00)	2.41	92
	night (22:00-6:00)	2.46	94
Light switch schedule	According to national standards		
Shading schedule	According to national standards		
Window use schedule			
	Prefering partial window airing	40%	
	Prefering full window airing	79%	
Equipment plug-load schedules	According to national standards		
Thermostat adjustment behaviour			
	Percentage of people using fixed setpoints	15%	
	Percentage of people using changing setpoints	10%	
	Percentage of people manually adjusting temperature	16%	
	Percentage of people not being able to adjust temperature	2.50%	
	Average temperature in heated rooms during winter	22°C	
	Average temperature in not heated rooms during winter	20°C	

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Annex 2

User archetype depicting user behaviour based on data for single family houses from a representative survey in Hungary.

Country:	**Hungary**		
Building type :	**Single family house**		
Occupancy	Weekdays	Number of people	%
	early mornings (6:00-8:00)	2.13	75
	mornings (8:00-12:00)	1.36	48
	lunchtime (12:00-14:00)	1.41	50
	afternoons (14:00-17:00)	1.96	69
	late afternoon (17:00-19:00)	2.43	86
	evening (19:00-22:00)	2.57	91
	later at night (22:00-06:00)	2.6	92
	Weekends	Number of people	%
	early mornings (6:00-8:00)	2.64	93
	mornings (8:00-12:00)	2.53	90
	afternoon (12:00-19:00)	2.54	90
	evening(19:00-22:00)	2.62	93
	night (22:00-6:00)	2.68	95
Light switch schedule	According to national standards		
Shading schedule	According to national standards		
Window use schedule			
	Prefering partial window airing	61%	
	Prefering full window airing	81%	
Equipment plug-load schedules	According to national standards		
Thermostat adjustment behaviour			
	Percentage of people using fixed setpoints	20%	
	Percentage of people using changing setpoints	13%	
	Percentage of people manually adjusting temperature	20%	
	Percentage of people not being able to adjust temperature	2.50%	
	Average temperature in heated rooms during winter	21.4°C	
	Average temperature in not heated rooms during winter	19.6°C	

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