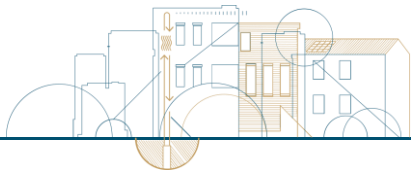
REHOUSE

D1.5

Social Life Cycle Assessment Plan (S-LCA) for the 4 local contexts.

Co-funded by the European Union

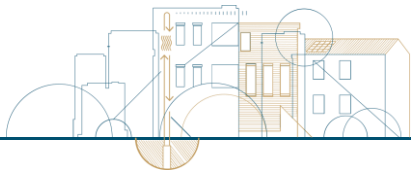
DUE DATE OF DELIVERABLE: M12
ACTUAL SUBMISSION DATE: 29.09.2023



Project Acronym	REHOUSE
Project Title	Renovation packagEs for HOlistic improvement of EU's bUildingS Efficiency, maximizing RES generation and cost-effectiveness
Project Duration	1 October 2022 – 30 September 2026 (48 months)
GA Number	101079951

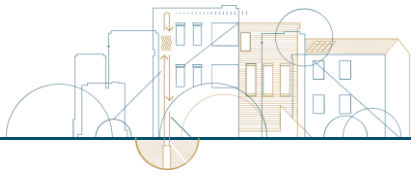
Work Package	WP1- Social Innovation for People centric Renovation Processes
Associated Task	Task 1.4: Definition of a Social Life Cycle Assessment plan for each demo.
Deliverable Lead Partner	CERTH
Contributors	CAR, DUTH, ENEA, ARCA, RINA-C, CEA, FCHURCH, STEINBEIS, TWR
Main Author (s)	Ioannis Lampropoulos (CERTH)
Other author(s)	P.Botsaris (DUTh), P.Dimitriadou (DUTh), Christine Leroy (RINA-C), Isabelle Dubreuilh (STEINBEIS), Vipul Sarnot (STEINBEIS), Javier Antolin (CAR), Julia Vicente (CAR), Fabrice Claudon (CEA), CERTH (Petros Iliadis, Eleni Chatzigeorgiou, Georgios Martinopoulos, Nikolas Tagkoulis, Angeliki Kitsopoulou)
Reviewer(s)	Silvio Viglia (ENEA), Isabelle Dubreuilh (STEINBEIS),
Dissemination Level	Public (PU)
Type	Report
Version	07
Status	Final version

This Project is co-funded by the European Union under the EU Programme Horizon-CL5-2021-D4-02-02 under Grant Agreement Number: 101079951. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the CINEA can be held responsible for them.



DOCUMENT HISTORY

VERSION	DATE	DESCRIPTION	AUTHOR(S)
V0.1	2023/07/18	Table of Contents	CERTH
V0.2	2023/08/11	1st Draft	CERTH
V0.3	During July/ August	Contributions from T1.4 partners	STEINBEIS, DUTH, RINA-C, CEA, CAR
V0.4	2023/09/04	Inputs and feedback for the questionnaire finalization	CAR, ARCA, ENEA, CEA
V0.5	2023/09/14	Inputs from demo leaders	DUTH, FCHURCH, TWR, CEA, ARCA, ENEA
V0.6	2023/09/20	Final draft	CERTH
V0.7	2023/09/29	Final version for submission	CERTH



EXECUTIVE SUMMARY

The present document is Deliverable D1.5 "*Social Life Cycle Assessment Plan (S-LCA) for the 4 local contexts*", developed within WP1 in the framework of the Horizon Europe project REHOUSE. WP1 deals with the "Social innovation for people-centric renovation processes" and contains five deliverables. D1.5 displays the methodology of the s-LCA that will be followed in order to investigate the social perspective of the innovative RPs (Renovation Packages) and conventional interventions implemented to the project's four demo sites. More specifically, the social aspect assessment of the renovation action will look into the potential positive or negative social impacts of the implemented solutions on different stakeholder groups during the pilots' entire life cycle. The main goal of the deliverable is to present the method developed in WP1 (T1.4) to assess and evaluate the social and socio-economic impacts associated with the renovation process and the continued use of the building.

This deliverable has been developed by CERTH (Task 1.4 leader) in collaboration with the partners that are involved in this task and includes all the activities concerning the preparation of all the necessary actions with the aim of examining the social impact of the proposed innovative renovation packages and conventional activities considering the construction and operational stages of the life cycle. In order for the foreseen work to be implemented, a 4-stage methodology is followed. The activities performed within this report consist of the implementation of the proposed 4-stage methodology, which includes setting the goal and scope of the s-LCA, building a social life cycle inventory through a two -step accroach encompasses literature review and UNEP Guidelines for s-LCA with focus on the identification of the stakeholder categories, relevant social topics and indicators, preparing for the life cycle impact assessment with a specific framework implemented, and guidelines for the analysis and interpretation of the LCA outcomes for the retrofitting processes and renovation packages, as well as the development of dedicated questionnaires to collect the necessary data in order to support the implementation of the s-LCA. The implementation of a s-LCA for retrofitting processes is important as it takes into account existing, and often overlooked, social needs, and can highlight problematic areas allowing for their examination and potential optimization in future renovation scenarios.

This document is structured into 4 main chapters, Chapter 1 provides the Introduction, and Chapter 2 presents through a literature review the current situation of the global and European social aspects of house renovation. Chapter 3 focuses on the definition of the s-LCA methodology with a detailed description of each of the different stages in order to assess the social aspects of the four REHOUSE renovated demo sites. Also, the development of the specific questionnaires and the way that will be distributed by the demo leaders are included. In Chapter 4 the conclusion and a recapitulation of the work that took place in the deliverable are presented.

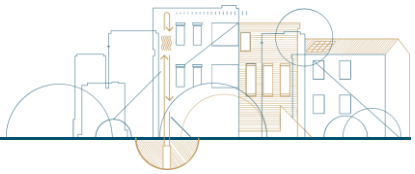


TABLE OF CONTENT

1 INTRODUCTION 1
1.1 PURPOSE AND SCOPE OF THE DOCUMENT 2
1.2 CONTRIBUTIONS OF PARTNERS 2
1.3 RELATION TO OTHER ACTIVITIES IN THE PROJECT 3
2 LITERATURE REVIEW 4
3 S-LCA METHODOLOGY 8
3.1 DEMO SITES 9
3.2 STAGE 1: GOAL AND SCOPE OF S-LCA 13
3.3 STAGE 2: SOCIAL- LIFE CYCLE INVENTORY (S-LCI) 14
3.3.1 FINAL REHOUSE KEY STAKEHOLDERS' CATEGORIES 22
3.3.2 FINAL REHOUSE SOCIAL TOPICS 23
3.3.3 FINAL REHOUSE INDICATORS 24
3.4 STAGE 3: SOCIAL LIFE CYCLE IMPACT ASSESSMENT (S-LCIA) 25
3.4.1 QUESTIONNAIRE'S DEVELOPMENT 25
3.4.1.1 QUESTIONNAIRE DISTRIBUTION IN THE DEMO-SITES 26
3.4.2 IMPACT ASSESSMENT METHODS AND SUGGESTED FRAMEWORK 27
3.5 STAGE 4: INTERPRETATION 31
4 CONCLUSION 32
5 REFERENCES 33
ANNEX I: QUESTIONNAIRE - PART A: GENERAL PERSONAL INFO 36
ANNEX II: QUESTIONNAIRE - PART B: SOCIAL ASSESSMENT QUESTIONNAIRE FOR EACH STAKEHOLDER CATEGORY 38

LIST OF TABLES

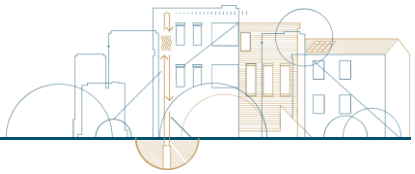
Table 1 Presentation of Task 1.4 actions and partners 'contribution *2*
Table 2. Proposed stakeholder categories and social issues according to UNEP 2020 (UNEP, 2021) *15*
Table 3. Literature review with focus on stakeholder, social topics and indicator selection. *16*
Table 4. Indicators for social issues related to users/inhabitants. *24*
Table 5. Indicators for social issues related to workers. *24*
Table 6. Indicators for social issues related to Local community and Neighbors. *25*

LIST OF FIGURES

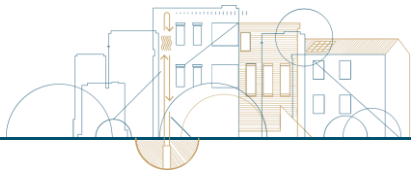
Figure 1: Inability to keep home adequately warm (% per year) *5*
Figure 2: Total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor (% per year). *5*
Figure 3 The flowchart of the four stages of the S-LCA (UNEP, 2020) *9*
Figure 4. Process of the Reference Scale Assessment (adapted from UNEP 2020) *28*

LIST OF ABBREVATIONS

ACRONYM	DESCRIPTION
ADBE	Adaptable/Dynamic Building Envelope
AHP	Analytic Hierarchy Process
BAL	Budget Allocation
BIPV	Building-Integrated Photovoltaic
BMS	Building Management System
CA	Conjoint Analysis
D	Deliverable
DHW	Domestic Hot Water
EC	European Commission
EU	European Union
FA	Factor Analysis
FCU	Fan Coil Unit
GHG	Greenhouse Gas
GWP	Global Warming Potential
HP	Horsepower
ICT	Information and Communications Technology



ACRONYM	DESCRIPTION
IP s-LCIA	Impact Pathway Assessment
ISO	International Organization for Standardization
IWS	Intelligent Window System
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
ML	Machine Learning
MPC	Model Predictive Control
n-ZEB	nearly Zero Energy Building
PCA	Principal Component Analysis
PCM	Phase Change Materials
PLC	Programmable Logic Controller
PRP	Performance Reference Point
PV	Photovoltaic
RP	Renovation Package
RS s-LCIA	Reference Scale social Life Cycle Impact Assessment
s-LCA	social Life Cycle Assessment
TES	Thermal Energy Storage
TSaF	Thermal Sound-absorbing Facade
UNEP	United Nations Environment Program
WP	Work Package
WT	Work Task

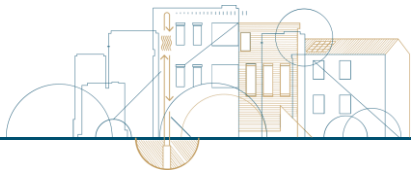


1 INTRODUCTION

Buildings accounted for 35% of EU emissions connected to energy in 2020, making them a significant contribution to greenhouse gas (GHG) emissions (EEA, 2023). These emissions are a result of both the production of electricity and heat for use in buildings (e.g., electrical appliances), as well as the direct use of fossil fuels in buildings (e.g., gas used in boilers). To address and mitigate these issues successfully, a life cycle assessment (LCA) investigating the implemented practices concerning energy use, and their impacts, throughout the entire life of a building, including the construction, operation, renovation and demolition phase, is imperative. According to the Energy Environment Agency (EEA), LCA is the process of evaluating the effect that certain products or processes have on the environment. In the case of the built environment, an LCA can be performed on a building, a building component or a building process, and evaluate its environmental, economic or social impact (Mälkki & Alanne, 2017).

Additionally, to the environmental impact of the building stock, building construction/renovation and operation has effects on the people involved in these processes, whether they be workers, owners or inhabitants. A defining factor affecting people's wellbeing within the built environment is energy poverty. Energy poverty describes "the inability to realise essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services" (Day et al., 2016). This issue has a significant impact on people's physical (e.g., respiratory and circulatory problems), as well as mental health, and its roots are found in social inequalities, high energy prices and energy insufficient housing (Powerpoor, 2021). To address energy poverty, as well as other building related issues, such as poor working conditions on construction sites, and enhance social equity in terms of energy availability and appropriate housing, the implementation of a s-LCA could be particularly effective. S-LCA is suitable for examining the social impact of the existing building stock and evaluate the effect of the selected actions and tools for its optimisation. Through the evaluation process it can also assist in lessening the identified effects by proposing mitigation actions on the most prominent issues discovered. More specifically, s-LCA can assist in recognizing ways to achieve energy savings, lowering energy expenditures and GHG emissions, taking into account the citizens wellbeing in the process. The purpose of this document is to define a plan on how to measure the social perspective during the whole Life Cycle of the demo buildings, in addition to understand which are the social challenges in the framework of the renovation packages (RPs) and how the technological aspects are beneficial or not, to the buildings' owners, users and the local community. Building retrofitting is usually expensive, involves both noisy and time-consuming construction actions. However, the renovation decreases energy use contributing to environmental impacts' reduction (Hasik et al, 2019) and can benefit the building user by addressing energy poverty and ensuring adequate levels of comfort, health and happiness during the operation phase of the building, as well as minimise disruption during the renovation phase.

In the framework of the ReHOUSE project eight RPs are going to be developed. These packages provide innovative technological solutions that are simultaneously financially affordable and sustainable. These solutions are based on circular economy principles, with respect to building aesthetics, to cultural and historic building conservation including prefabrication and off-site component construction. The RPs together with other several conventional interventions will be implemented at four demo sites located in Greece, Italy, France, and Hungary. This will involve thorough designs, pilot setup, and demonstrations in order to validate the solutions. The conclusions drawn from the s-LCA analysis regarding the social and environmental impact of the implemented solutions, combined with the scalability and replicability actions of the renovation packages will ensure that the goals of the ReHOUSE project will be reached.



1.1 PURPOSE AND SCOPE OF THE DOCUMENT

The aim of this deliverable is to develop s-LCA plans for the four demos which will be renovated. The ultimate goal is to investigate and assess the social acceptance of all the interventions that will take place in the selected demo-sites, by performing a s-LCA for each building as a whole. To assess the social aspects of the renovated buildings and investigate their social impacts (negative or positive) on the various stakeholder groups involved throughout the life cycle of the building, a s-LCA plan is developed, taking into account the detailed design, construction and operation stages. The s-LCA plan comes as an addition to the evaluation program defined in WP3. In this deliverable, inhabitants, tenants as well as owners, and the local community are among the main target groups of social engagement.

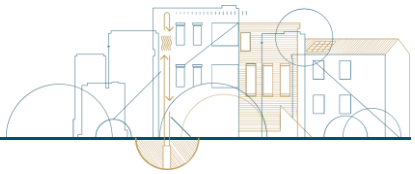
The scope of the document is the presentation of the s-LCA methodology, the definition of the s-LCA plan for each demo site and how this can be applied in the case of different renovation solutions at public and private residential buildings. A preliminary way of evaluation of the different renovation activities aligned with their social impacts is going to be demonstrated with a focus on improving users' comfort, acceptance of the renovation actions and buildings' energy efficiency. The approach for conducting the s-LCA was achieved through the development of specific questionnaires for each demo site using a scale-based approach. The stakeholders target groups, the social topics and the indicators were defined in this process.

1.2 CONTRIBUTIONS OF PARTNERS

The contribution of the partners to task 1.4 and deliverable 1.5 is shown in table 1.

Table 1 Presentation of Task 1.4 actions and partners 'contribution

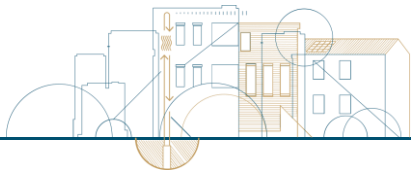
PARTICIPANT SHORT NAME	CONTRIBUTIONS
CERTH	Task Leader, deliverable leader, literature screening of global social aspects and s-LCA case studies on house renovation, define the s-LCA methodology, define the initial key stakeholders' categories, the social topics the indicators and the impact assessment methods, preparation of questionnaires
CAR	Support on defining the social topics, indicators, and the creation of the final questionnaires
DUTH	Support on defining the stakeholder categories, social topics, indicators, and the creation of the final questionnaires. Information on how the questionnaires will be shared and filled in the Greek Demo.
ENEA	Support on defining the stakeholder categories, social topics, indicators, and the creation of the final questionnaires
ARCA	Support on defining the stakeholder categories, social topics, indicators, and the creation of the final questionnaires
RINA-C	Literature screening of global social aspects and s-LCA case studies on house renovation, define the s-LCA methodology
CEA	Support on defining the stakeholder categories, social topics, indicators, and the creation of the final questionnaires. Information on how the



PARTICIPANT SHORT NAME	CONTRIBUTIONS
	questionnaires will be shared and filled in the French Demo.
TWR	Support on defining the stakeholder categories, social topics, indicators. Information on how the questionnaires will be shared and filled in the Hungarian Demo.
WOODS	Information on how the questionnaires will be shared and filled in the Hungarian Demo.
PLATAN	Information on how the questionnaires will be shared and filled in the Hungarian Demo.
FCHURCH	Information on how the questionnaires will be shared and filled in the Hungarian Demo.
STEINBEIS	Support on defining the stakeholder categories, social topics, indicators, and the creation of the final questionnaires. Literature screening of global social aspects and s-LCA case studies on house renovation, define the s-LCA methodology

1.3 RELATION TO OTHER ACTIVITIES IN THE PROJECT

ACTIVITY (DELIVERABLE NUMBER)	DESCRIPTION
T3.4 and D3.4	The s -LCA plan (D1.5) will be complementing D3.4 for the complete monitoring plan definition.
T4.3 and D4.6	The s -LCA plan (D1.5) will be considered during the development of T4.3 through the deployment of the social innovation activities in the demo-sites.
T4.4 and D4.7	The s -LCA plan (D1.5) will be considered during the development of T4.4 through the following up and supervision of the disturbance in the demo-sites in the construction process.
T4.5 and D4.8	The data acquisition from the questionnaires developed within this deliverable will be take place during the monitoring of the building performance in T4.5.
T4.6 and D4.9	The s-LCA methodology will be applied, and the results will be evaluated in T4.6.



2 LITERATURE REVIEW

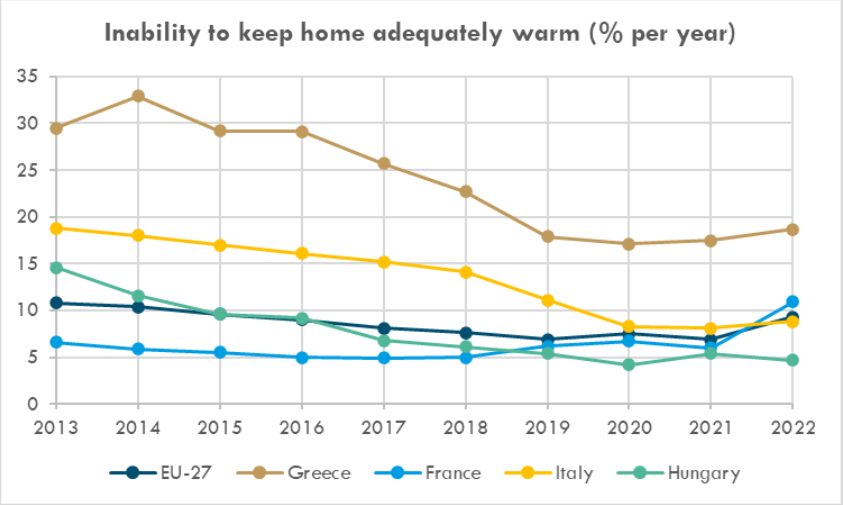
A literature review was conducted to record the current situation of the global and European social aspects of house renovation. The scope of this literature review is to present the domain of building renovation within the European context and the reasons of necessity arising from the building renovation taking into consideration the environmental and social point of view. Additionally, the policy concerns that arise throughout a renovation process and the factors that should be taken into account while planning renovation operations are highlighted. Community engagement is essential to the renovation acceptance through the community consultations and education sessions held during the planning stages of the retrofits in order to enlighten occupants who may be hesitant to undertake retrofits.

There is a huge need for retrofit in EU, as most buildings are not energy efficient. Meijer et al, 2009 discovered that in many European countries the building stock increased at a rapid pace during the period 1950–1975 and Majcen et al, 2015 found that a significant portion of European buildings constructed between 1960 and 1970 lack proper thermal insulation for both opaque and transparent building elements. These buildings, also exhibit subpar indoor environmental quality, inadequate seismic and structural safety performance, and low efficiency in integrating renewable energy systems. According to Mangold et al, 2016 in several European nations, the building stock from that era requires renovation. This presents a chance to incorporate energy efficiency measures during the renovation process, while also considering social aspects. House renovation is not merely a technical endeavour; it is influenced by various social and cultural factors that shape the choices, motivations, and outcomes of such projects.

It is worth mentioning that the EU needs to tackle simultaneously two issues: achieve climate goal and eliminate energy poverty, that are defined by two aspects, the environmental and the social. Measures to mitigate climate change need to be inclusive, socially-just and produce benefits for households with the lowest incomes so they can access clean, affordable heating and live in energy efficient homes (IEECP, 2022). According to IEECP, the EU's building sector is responsible for 36% of the EU's energy related GHG emissions and 40% of its energy consumption (IEECP, 2022). To meet its climate goals, the EU will need to cut 60% of the building sector GHG emissions by 2030 and fully decarbonize it by 2050. If well-designed, the EU Renovation Wave can cut low-income households' energy costs by a third, reduce energy waste from badly insulated homes and increase the disposable income of low-income households in the medium to long term. Palacios-Munoz et al. (2019) evaluated impact assessment of retrofitting buildings with low and high energy consumption and a newly constructed one. They concluded that from an environmental aspect the best choice is the retrofitting of buildings with low energy consumption. Furthermore, Hasik et al. (2019) performed a comparison of life cycle assessment of the entire building between retrofitting and newly constructed building. They highlighted a decrease by 53-73% in environmental impact categories in case of retrofitting. On the other hand, Ramírez-Villegas et al. (2019) assessed the environmental impacts of a residential building in Sweden considering four different RPs related to ventilation system, reduction of room temperature and better insulation. Due to one of the RPs the Global Warming Potential (GWP) of energy use was decreased by 42% in comparison with the pre-renovated building. It is worth mentioning that different approaches can achieve a similar overall environmental impact when considering the environmental impact during the life cycle of the various alternatives.

The recent increase in gas prices pushes the most vulnerable persons into energy poverty (this affects more than 34 million European households) (Cornelis, 2023). Energy poverty is evident when energy expenses consume a significant portion of individuals' earnings or when they are compelled to decrease their household's energy usage to an extent that detrimentally affects their

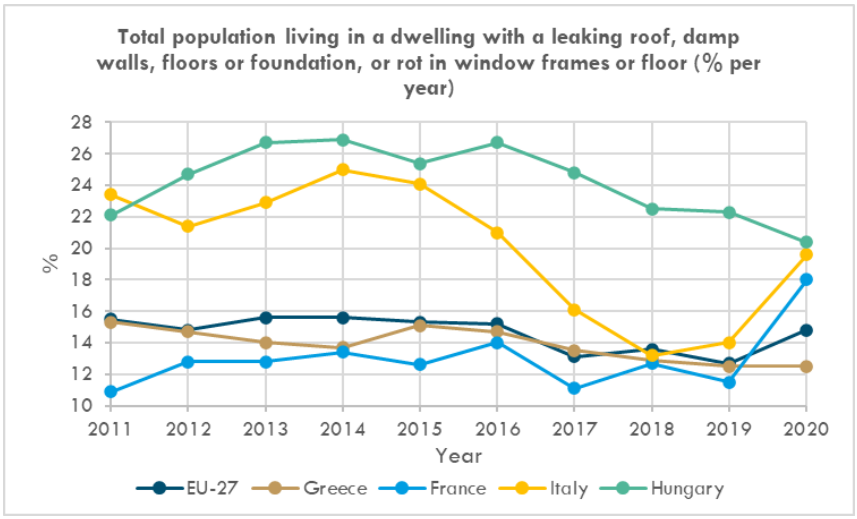
health and overall quality of life (European Commission, 2023). An example of situation of energy poverty is illustrated in Figure 1, with a graph showing the trend in the *Inability to keep home adequately warm* for the four countries hosting demo sites in the REHOUSE project and for EU-27, for the period spanning from 2013 to 2022.



Eurostat (last update of data 11/07/2023), EU-SILC survey [ILC_MDES01_custom_7283455]
EU-27 values are estimated for the period 2013-2019; France value for 2022 is provisional.

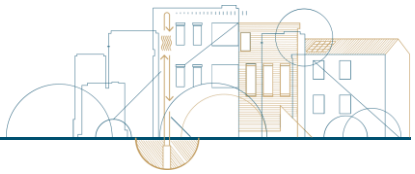
Figure 1: Inability to keep home adequately warm (% per year)

Another critical situation of energy poverty is presented in Figure 2 through a graph representing, for each of the demo site countries and for EU27, the trend of the *percentage of the population living in dwellings with a leaking roof, damp walls, floors or foundations, or rot in windows frames or floor*. This graph shows that part of the population does not live in healthy conditions and how important it is to fight against energy poverty. Jowkar et al. (2022) questionnaire survey in Norway revealed that financial difficulties are the inhibitory factor in building retrofitting and suggested financial support emphasizing the importance of social engagement.



Eurostat (last update of data 09/06/2023), EU-SILC survey [ILC_MDHO01_custom_7283818]. EU-27 values are estimated.

Figure 2: Total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor (% per year).



There are many benefits arising from buildings renovation for the tenants (Artola et al., 2016); such benefits can be:

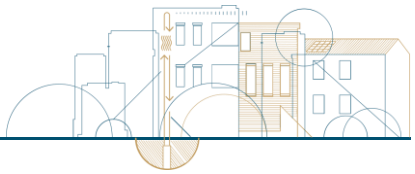
- Health benefits: in particular reduction of symptoms of chronic illness due to humidity, low temperature, etc.
- Reduction of energy poverty.
- Wellbeing/comfort benefits: better temperature, reduction of noise (for example thanks to triple-glazing).
- Energy bill savings.
- Increase in property value and tenant satisfaction.
- Contribution to a positive impact on environment and climate change.

However, multiple challenges and policies all around the world make the renovation process difficult and sometimes ineffective with potential negative social impacts. According to Cornelis, 2022**,** the renovation brings with itself renoviction (defined as “a renovation undertaken by a residential landlord on residential premises, or a building containing residential premises, that will require the tenant to vacate the premises”). In the report, the author studied two cases where the citizens faced negative facets of the renovation wave. In the case of California, a practice called Greenmailing has made it easier for construction unions to delay construction under the justification of environmental protection. Improper utilization of environmental rules has given rise to NIMBYism (Not In My Back Yard), and disproportionately affecting low-income families in a state where the real estate prices have been staggering. This contributes to the rise of homeless people in California as it has half of the homeless people in the United States. Whereas, in Canada policies to address renovictions were proven ineffective. The replacement of the renoviction ban in Canada with a new legal framework emphasizes tenant safeguards. The framework offers two termination options: mutual agreement or a Director's Order from the Residential Tenancies board. If both parties disagree on termination, the landlord can request an order from the Director, specifying a departure date within three to twelve months. The Canadian case illustrates that policies against renoviction may lack efficacy without effective implementation measures.

In Europe, Cornelis (2023) found several policies and programs ineffective, leading to discriminatory and expensive renovation. For instance, Bulgaria, Italy and Germany’s untargeted financial incentives led to inflation. In the case of Croatia and Slovakia the most vulnerable are often excluded due to eligibility criteria and documentation related issues. The absence of tenant protection measures is leading to social exclusion. Cities with elevated real estate demand are leading to displacement of low-income households and housing insecurity.

Therefore, renovation must be prepared to avoid or limit inherent risks. Indeed, the following considerations should be taken into consideration when envisioning renovation activities:

- The renovation process can be perceived as invasive and create unease for people living in the building: noise, dust, impossibility to empty the loft or part of it (lack of place or physical inability to move furniture (Chahal et al, 2012), etc.).
- Installation of new technologies such as smart meters for example, can be difficult to manage for people (lack of comprehension that can be due to a lack of understanding in “technology”, for elderly people for example). A study from Chahal et al. (2012) reported that very often, there is a lack of information and follow-up support from installers. Unfortunately, if people are not able to use the new devices properly, these devices will not perform at their best and expected impacts will not be obtained. In this way, tenants will not see the benefit of the installation such as lower bills or better comfort. This results in a lack of faith in new technologies.

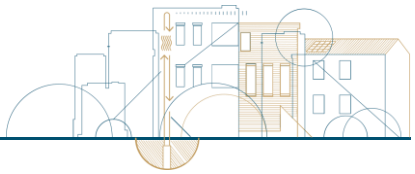


- Adopting new technologies but also changing habits, even knowing the negative impacts of these habits on the environment can be difficult for people (Neal, Wood and Quinn, 2006). A study (GM LCEA, 2011) identified nine barriers to an individual's understanding of the knowledge, causes, impacts and solutions of climate change:
    - Lack of knowledge about where to find information.
    - Lack of desire to seek information.
    - Perceived information overload.
    - Confusion about conflicting information or partial evidence.
    - Perceived lack of locally relevant information.
    - The format of information is not accessible to non-experts.
    - Source of information is not credible or trustworthy, particularly the mass media.
    - Confusion about links between environmental issues and their respective solutions.
    - Information conflicts with values or experience and is therefore ignored.

  Furthermore, D'Oca et al. (2018) mentioned the necessity of deep retrofitting which is at a low rate in EU. They studied the social obstacles in deep retrofitting based on lessons learnt from the H2020 projects (holistic approach at the whole building) which includes "..lack of trust, lack of energy culture, lack of future vision, lack of knowledge on nearly Zero Energy Building..". With a view to overcoming these obstacles and building the trust between building users and decision-makers, some actions suggested to take place such as training sessions, participative tactics, and numerous on-site visits.
- Not all residents can face the costs of renovations: when people have a small amount of money, they sometimes prefer using it for personal activities such as holidays, clothes, education, leisure which will give them more direct and effective benefits and satisfaction. This will depend on their values and priorities. It is important to take into consideration the fact that people believe they personally have limited impact on climate change (Lainé, 2011) and thus do not envision retrofitting their homes. Regarding the cost, it is important to orient people towards possible grants that very often are difficult to find and understand
- Another important barrier concerns persons renting a house: sometimes, the landlord is not interested in performing retrofitting since he will himself not directly benefit from it so the renter will not benefit from a better comfort or bills reduction. Or on the contrary, the landlord will proceed with renovation and reflect the cost of the interventions on the rent leading to an exclusion of low-income tenants. This is part of the "renoviction" phenomena, where retrofits are used by the owner, as a pretext to raise rents and evict tenants and low-income homeowners. Implementing social safeguards is imperative to ensure the Renovation Wave benefits the most disadvantaged and energy-poor (Cornelis M., 2023).
- Some considerations such as aesthetics can hinder the motivation for renovating; as mentioned by Mallaband (2012) some persons for example, do not want PVC windows or double glazing judging them not visually pleasant.

Although some social risks/obstacles are inherent to renovation activities, they can be overcome by engaging in social activities and involvement of householders at early stage.

- Planning retrofit (BUILDHEAT, EU 2020) with the householders to understand their expectations and their habits, how they use their house. Regarding this last point it is important for example to discuss any disability that may encounter the householder and adapt retrofit works to his/her situation. This can also be, for example, the physical impossibility to empty the loft for interventions (Chahal et al, 2012). Sometimes, people are



reluctant to have workers at home; this should also be discussed at the beginning. In some situations, in which the resident could not stay at home during retrofit activities, solutions must be envisioned from the very beginning.

- Explaining the use of the devices so benefits can be fully reached; if householders are satisfied, they can become promoters of retrofitting. As mentioned by Chahal et al. (2012), rumours, myths and misinformation transmitted by unknown and non-specific sources can have serious impacts on the ability of practitioners to introduce new programs in local areas.
- Creating groups of discussion so people can share their experience as proposed by Chahal et al. (2012).
- Informing people not only on how to use devices but also on what it is possible to do: many people do not know what they already have at home and have little knowledge of possible retrofit solutions.

Considering the issues that arise from the building or house renovation it is convenient to assess the positive and the negative social impacts through conducting the s-LCA with ultimate aim to contribute to decision-making processes. The s-LCA is an appropriate tool for this process to prevent social risks/obstacles. Therefore, the s-LCA approach will be conducted in the REHOUSE project.

3 S-LCA METHODOLOGY

Early in the 1990s, attempts were made to incorporate social and socioeconomic factors into the LCA. This led to the development of a technique that addressed the social dimension of sustainability and a range of social challenges like poverty, child labour, income disparity etc., namely social Life Cycle Assessment (Lobsiger-Kägi et al, 2018).

S-LCA methodology focuses on processes that occur during the life cycle of a product/service (UNEP, 2020). It is developed as an addition to life cycle assessment (LCA) and it provides information on social and socioeconomic issues with the aim to improve stakeholders' lives and enlightening policy makers' decisions. S-LCA is mainly based on ISO 14040, and it comprises four stages (Figure 3).

- Stage 1 includes the goal and scope of the assessment. In this stage the aim and parameters of the evaluation are clearly stated. The functional unit, the system boundaries and the social factors that will be evaluated are all defined in this stage.
- Stage 2 includes the determination of the (Social) Life Cycle Inventory (S-LCI). Information is gathered on the social issues at each stage of the life cycle.
- Stage 3 includes the (Social) Life Cycle Impact Assessment (S-LCIA). In this stage, the importance of the social impacts that are indicated at the LCI are considered. Social impacts are categorized according to the stakeholders' groups. The impact categories and subcategories corresponding to socially significant aspects like working conditions, health and safety, human rights, cultural heritage and other more are defined and for each subcategory several performance indicators are taken into consideration.
- Stage 4 includes the Interpretation. Understanding the overall social performance of the product/service requires analysis and interpretation of the impact assessment's findings. This can entail scenarios comparison where interventions or enhancements might be required. Therefore, it is an iterative approach that can be improved under the assessment processes.

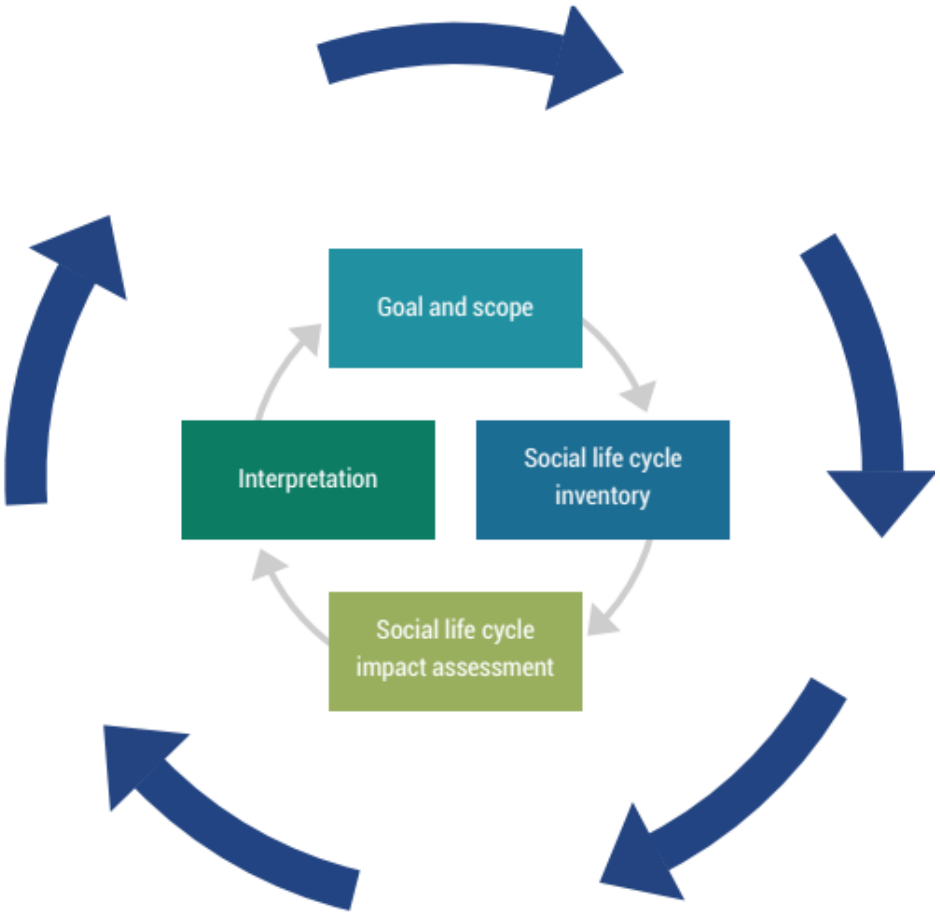


Figure 3 The flowchart of the four stages of the S-LCA (UNEP, 2020)

S-LCA is implemented to assess the potential impacts of a strategy or an investment decision. S-LCA as a decision-making methodology can assist to conduct social risk assessment and enhance social circumstances along the life cycle. S-LCA aims to assist organizations in developing future policies, and also help them detect and assess social risk involving different types of stakeholders and providing non-financial information (UNEP, 2020).

In the REHOUSE project the 4-stage s-LCA methodology will be implemented. In the subsequent chapters, there is a summary of the demo sites following by a descriptive analysis for each stage related to the REHOUSE project, including literature review to gain knowledge of the current status of the s-LCA on building renovation case studies. Additionally, explanations on both the methodological approach and the specific processes that were adopted are presented.

3.1 DEMO SITES

The first step before the implementation of the 4-stage s-LCA methodology is to have an overview of the buildings (four demo sites) that will be retrofitted, and their renovation activities that will take place in the framework of the REHOUSE project. Being aware of the demo sites and their planning renovation activities assists in setting the goals and scope of the S-LCA, identifying the different life cycle stages that the s-LCA will be conducted and allowing to determine the most relevant stakeholders, social aspects and indicators. Therefore, a brief description of each demonstration site and the actions (RPs and conventional actions) that will be performed are presented below.

Additional information regarding the demo sites and the RPs can be found in D3.2 “REHOUSE set of indicators selected for the impact assessment”.

Greek Demo-site

Brief Description

The Greek Demo-site pertains to a student residence facility situated within the campus of Democritus University of Thrace (DUTH), built in 1997. This demonstration site is positioned in the Kimmeria municipality, near the city of Xanthi in the Thrace region. The specific building targeted for the planned interventions is referred to as 'Building C2,' constituting only a portion of the entire campus.

Demonstration Actions

- **Renovation Packages:**
  - RP1- Multi-Source Heat Pump

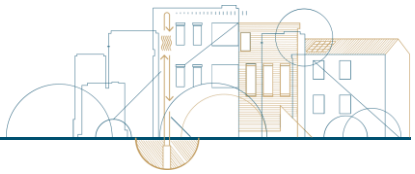
    An innovative 100 kW multi-source heat pump aims for high efficiency in heating renovated buildings. It targets a nominal COP of 4.5 for design conditions and a seasonal heating energy efficiency of at least 185%. Using R454C as a working medium, it can reach a COP of up to 6 for low-temperature heating. The heat pump can source heat from geothermal, ambient air, or other low-temperature sources. The system features energy management with optimization algorithms, allowing demand response and smart appliance utilization. Optimization goals include minimizing self-consumption, cost, or CO_2 emissions. Two optimization schemes (high-level and low-level) consider factors like when to charge space heating or use heat sources (air, ground, solar) on the evaporator side, based on the current system state and future requirements.

  - RP2- Adaptable/Dynamic Building Envelope (ADBE)

    ADBE is a building system for both residential and non-residential structures. Unlike traditional prefab methods, it creates individual elements like support structures, insulation, and ventilation units on-site, attaching them to the existing façade. The system extends the building envelope with a cost-effective aluminium-glass façade, allowing renovations without disrupting building operations. It also accommodates solar collectors and batteries, adjusting their placement based on building needs.

  - RP3- SmartWall

    The SmartWall is a highly adaptable prefabricated facade system suitable for both external and internal masonry, saving time and costs during installation. It offers over 120 material and component combinations, including eco-friendly options, to cater to specific building and owner requirements. This system works seamlessly with various heating, cooling, and ventilation technologies, as well as Domestic Hot Water (DHW) systems, solar panels, and photovoltaics. It can even integrate renewable energy sources for energy independence. The SmartWall monitors and controls Indoor Air Quality (IAQ) and energy consumption through the AMscope. Fire protection features can be included, and the system accommodates different window types, like energy-efficient thin-section frames with integrated shading blinds. The cladding is coated with thermal paste and multi-functional coatings from



AMS, providing benefits such as infrared reflectance, anti-mould properties, self-cleaning, and self-healing capabilities.

- **Other Interventions:** According to GA, the below-mentioned interventions will be part of the global renovation strategy within the DUTH campus (own investment plans amounting).

  i) Add thermal insulation to the building's envelope and replacement of many m^2 window frames and glazing, with new aluminium frames with thermal break and low-emissivity double-glazing, ii) replacement of old terminal units with FCU in rooms in 'Building C2', iii) refurbishment of existing piping network and pumps of building's heating system, iv) installation of PLC controller (expansion of existing BMS system), as well as other interventions such as firefighting systems, plumbing facilities, lighting, etc.

Italian Demo-site

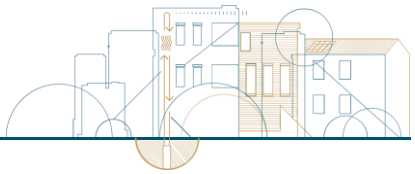
Brief Description

The Italian demo-site is located in a marginal area of Margherita di Savoia, an Adriatic coastal municipality in the Apulia region (Italy). The specific demo building is part of a cluster of similar ones, all characterized by problems of physical degradation and social vulnerability. The demo building has a rectangular footprint with four floors and eight apartments and is built in reinforced concrete frame with poor insulation. It is part of a larger social housing stock with similar buildings.

Demonstration Actions

- **Renovation Packages:**
  - RP4- Centralized Holistic Heating and Cooling Renovation Kit

    This RP consists of an holistic renovation kit for centralized heating and cooling supplying facilities. It is designed around a commercial reversible air-to-water heat pump fed by onsite building integrated PV (SUNAGE) and connected to a stratified bio-based PCM Thermal Energy Storage (TES) system (StT). In addition, these components are governed by a dedicated smart control system (StT + RINA) leveraging the use of smart rubber technology (K-FLEX) into the distribution pipes and integrated into an overall BIM-oriented platform (TERA). The reversible HP and the stratified bio-based PCM TES are at the core of the renovation kit. The innovative TES system combines latent energy storage (PCM) and thermal stratification into a single concept consisting of a simple tank filled with several layers of PCM with different phase-change temperatures. This enables a forced stratification inside the tank while adding the benefits from the higher specific storage capacity of the PCM. The optimized control system will rely on the mutual interaction of Model Predictive Control (MPC) and Machine Learning techniques that will reside in TERA's open-source monitoring and management framework. FIN Framework by J2Innovations is considered as a preliminary choice for the development, exploiting its multi-protocol features and its logic builder to create alarms, fault detection and diagnosis (FDD) routines for primary controllers like TERA GIoE. MPC and ML will be implemented to determine in each operational phase the best temperature level according to available source temperatures and those sink temperatures required to cover the space heating, space cooling and domestic hot water (DHW) needs. Moreover, such control will integrate continuous information on the distribution temperatures provided by a cutting-edge monitoring solution based on a PCM rubber embedded into the pipes' insulation.
  - RP5- Multi-purpose Facade with Bio-based Insulation and BIPV.



This RP introduces a prefabricated facade integrated system tailored for building renovations, with a focus on enhancing energy efficiency, minimizing installation time, and reducing tenant discomfort. The system, incorporates hemp-based insulation materials (PW) and user-friendly aesthetic Building-Integrated Photovoltaic (BIPV) panels (SUNAGE) within a dedicated exoskeleton or substructure designed to support these components effectively. The insulation material used is eco-friendly, providing excellent thermal and acoustic insulation while also possessing superior dehumidification and thermo-hygrometric regulation properties due to hemp fibres. It is designed as a layered insulating panel with variable density, increasing from the inside to the outside to ensure effective coupling with standard fixing systems, and it enhances impact resistance and durability. The facade system includes BIPV opaque cladding elements that have been optimized for cost and time efficiency during manufacturing. These elements are adaptable to various architectural, energy, and construction requirements. RP5 comprises the design, construction, and installation of a multipurpose facade with two key elements: TSaF (Thermal Sound-absorbing Facade) and BIPV (Building-Integrated Photovoltaic Facade). Both facade types share a common anchorage substructure to the existing building, providing versatility and energy efficiency enhancements.

- **Other Interventions:** I) Replacement of window frames and glazing for energy upgrading II) Seismic improvement of the building III) Smart wall and internet connection.

French Demo-site

Brief Description

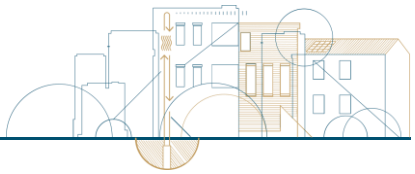
The French demo-site entails a structure designated for public housing purposes. Positioned in the eastern part of France, the building is aligned in an East-West direction and encompasses roughly twenty apartments. No insulation enhancements have been implemented since the building‘s initial construction. Although the windows have been replaced, ongoing maintenance will not be upheld. The heating and hot water provisions are reliant on individual gas boilers.

Demonstration Actions

- **Renovation Packages:**
  - RP6- PANOREN

    This RP presents an innovative concept for a multi-functional building envelope solution. This concept builds upon an existing insulation panel product called Panobloc© and expands its capabilities with additional components and design enhancements, resulting in an optimized integrated facade system. PanoRen integrates a recycled wood-based insulation solution from Panobloc©, a second-life photovoltaic (PV) facing slab for both energy generation and improved rain protection, design adaptations to streamline construction processes using robotics, and architectural elements within the core insulation panel to accommodate ventilation ducts. This comprehensive approach aims to deliver a sustainable and energy-efficient building envelope solution while enhancing construction efficiency.

- **Other Interventions:** Approximatively 90 kW_p Solar Panel on the roof east - west orientation will be installed.



Hungarian Demo-site

Brief Description

The Hungarian demo-site is located in Budapest and is a dormitory building accommodating students of the Saint Paul Academy. It accommodates approximately 65 students from rural areas or abroad. The initial intent of the building was for industrial usage, characterized by minimal energy efficiency and insulation attributes. The university has undertaken the task of transforming the building into a Nearly Zero Energy Building (n-ZEB).

Demonstration Actions

- **Renovation Packages:**
  - RP2- Adaptable/dynamic Building Envelope (ADBE)

    The same ADBE system mentioned previously will be installed in Budapest demo site as well as frame component. The aluminium structure of the ADBE system will be installed on the existing façade of the building, where the PV modules will be placed.

  - RP7- Activated Cellulose Insulation

    This RP introduces an innovative thermal insulation material made from activated cellulose sourced from sawdust or agricultural waste materials. It aligns with circular economy principles and green product standards. Notably, it stands out for being completely chemical-free, as no adhesives are used in its production. This new insulation material offers several key advantages, including environmental friendliness, excellent thermal performance, and easy recyclability. Surface modifications may be required through post-production treatment. The insulation utilizes waste or even 100% recycled/reused materials, resulting in a highly positive environmental balance.

  - RP8- Intelligent Window System (IWS).

    The Intelligent Window System (IWS) is a cost-effective solution suitable for both old and new windows in new or existing buildings. It is particularly useful for renovations, reducing costs, waste, and disruption. Instead of replacing the old window, the IWS is installed as an adapter on the outer side, enhancing thermal resistance. This system has sensors and a microcontroller to automatically open and close the IWS, focusing on maximizing energy efficiency. When closed, it improves thermal resistance, reducing heat loss in winter, and when open, it returns the window to its original state. This technology saves energy in both winter and summer, making it a versatile option for energy-conscious buildings.

- **Other Interventions:** 80 PV panels on the sloped, south-west oriented roof will be installed.

3.2 STAGE 1: GOAL AND SCOPE OF s-LCA

The main goal of creating the s-LCA plans for the 4 demo-sites within the REHOUSE project is to assess and evaluate the social and socio-economic impacts associated with the renovation process and the continued use of the building. All the innovative (RPs) and conventional interventions that will take place in the demo-sites are part of the renovation and therefore will be

assessed as a whole. The functional unit of the REHOUSE s-LCA could be considered the number of people from different stakeholder groups that are affected by building renovation works (through the implementation of innovative RPs). To conduct a s-LCA for renovated buildings, several pivotal considerations and objectives come into focus. Firstly, it is important to assess the social implications of the renovation process itself, including the influence of residents' life during and after the construction, how it affects workers involved in the project and any disruptions to the local community during construction. Ensuring fair labour practices, worker safety, and rights protection are essential. Secondly, community engagement is another critical aspect, involving consultation with and benefits for the local community, addressing any potential negative social impacts, and supporting the overall well-being of residents. The renovation should also strive to enhance accessibility and inclusivity, making the building accommodating for people with disabilities and diverse user groups. These contemplations will be examined to develop the s-LCA plans within the REHOUSE project.

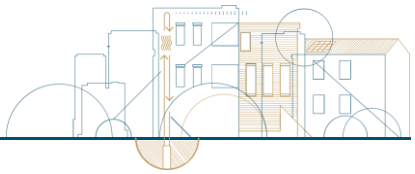
The scope of conducting the specific s-LCA is to assess the social parameters, which will be defined in the next stages, of all the interventions, including both innovative (RPs) and conventional, throughout the construction and operational phases of the four demo-sites. The s-LCA of the REHOUSE project will follow the reference scale assessment, identifying the social topics related to the building renovation and determining the indicators. The social topics will be assessed by data collection on several indicators which will be collected throughout questionnaires in line with the stakeholder categories and the four demo-sites. By conducting this s-LCA for the four renovated buildings, involved stakeholders will gain, after the whole process, a comprehensive understanding of the social challenges associated with the works in demo sites during construction and operational stages. This information in future renovation projects will guide decision-making, promote socially responsible practices, and contribute to the creation of renovated buildings that enhance the well-being of both the occupants and the surrounding community.

3.3 STAGE 2: SOCIAL-LIFE CYCLE INVENTORY (s-LCI).

For the life cycle inventory analysis, it was essential to identify, define and set the stakeholder categories, the social topics and relevant indicators. A two-step approach was followed in the REHOUSE project. Initially, it was taken into consideration the UNEP Guideline and Methodological Sheets (2020) for the selection of stakeholder categories and their relevant social aspects. Secondly, a literature review of s-LCA studies was conducted regarding building renovation and construction or construction/building materials in addition to a review of relevant social surveys. The aim of the literature review was to identify the most prevalent stakeholder categories, social topics for each stakeholder category and indicators for each social topic.

Step 1. UNEP Guideline and Methodological Sheets

United Nations Environment Programme (2020) provided detailed Guidelines and examples on the way of performing a social life cycle assessment for products and organizations. This guidance includes the methodological approach and comprehensive explanations on each one of the four stages of an s-LCA: *Goal and Scope, Inventory, Impact Assessment and Interpretation,* helping the s-LCA researchers and practitioners to assess the social impacts of a product or an organization. These Guidelines do not define a specific compact way as the goals and the applications of the s-LCA can be different. On the contrary, these Guidelines outline the benefits and drawbacks of several strategies for resolving numerous questions. Furthermore, Methodological Sheets (2021) have been developed as a supplement of the Guidelines. Methodological Sheets are a tool to provide thorough information on each of the subcategories presented in the Guidelines, separately for each category of stakeholders.



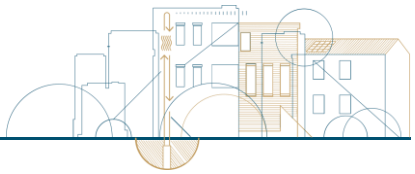
The updated version of Guidelines and Methodological Sheets social life cycle assessment (s-LCA) proposed six main stakeholder categories and specifically workers, local communities, value chain actors (e.g. suppliers), consumers, society, and children (UNEP, 2021). Table 2 presents all the stakeholders' categories and the impacted subcategories related to social issues that can be investigated in a s-LCA. The Methodological Sheets present each social topic in a practical manner, providing definition of the social topic, indicating the goal and the way that the indicator can contribute to the impact, presenting the connection with the Sustainable Development and including lists of international instruments related to the social topic (Policy Relevance), defining generic and site-specific indicators (Assessment of data), and providing examples of data sources and indicators (UNEP, 2021).

Table 2. Proposed stakeholder categories and social issues according to UNEP 2020 (UNEP, 2021)

Stakeholder categories	Worker	Local community	Value chain actors (not including consumers)	Consumer	Society	Children
Subcategories/ Social topics	1. Freedom of association and collective bargaining	1. Access to material resources	1. Fair competition	1. Health and safety	1. Public commitments to sustainability issues	1. Education provided in the local community
	2. Child labour	2. Access to immaterial resources	2. Promoting social responsibility	2. Feedback mechanism	2. Contribution to economic development	2. Health issues for children as consumers
	3. Fair salary	3. Delocalization and migration	3. Supplier relationships	3. Consumer privacy	3. Prevention and mitigation of armed conflicts	3. Children concerns regarding marketing practices
	4. Working hours	4.Cultural heritage	4. Respect of intellectual property rights	4. Transparency	4. Technology development	-
	5. Forced labour	5. Safe and healthy living conditions	5. Wealth distribution	5. End-of-life responsibility	5. Corruption	-
	6. Equal opportunities/discrimination	6. Respect of indigenous rights	-	-	6. Ethical treatment of animals	-
	7. Health and safety	7. Community engagement	-	-	7. Poverty alleviation	-
	8. Social benefits/social security	8. Local employment	-	-	-	-
	9. Employment relationship	9. Secure living conditions	-	-	-	-
	10. Sexual harassment	-	-	-	-	-
	11. Smallholders including farmers	-	-	-	-	-

Step 2. S-LCA case studies on building renovation

According to Vilches et al. (2016) who conducted a literature review on building renovation, none of the examined studies analysed the social impacts of the building renovation though, they were mainly focused on energy consumption and GHG emissions. Kamal et al. (2019) also reached the same conclusion about negligible social studies. Moreover, Huertas-Valdivia (2020) has reviewed

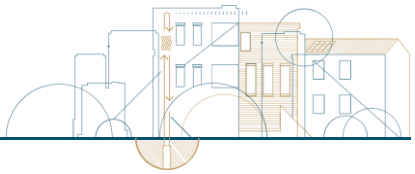


s-LCA case studies between 2003 and 2018 regarding different sectors encompassing food and chemical products, agriculture, transport, forestry, electronics, biofuel, tourism and water management. However, there is a limited number of social life cycle assessment on building renovation and construction or construction materials (Flores-Abascal et al, 2023; Balasbaneh et al. 2021; Balasbaneh et al., 2018; Liu and Qian, 2019; Dong and Ng, 2015; Fan et al, 2018). The literature review conducted in the framework of the REHOUSE project is based on eleven studies and surveys (Flores-Abascal et al, 2023; Mjörnell et al, 2022; Balasbaneh et al. 2021; Balasbaneh et al., 2018; Liu and Qian, 2019; Hossain et al, 2018; Fan et al, 2018; Moussavi Nadoushani et al, 2017; Synnefa et al, 2017; Dong and Ng, 2015; Bork et al 2015;).

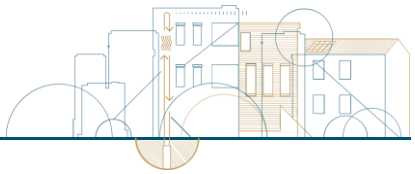
Table 3 illustrates the stakeholder categories, the social issues and the relevant indicators in accordance with the literature review. The number of social surveys were three and were based on the outcomes of questionnaires. Specifically, Synnefa et al. (2017) conducted a social survey in a social housing in Athens, Greece that underwent energy efficient retrofitting. The survey took place by distributing questionnaires and recording interviews before and after retrofitting. The study showed the implementation of novel technologies gained the acceptance and the satisfaction of building users as these technologies; lower energy use successfully and enhance indoor air quality. Mjörnell et al. (2022) contributed to clarifying the conflict between the social responsibility of occupants and financial responsibility of housing business enterprises. A qualitative survey among occupants in Sweden took place to whom were given the opportunity to choose between various renovation options with various associated rent increases. The survey's findings indicate that occupants like having a variety of renovation options since it offers them the freedom to choose the price and quality of their apartment/home.

Table 3. Literature review with focus on stakeholder, social topics and indicator selection.

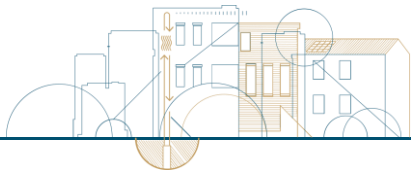
STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
Worker	· Freedom of association and collective bargaining · Child labour · Fair salary · Working hours · Forced labour · Equal opportunities/ discrimination · Health and safety	· FACB right violations · Percentage of child labour · Comply with minimum regulation= 1; does not comply=−1 Working hour >60 h=−1; <60 h=1 · Percentage of forced labour social institutions and gender index · Fatality rate	Dong and Ng, 2015
Local community	· Access to material resources · Cultural heritage · Safe/healthy living conditions · Community engagement · Local employment	· Improved sanitation facilities % of population with access · Protection=1; no change=0; damage=−1 · Reliability of the police services · Index of transparency of policymaking · Unemployment rate · Obligation on public sustainability reporting	
Society	· Public commitments to sustainability issues	· Obligation on public sustainability reporting	
Worker	· Respect for freedom of association · Occupational accidents · Living/non-poverty wages	-	Balasbaneh et al. 2021



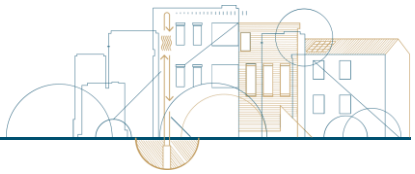
STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
Local community	· Land use · Level of industrial water use · Extraction of material resource · Pollution levels · Waste generations · Job creation · Use of local labour · Contribution of product to economy (GDP)	-	
Society	· Easier to install · Less wastage during set up · Functionality and appeal · Non-toxic floor · Durability · Maintenance cost and frequency	-	
Consumer groups	· Cleaning comfort · Less sound producing · More beauty	-	
Worker	· Living wages · Job creation	· Wage of foreman · Number based on Job creation	Balasbaneh et al. 2018
Workers/ Employees	-	· Child / Juvenile labour (under 18 years) · Forced Labour (overtime) · Health and Safety (occupational accident) · Maternity Protection (day-care or day-care assistance) · Collective association / Relationship with the unions · Equal opportunity /Diversity (gender preference) · Fair salary (salary in accordance with the job) · Benefits (sickness allowance, dental assistance or medical care) · Refectory · Internal training (new technologies, new jobs) · Employee satisfaction research	Bork et al 2015
Government	-	· Operating and environmental licenses · Job description and operational instructions (legislation) · External indicators (Fiscal contributions / Taxes)	
Consumers	-	· Tax incentive · Customer assistance service · Customer satisfaction information	
Suppliers	-	· Relationship with Suppliers (fixed suppliers, training)	



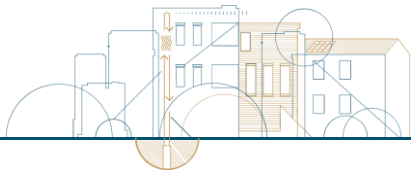
STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
Local Community	-	· Local employment (close to the company) · Relation with the local community (visits, sponsoring events)	
Users Building designers Social housing managers Public administrators	· Energy Efficiency	· Primary energy consumption · Energy Needs · Renewable energy self-sufficiency ratio · RP Renewable energy self- consumption ratio · Heat Loss Coefficient · Reduction of the Global · Warming Potential	Flores-Abascal et al, 2023
	· Energy Poverty	· Measures the relation between the energy expenditure, when reaching comfort conditions, and the net income of the dwelling	
	· Indoor Air Quality	· Thermal comfort (Temperature) · Acoustic comfort, Acoustic Comfort · Indoor Air Quality (CO2 (above outdoors), · Relative Humidity, Ventilation Flow Rate, Mould, Particulate matter PM2.5, VOC Formaldehyde, VOC Benzene, Radon) Visual Comfort (Illuminance, Daylight factor)	



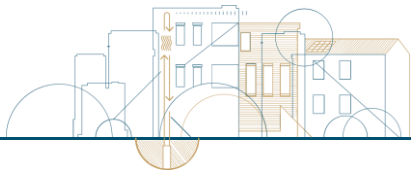
STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
Worker (Construction)	· Health and Safety · Fair Salary · Working Hours · Discrimination · Forced Labour · Child Labour	**Generic Analysis** · Non-fatal and fatal occupational injuries per 100,000 worker · Ratio between average sector wage and living wage · Excessive weekly working hours per employed person compared with 48h · Gender inequality index · Proportion of population in modern slavery · Percentage of children 5e14 years old involved in child labour **Site-Specific Analysis** · Status of managerial practices · Accident frequency rate · Status of managerial practices Percentage of workers whose wages meet a legal minimum wage or sectorial standard. · Percentage of workers who are paid a living · Status of managerial practices · Contractual working hours · Management of overtime · Status of managerial practices · Numbers of incidents of discrimination · Status of managerial practices · Numbers of forced labour · Status of managerial practices · Numbers of child labour	Liu and Qian, 2019
Occupant	· Functionality and Usability · Health and Comfort · Accessibility · Feedback Mechanism	**Generic Analysis** no data **Site-Specific Analysis** · Status of design consideration Performance regarding meeting functionality needs and provision of essential amenities and building equipment · Status of design consideration · Performance regarding indoor air quality, acoustic, hydrothermal and visual comfort · Status of design consideration · Performance regarding proximity to public transportations and amenities · Status of managerial practices · Performance regarding efficiency of dealing with fault reporting and general enquiries	
Local Community (Construction & Use)	· Safety and Health · Accessibility	**Generic Analysis** · Reliability of police services · Burden of disease · Dealing with construction permits · Percentage of population with access to	



STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
		improved water source and improved sanitation facilities · Quality of road	
	· Integration and Interaction	· Transparency of government · Policymaking · Public trust in politicians	
	· Local Employment	· Unemployment rate · Local supplier quantity **Site-Specific Analysis** · Status of managerial practices · Performance regarding controlling disturbance to surroundings regarding dust emission, noise emission, and preventing safety issues · Status of managerial practices · Performance regarding preventing mobility disturbance (construction phase) · Status of design consideration · Performance regarding proving open places, paths and facility for public (O&M phase) · Status of managerial practices · Performance regarding the preservation of local characteristics, and involvement of neighbourhoods into project-related activities, such as design and construction process planning, knowledge sharing and skill transfer · Status of managerial practices · Percentage of workforce hired locally · Percentage of spending on locally-based suppliers.	
Society	· Technology development · Public Commitment to Sustainability Issues	**Generic Analysis** No data **Site-Specific Analysis** · Status of managerial practices · Performance regarding technology development strategies · Status of managerial practices · Performance regarding public sustainability reporting	
Local government	-	· Promote green construction and protect the rights and interests of workers Improvement for green and consciousness of humanity · Costs for policy promotion	Fan et al, 2018
Construction enterprises	-	· Enhance enterprise's reputation and protect the rights and interests of workers · Increase construction difficulty and requirement · Accumulate construction experience of green building	



STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
Real Estate Developments	-	· Enhance enterprise's reputation and protect the rights and interests of workers · Increase investment funds · Accumulate construction experience of green buildings	
Community residents	-	· Healthy living environment · Completed infrastructure · Community interpersonal relationship · Degree of satisfaction with property service · Care for special groups · Extra purchase cost	
Producer of the materials	-	· Health and safety · Use stage responsibility · End-of-life responsibility · Labelling of the products · User satisfaction on the concerned materials/products	Hossain et al, 2018
Worker/ Employee	-	· Health and Safety · Fair Salary · Working Hours · Forced Labour · Training and education	
General public (local community)	-	· Local employment · Community engagement · Health and safety of the living environment · Accessibility of material resources, · Public attitude/opinion on the concerned materials/products	
Society and government	-	· Contribution to economic development · Commitment to sustainability · Technology development · Support from the government	
Traders of the materials/products	-	· Fair competition · Social responsibility · Supplier relationships · Intellectual property right	
Relevant stakeholders (socio-environment)	-	· Materials · Energy and water · Emission · Solid waste and effluent · Biodiversity	



STAKEHOLDER CATEGORIES	SOCIAL TOPICS	INDICATOR	REFERENCE
Tenants	-	· Selection of the renovation option · Adequate information on renovation options · Adequate time to select renovation · Rent importance · Missing renovation measures · Identification of unnecessary renovation measures · Possibility to influence the selection of renovation option · Experience regarding cooperation and dialogue with the housing company · Experience regarding cooperation and dialogue with the tenants' association	Mjörnell et al, 2022
Occupants	-	· Indoor environmental quality Occupants' satisfaction after retrofitting	Synnefa et al, 2017
No data	· Social benefit	· Aesthetics · Suitability to location · Suitability to climate	Moussavi Nadoushani et al, 2017
No data	· Building materials performance	· Thermal resistance · Thermal mass · Acoustic insulation · Resistance to decay	

In accordance with Table 2 and Table 3, a set of social topics for each stakeholder was determined and specific indicators regarding social aspects identified. The next step was to select the most suitable for the REHOUSE project. The two tables were presented and explicitly explained to all the T1.4 partners and then a specific process was followed, which is illustrated in the upcoming chapters, to finalize the REHOUSE stakeholders' categories, social topics and indicators.

3.3.1 FINAL REHOUSE KEY STAKEHOLDERS' CATEGORIES

After the presentation of Table 2 and Table 3 to all the T4.1 partners, CERTH proposed the four most related stakeholder categories considering the fact that the REHOUSE project involves buildings and their renovation actions. The four selected stakeholder categories were the "Consumers", the "Workers", the "Local community" and the "Society". After receiving feedback from the s-LCA experts, the core working group (Task 1.4 leader and WP1 leader), it was decided to reduce the number of the stakeholder categories to three. The category "Consumers" was replaced by "Users/ Inhabitants" and the categories "Local community", and "Society" were merged into one category named "Local Community and Neighbours".

The selected stakeholder categories with a brief description are presented below:

1) **Users/ Inhabitants**: Referred to building owners that the buildings/apartments belong to, and occupants/renters who live or work in the buildings where the renovation will take place. Retrofitting has a direct impact on their comfort, their health and the energy efficiency of their apartments.

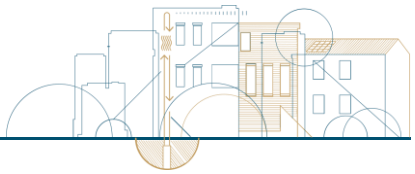
2) **Workers**: Laborers who contributed to the construction process and executed all the renovation activities according to the guidelines of the manufacturers of the RPs.
3) **Local Community and neighbours**: Residents and businesses adjacent to the retrofitted buildings. These are maybe affected by noise, dust and traffic during the renovation process. Also, the renovated building might influence their local economy, their environmental awareness and their aesthetic since the renovated building should fit with the surroundings.

3.3.2 FINAL REHOUSE SOCIAL TOPICS

Having defined the three stakeholder categories, the next step was to decide the social topics for each category. Taking into account Tables 2 and 3 the core working group proposed 48 social topics as the most relevant for the REHOUSE project. Afterwards, discussions through dedicated meetings among the experts within Task 1.4 took place in order to select the most accurate and relevant topics. The social topics related to the stakeholder categories and the interventions (innovative (RPs) and conventional) of each demo site were examined with the aim of assessing the quality of living, the safety, the environmental awareness and the economic impact of the inhabitants and the neighbours but also the work fairness and the education/training of the laborers. Based on the above-mentioned, 9 social topics were considered crucial for the s-LCA.

The social topics, with a brief description, that were selected are the following:

- **Convenience & Well-Being**: Evaluate the well-being of inhabitants/users during and after the renovation process and how the interventions affect their convenience.
- **Health and Safety**: Maintenance of the highest degree of physical and mental health of inhabitants, workers and locals as well. Prevention and protection of their safety during and after the renovation process.
- **Economic**: The impact of retrofitting on inhabitants housing expense, on local employment and the affordability of the renovation.
- **Environmental Protection/ Awareness:** Knowledge concerning the environment, how human actions affect it, and the significance of protecting it. Analyse the extent to which retrofitting benefits the environment.
- **Increase asset value of the building:** Examine whether the retrofitting leads to boost of building's value.
- **Cultural heritage**: Respecting the buildings' cultural legacy during and after the retrofitting. In the REHOUSE project, this social topic will be applicable to the HU demo site since is the only heritage building.
- **Aesthetics:** Examine whether the interventions improve the aesthetics of the neighbourhood.
- **Working Hours:** Concerns the hours that each labourer will work in compliance with its contract.
- **Education/Training:** Refers to workplace policies and activities that aim to increase workers' capacity and employability by enhancing their capabilities and skills. Conduct workers' training assessment.



3.3.3 FINAL REHOUSE INDICATORS

Having defined the stakeholder categories and the social topics the next phase was to find the most appropriate indicators. The same process, as described in the above chapters, was followed by the core working group and the expert partners within T1.4. Forty (40) indicators in accordance with the social topic separately for each stakeholder category were selected and are presented in Table 4, Table 5 and Table 6.

Table 4. Indicators for social issues related to users/inhabitants.

Stakeholder	Social topics	Indicator
Users/ Inhabitants	**Convenience & Well-Being**	Improvement of living conditions
		Satisfaction on the implementation time of the RP
		Influence of the lifestyle during construction
		Change of the daily routine
		Acceptance of new technologies
	Health and Safety	Noise annoyance during construction
		Dust annoyance during construction
		Humidity level improvement
		Acoustic level improvement
		Lighting improvement
		Thermal comfort status
		Ventilation status
		Air Quality status
	Economic	Financial difficulties to satisfy basic needs
		Affordability of operation and maintenance cost of new technologies
	Environmental Protection/ Awareness	Interest on benefits of ecological construction
		Reduction in energy bills
	Increase asset value of the building	Improvement on building aesthetic
		Increments in building value
		Satisfaction on the renovation solutions aesthetics
		Involvement on the design phase of the building

Table 5. Indicators for social issues related to workers.

Stakeholder	Social topics	Indicator
Workers	**Health and safety**	Insurance coverage
		Usage of Personal Protective Equipment (PPE)
		Deployment of auxiliary equipment related to specific renovation activities
	Working hours	Working hours in compliance with the contract
	Education/ Training	Training or seminar participation in general
		Specific training in RP installation

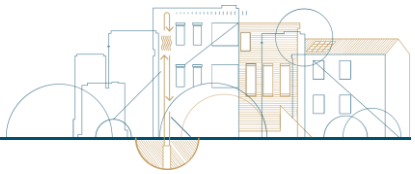


Table 6. Indicators for social issues related to Local community and Neighbours.

Stakeholder	Social topics	Indicator
Local Community & Neighbours	**Health and Safety**	Disturbance during construction
	Economic	Increment of employment/job opportunities
		Reduction in the energy-related public expenditures
		Integration of new technologies in a building with the appropriate financial consideration
		Attractive neighbourhood for buyers and/or tenants
	Cultural heritage (HU Demo)	Protection of heritage building
	Aesthetics (design must fit with the surroundings	Attractiveness of neighbourhood
		Aesthetic of neighbourhood
	Environmental Protection/ awareness	Environmental benefits of the new technologies
		Installation of environmentally friendly technologies
		Improvement of neighbourhood due to environmental interventions
		Increase of building value
		Interest on installation of new RP

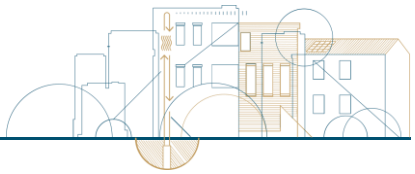
3.4 STAGE 3: SOCIAL LIFE CYCLE IMPACT ASSESSMENT (S-LCIA)

In general, this phase involves classification, characterization, and weighting of results. In previous stages, the indicators have been classified into three groups according to stakeholders. In this section the development of questionnaires to assess the selected indicators will be presented and a framework to extract different sub-indexes per social topic and per stakeholder group suggested.

3.4.1 QUESTIONNAIRE'S DEVELOPMENT

To assess the selected indicators and investigate the opinion and the social acceptance of the demos' retrofitting and the renovation packages, three specific questionnaires were developed, one for each stakeholder category. Each questionnaire was divided into two main parts; the first part (PART A) regarding preliminary data of stakeholders and the second part (PART B) regarding data related to RP/demos and the degree of the effect on social aspects on social impacts that have been induced due to renovation.

- Part A of the questionnaire is the same for all the stakeholder groups and consists of 9 questions related to personal information of the respondent. These questions focus on the gender, the age, the education level, the employment and the accommodation conditions of the responder. This part will be the same for all the participants. PART A can be found in ANNEX I.
- Part B of the questionnaire is specific to each group and has a different number of questions depending on the stakeholders addressed, being 21 questions for Users/Inhabitants, 6 for



Workers and 13 for Local community/Neighbours. PART B can be found in ANNEX II.

It is worth mentioning that Part B of the questionnaire can be slightly customized based on the demo sites and the features of the RPs. For example, the questions related to the cultural heritage concerns only the Hungarian demo site. The demo leaders with the necessary justification would be in a position to exclude questions which are not related to their demo. The deployment of the s-LCA will take place during the construction/retrofitting (Task 4.4) and operational stages (Task 4.5) (once RPs are implemented) of the demo-sites and will be reported at M48 of the REHOUSE project in D4.9 “Report of the Evaluation/Impact assessment”.

3.4.1.1 QUESTIONNAIRE DISTRIBUTION IN THE DEMO-SITES

The questionnaires will be distributed by each demo-site leader during (to workers) and after the construction (to users/Inhabitants and local community/neighbours) considering the different target groups. The way in which the questionnaires will be shared and filled in by each demo is presented below.

Greek Demo-Site

Regarding the Greek Demo-Site, the following actions will be taken. The questionnaire will be shared in both printed and electronic form.

- Users/ Inhabitants

  Members of the implementation team of the project will visit every room separately and either in printed or electronic form will collect the answers of each tenant/student. In addition to that and in order to ensure that as many tenants/students as possible have given their feedback, a printed notice will be posted with the link to the questionnaire at the entrance of the building.

- Workers

  Members of the implementation team of the project will visit the site during construction to conduct individual interviews and make sure all or at least most of the workers will provide feedback.

- Local community and neighbours

  The questionnaire will be shared with the tenants/students of neighbouring dormitory buildings and also with the students that visit the Campus Restaurant/Cafeteria. Again, the questionnaire will be provided in both printed and electronic form, the printed will be shared in person by the members of the implementation team of the project and the electronic via printed notices that will be posted with the link to the questionnaire at the entrance of each neighbouring dormitory building as well as the entrance of the Campus Restaurant/Cafeteria.

Italian Demo-site

In the Italian Demo-site the approach will be the following:

- Users/ Inhabitants

  The inhabitants of the 8 apartments in the demo-site building will be interviewed in person, in several meetings, assemblies and door-to-door visits, thanks to the support of the social task force. ARCA staff (the organization is the building owner) will organize and will always attend meetings and social events. Great support is provided by personnel from Apulia Region, in particulars a “facilitator”.

- Workers

  Workers will be interviewed by the contractors (ARCA). ARCA plans to visit the construction

site to carry out individual interviews, ensuring that a significant majority, if not all, of the workers provide their feedback.

- Local community and neighbours

To ensure a high number of replies from the local community and neighbours, printed questionnaires will be delivered during multiple public events.

French demo-site

Initially, the questionnaire will be translated into French in order all the stakeholder categories will be able to easily answer all the questions. The questionnaire will be accessible in both printed and online formats.

- Users/ Inhabitants

The demo leader will distribute the translated questionnaire to all the residents. To achieve high involvement the demo leader will probably also conduct interviews with the inhabitants.

- Workers

During the construction phase, the demo leader will visit the construction site and will distribute and interview, if needed, the workers who are participating in the process.

- Local community and neighbours

The demo leader will share the questionnaire with multiple neighbours and the local community through different avenues.

Hungarian demo-site

The Hungarian demo site provides different methods to fill in the questionnaires.

- Users/ Inhabitants

The largest group concerned, dormitory residents, will access the translated questionnaire online. An announcement with a QR code will be posted at the dormitory entrance, and a link to the questionnaire will be sent to students by email.

- Workers

The workers involved in the renovation will be contacted through the contractors, who will be interviewed in person to complete the questionnaires.

- Local community and neighbours

Given that the college building is located on the edge of a church campus adjacent to industrial areas, the smallest group of respondents are the members of local communities and neighbours. For them, as for university students, the questionnaire will be available online.

3.4.2 IMPACT ASSESSMENT METHODS AND SUGGESTED FRAMEWORK

Life cycle impact assessment is implemented either with the Reference Scale Assessment (RS s-LCIA) or with the Impact Pathway Assessment (IP s-LCIA). The first approach is focused on evaluation of social performance or social risk whereas the second approach is focused on social consequences that arise from "cause-effect chains' (UNEP, 2020). RS s-LCIA places a heavy emphasis on stakeholder categories however IP s-LCIA attempts to provide generic measures for relevant social consequences using midpoint ("*impacts that occur halfway through the cause-effect chain*" and/or endpoint *("impacts that occur at the end of the cause-effect chain")* indicators. Figure 4 presents the stages of the strategy that should be approached for the Reference Scale

Assessment. Some stages are associated with the LCIA phase, while others are associated with preceding processes in the s-LCA process. In the case of the REHOUSE, the evaluation of the social issues that arising from the interventions in demo sites and the essential role that the involved stakeholders play in policy process, the selection of the Reference Scale is considered the most appropriate approach.

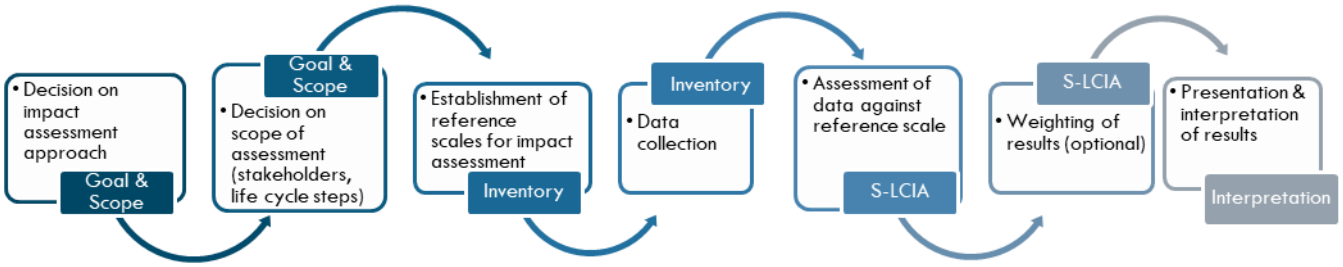


Figure 4. Process of the Reference Scale Assessment (adapted from UNEP 2020)

To support better decision making and enhance the communication of results, a framework is suggested in order to extract different sub-indexes (per social topic and per stakeholder group). The proposed framework was developed building upon standard methodologies for constructing composite indicators and consists of four major steps: a) normalization and scoring of indicators; b) weighting of results; c) aggregation of results, d) presentation of results. These steps are described in more detail below.

a) Normalization and scoring of indicators

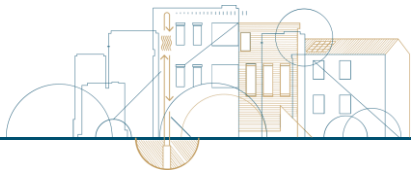
Every indicator is assessed through a dedicated question using a 5-point Likert scale for stakeholder categories Users/inhabitants and Local community and neighbours, and a 2-point Likert scale (Yes/No) for stakeholder category Workers. Respectively a 5-point (ranging from 1 to 5 with 5 indicating best performance) or 2-point (ranging from 1 to 2 with 2 indicating best performance) semi-qualitative evaluation scale with the following conventions can be constructed:

<u>For stakeholder categories Users/inhabitants and Local community and neighbours</u>:

1. Answer to question: Not at all or Strongly Disagree or Very Dissatisfied or relevant answer indicating very negative impact (1 point is assigned to the examined indicator);
2. Answer to question: Slightly or Disagree or Dissatisfied or relevant answer indicating negative impact (2 points are assigned to the examined indicator);
3. Answer to question: Moderately or Neutral or Neither or relevant answer indicating neutral impact (3 points are assigned to the examined indicator);
4. Answer to question: Very or Agree or Satisfied or relevant answer indicating positive impact (4 points are assigned to the examined indicator);
5. Answer to question: Extremely or Strongly Agree or Very Satisfied or relevant answer indicating very positive impact (5 points are assigned to the examined indicator).

<u>For stakeholder category Workers</u>:

1. Answer to question: No (1 point is assigned to the examined indicator);
2. Answer to question: Yes (2 points are assigned to the examined indicator).



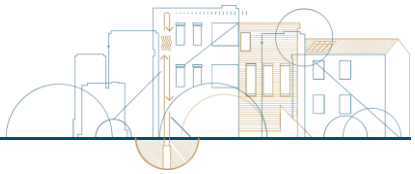
b) Weighting of the results

Weighting (expression of how important a parameter is, in this case social topic compared to another) is a particularly significant step during the development of a composite indicator (Singh et al, 2012). Weights selected by the analyst is not necessarily a bad practice, however it is very likely to have negative consequences regarding the acceptance of the results (Gasparatos, 2010). On the other hand, weights result from statistical methods, may be even less acceptable from the perspective of decision-making and policy development towards sustainability, as insignificant political parameters can receive high scores while innovative approaches on sustainable development may not even taken into consideration (Bohringer and Jochem, 2007).

For the case of REHOUSE, two alternatives are suggested regarding weighting of results (final option to be decided in T4.6):

Option 1: **Assign equal weights** to all indicators and social topics. The specific decision is based on two basic reasons. The indicators and social topics were selected using a concrete procedure to ensure that key social issues are examined. Every indicator serves a different aspect of social sustainability and all issues must be taken into account if we want to move towards sustainable development. Equal weights discourage different actors from merely focusing on the improvement of the indicators with the higher weights. This approach serves better the sustainability notion according to which the performance of a system should be assessed taking into account various parameters (holistic approach). Secondly, if weights were to be adopted, these would have to be adapted to specific types, size and spatial characteristics of the RP/demo site which would significantly increase the complexity and uncertainty of the results, especially if used for benchmarking purposes.

Option 2: **Assign different weights** to all indicators and social topics. Different weighting methods are already explored on how to assign scores to indicators. Equal weighting (Option 1), although questioned by scholars in terms of validity and transparency, offers a simple and replicable method (Geniaux, 2009). Principal component analysis (PCA) and factor analysis (FA), although used for constructing composite indicators, their original scope is to examine relationships and not to weight variables (Hermans et al, 2008). Regression analysis assumes that there is no multi-collinearity. Unobserved component models (Muldur, 2001) used in literature for constructing aggregate governance indicators assume enough data are collected, and indicators are not highly correlated, while it is quite sensitive to outliers of an indicator leading to low weighting (Nardo et al, 2005) of this indicator. The analytic hierarchy process (AHP) although used for multiple-criteria decision-making and for weighting indicators, requires a high number of pairwise comparisons and a relatively short number of indicators (Becker, 2014). The budget allocation method (BAL) applies weighting on indicators based on expert opinion by distributing “n” points over a number of indicators (JRC-EC, 2008). This method weights may be based upon current needs at policy level in a specific region, therefore it is questioned if weightings are transferable to other regions with different context conditions (Becker,2014). In public opinion polling method stakeholders express their “concern” towards a public agenda and weighting is based mainly on the respondents concern rather than importance, raising also questions on transferability to different local conditions. Finally, conjoint analysis (CA) assigns weights to indicators based on individual preferences, ranking a set of alternative scenarios. This method focuses on the preferences of respondents and requires a large sample and large preference data set (Ülengin et al, 2001).



In the proposed framework the participatory method of BAL is initially suggested for adoption (to be confirmed during T4.6) for its validity as a priority for determining indicator's weights due to its transparency, explicitness and short time of execution. The expert pool should include experts (that can be either internal or external from the project) from multiple disciplines with a wide spectrum of knowledge, experience, and concerns, e.g., experts in energy efficiency, climate change, social science, ICT, technology providers, and financiers. Experts shall cover a wider geographical area to ensure that policy initiatives in a specific region do not determine the weights on indicators rendering those weights transferable to other regions. Experts will be introduced in the BAL method and appointed "n" points, which they could then distribute over a set of indicators in each sub-indicator.

c) Aggregation of the results

The utilization of a high number of indicators might be problematic for the efficient communication of the results to upper management and decision-making levels and the general public. Since all indicators are expressed in a common quantitative scale (1-5 points or 1-2 points depending on the stakeholder), the extraction of individual sub-indices is possible. More specifically, by applying the proposed framework, the following scores can be extracted:

For stakeholder group 'Users/Inhabitants':

- I_1: Convenience and Well-Being index
- I_2: Health and Safety index
- I_3: Economic index
- I_4: Environmental Protection/Awareness index
- I_5: Increased asset value of the building index
- Total – (1) final index of social performance for Users/Inhabitants

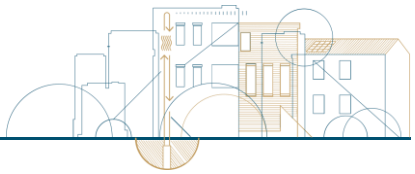
For stakeholder group 'Workers':

- I_1: Health and Safety index
- I_2: Working hours index
- I_3: Education/Training index
- Total – (1) final index of social performance for Workers

For stakeholder group 'Local Community and Neighbours':

- I_1: Health and Safety index
- I_2: Economic index
- I_3: Cultural heritage index
- I_4: Aesthetics index
- I_5: Environmental Protection/Awareness index
- Total – (1) final index of social performance for Local Community and Neighbours

The arithmetic mean (weighted or not depending on final weighting option from previous step) is suggested to be adopted for aggregating the results. In that case, the social topic sub-indices result from the average score of all the indicators that compose each topic, whereas the final index of performance results from the average score of all social topics relevant to the stakeholder group.



d) Presentation of the results

The presentation of the results is an issue that should not be neglected and depends on many factors such as the target audience (Becker,2014). The proposed framework provides significant feedback (indicators utilization, extraction of sub-indices quantitative scores etc.) for the efficient presentation of the results despite the fact that social issues are handled in a semi-qualitative way. A number of key techniques for enhancing the presentation of the results include: the development of summarized tables of results, the development of trend charts per indicator for consecutive years, the development of graphs depicting the scores per sub-indices, the presentation of key results to websites, leaflets and others. The results from the implementation of the framework could serve as an important means of strengthening REHOUSE reports and relevant presentations at meetings and conferences.

3.5 STAGE 4: INTERPRETATION

The scope of stage 4 is to gain a comprehensive understanding of the overall societal performance of the retrofitting buildings and the RPs. This is the final stage where the analysis and the interpretation of the results will take place. The analysis of the results is the step with the highest impact on the RP/demo under examination since their interpretation will lead to successful decision making and formulation of strategies for improving social performance - sustainability. Consequently, it should be performed with great attention. A successful analysis of results should be able to answer the following key questions:

Analysis per social topic: Which social topics present the lowest score and what factors (indicators) caused this?

Total analysis: What is the final score of social performance - sustainability and how it can be improved? The conduction of a sensitivity analysis to quantify the alternative actions of improvement is highly encouraged at this stage. For the easier analysis of the results, the following general rule of interpretation is proposed depending on the rating of the index:

For stakeholder categories Users/inhabitants and Local community and neighbours:

- Score: 1-1.5 points: Very Low social performance
- Score: 1.5-2.5 points: Low social performance
- Score: 2.5-3.5 points: Moderate social performance
- Score: 3.5-4.5 points: High social performance
- Score: 4.5-5 points: Very High social performance

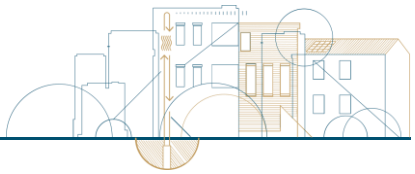
For stakeholder category Workers:

- Score: 1-1.2 points: Very Low social performance
- Score: 1.2-1.4 points: Low social performance
- Score: 1.4-1.6 points: Moderate social performance
- Score: 1.6-1.8 points: High social performance
- Score: 1.8-2 points: Very High social performance

The interpretation and analysis of the results is not within the scope of this deliverable and will be included on D4.9 “Report of the Evaluation/Impact assessment (final values vs. baseline)”.

4 CONCLUSION

Deliverable D1.5 deals with the development of a plan for the implementation of the social life cycle analysis (s-LCA) of the solutions demonstrated within the REHOUSE project. The s-LCA plan was developed as part of WP1, dealing with the social impact of renovation processes aiming to improve the environmental impact and energy performance of the building sector. A literature review was performed in Chapter 2, investigating the state of the art regarding the evaluation of the social impact of renovation processes in Europe and in the world. Based on the information retrieved and the specific need of the REHOUSE project, a four-stage social impact assessment methodology was developed and described in detail in Chapter 3. Starting from the existing literature in the first stage of the s-LCA methodology, a large repository of potential social indicators, as well as stakeholder categories and social topics, appropriate for assessing the social impacts of renovation was created and communicated to the relevant partners of this task. The most appropriate stakeholder categories, social topics and indicators for the case of REHOUSE were identified by a dedicated group of experts (the core working group) in the second stage of the presented methodology. During the third stage, a suitable impact assessment method based on the selected categories, social topics and indicators was created. A set of questionnaires was developed to be distributed to the “Users/inhabitants and Local community and neighbours” and the “Workers” stakeholder categories and the methodology for the assessment of the results was described, including the following steps: normalization and scoring of indicators, weighting of the results, aggregation of the results and presentation of the results. The final stage of the presented methodology refers to the analysis and the interpretation of the results, which is going to be performed within D4.9 “Report of the Evaluation/Impact assessment (final values vs. baseline)”. Summing up, D1.5 presents the methodology for the evaluation of the social impact of the REHOUSE planned interventions, including a comprehensive indicator list, the necessary questionnaires, as well as assessment guidelines, for the s-LCA to be implemented. This document can act as a guide for the evaluation of the social impact of all REHOUSE interventions to be performed in Task 4.6 “Evaluation – Impact assessment and evaluation of performance”.



5 REFERENCES

Artola I., Rademaekers K., Williams R., Yearwood J. (2016) Boosting building renovation: What potential and value for Europe?. Directorate General for Internal Policies: Policy department A: Economic and Scientific Policy

Balasbaneh, A. T., Marsono, A. K. B., & Khaleghi, S. J. (2018). Sustainability choice of different hybrid timber structure for low medium cost single-story residential building: Environmental, economic and social assessment. Journal of Building Engineering, 20, 235-247. doi:https://doi.org/10.1016/j.jobe.2018.07.006

Balasbaneh, A. T., Yeoh, D., Juki, M. I., Gohari, A., Abidin, A. R. Z., & Marsono, A. B. (2021). Applying three pillar indicator assessments on alternative floor systems: life cycle study. The International Journal of Life Cycle Assessment, 26, 1439 - 1455.

Bohringer C. and Jochem P.E.P., Measuring the immeasurable – A survey of sustainability indices, Ecol. Econ. 63 (2007), pp. 1-8.

Bork, C. A. S., Junior, D. J. D. B., & Gomes, J. d. O. (2015). Social Life Cycle Assessment of three Companies of the Furniture Sector. Procedia CIRP, 29, 150-155. doi:https://doi.org/10.1016/j.procir.2015.02.191

Chahal S., Swan W., Brown P. (2012) Tenant Perceptions and Experiences of Retrofit. University of Salford.

Cornelis M. (2023) Social safeguards: the key to a successful renovation wave. European Climate, Infrastructure and Environment Executive Agency. Available at: https://sustainable-energy-week.ec.europa.eu/news/social-safeguards-key-successful-renovation-wave-2023-03-06_en (Accessed: September 2023)

D'Oca S., Ferrante A., Ferrer C., Pernetti R., Gralka A., Sebastian R., Op 't Veld P., (2018), Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects. Buildings, 8(12), 174.

Day R., Walker G., Simcock, N. (2016). Conceptualising energy use and energy poverty using a capabilities framework. Energy Policy (93), 255-264, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2016.03.019.

Dong, Y. H., & Ng, S. T. (2015). A social life cycle assessment model for building construction in Hong Kong. The International Journal of Life Cycle Assessment, 20(8), 1166-1180. doi:10.1007/s11367-015-0908-5

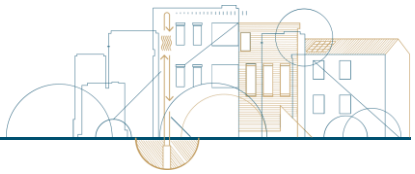
European Commission (EC) (2023) Energy poverty in the EU. Available at: https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumer-rights/energy-poverty-eu_en (Accessed: September 2023)

European Environment Agency (EEA), (2023). Greenhouse gas emissions from energy use in buildings in Europe. On line at: https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-energy

European Environment Agency (EEA). Glossary: Life Cycle Assessment. Available at: https://www.eea.europa.eu/help/glossary/eea-glossary/life-cycle-assessment

Fan, L., Pang, B., Zhang, Y., Zhang, X., Sun, Y., & Wang, Y. (2018). Evaluation for social and humanity demand on green residential districts in China based on SLCA. The International Journal of Life Cycle Assessment, 23(3), 640-650. doi:10.1007/s11367-016-1166-x

Flores-Abascal, I., Hernandez-Cruz, P., Odriozola-Maritorena, M., Almeida, M., Onety, B., Nicolle, J., . Suárez, E. (2023). A novel multicriteria methodology to assess the renovation of social buildings. Journal of Building Engineering, 77, 107505.



doi:https://doi.org/10.1016/j.jobe.2023.107505

Fontes J., Gaasbeek A., Goedkoop M., Contreras S., Evitts S. (2016). Handbook for Product Social Impact Assessment 3.0.

Gasparatos A., Embedded value systems in sustainability assessment tools and their implications, J. Environ. Manage. 91 (2010), pp. 1613-1622

Geniaux, G. Sustainable Development Indicator Frameworks and Initiatives; Technical report; Seamless: Paris, France, 2009.

Greater Manchester Low Carbon Economic Area (2011) The Missing Quarter: Integrating behaviour Change in Low Caron Housing Retrofit, LCEA, Manchester

Hasik V., Escott E., Bates R., Carlisle S., Faircloth B., Bilec M. M., (2019), Comparative whole-building life cycle assessment of renovation and new construction. Building and Environment, 161, 106218.

Hermans, E.; Van den Bossche, F.; Wets, G. Combining road safety information in a performance index. Accid. Anal. Prev. 2008, 40, 1337–1344.

Hirvonen, J., Saari, A., Jokisalo, J., & Kosonen, R. (2022). Socio-economic impacts of large-scale deep energy retrofits in Finnish apartment buildings. Journal of Cleaner Production, 368, 133187. doi:https://doi.org/10.1016/j.jclepro.2022.133187

Hossain, M. U., Poon, C. S., Dong, Y. H., Lo, I. M. C., & Cheng, J. C. P. (2018). Development of social sustainability assessment method and a comparative case study on assessing recycled construction materials. The International Journal of Life Cycle Assessment, 23(8), 1654-1674. doi:10.1007/s11367-017-1373-0

Institute for European Energy and Climate Policy (IEECP). (2022) A socially just EU renovation wave: Recommendations for EU policymakers based on findings in 10 member states. European Climate Foundation. Available at: https://europeanclimate.org/wp-content/uploads/2022/05/ieecp-socially-just-homes-summary-report-may-2022.pdf (Accessed: September 2023).

ISO 14040, (2006). ISO, International Standard. Environmental Management and Life Cycle Assessment and Principles and Framework. International Organization for Standardization, Geneva, Switzerland.

Joint Research Centre-European Commission; OECD. Handbook on Constructing Composite Indicators: Methodology and User Guide; OECD Publishing: Paris , France, 2008.

Jowkar M., Temeljotov-Salaj A., Lindkvist C. M., Støre-Valen M., (2022), Sustainable building renovation in residential buildings: barriers and potential motivations in Norwegian culture. Construction Management and Economics, 40(3), 161-172.

Kamal A., Al-Ghamdi S. G., Koc M., (2019), Revaluing the costs and benefits of energy efficiency: A systematic review. Energy Research & Social Science, 54, 68-84.

Liu, S., & Qian, S. (2019). Evaluation of social life-cycle performance of buildings: Theoretical framework and impact assessment approach. Journal of Cleaner Production, 213, 792-807. doi:https://doi.org/10.1016/j.jclepro.2018.12.200

Lobsiger-Kägi E., López L., Kuehn T., Roth R., Carabias V., Zipper C., (2018), Social Life Cycle Assessment: Specific Approach and Case Study for Switzerland. Sustainability, 10(12), 4382.

Majcen, D.; Itard, L.; Visscher, H. Statistical model of the heating prediction gap in Dutch dwellings: Relative importance of building, household and behavioural characteristics. Energy Build. 2015, 105, 43–59.

Mälkki H., Alanne K. (2017). An overview of life cycle assessment (LCA) and research-based

teaching in renewable and sustainable energy education. Renewable and Sustainable Energy Reviews (69), 218-231. ISSN 1364-0321. https://doi.org/10.1016/j.rser.2016.11.176.

Mallaband B., Haines V., Mitchell V. (2012) Barriers to domestic retrofit–learning from past home improvement experiences. Retrofit 2012, Salfort, UK

Mangold, M., Österbring, M., Wallbaum, H., Thuvander, L., & Femenias, P. (2016). Socio-economic impact of renovation and energy retrofitting of the Gothenburg building stock. Energy and buildings, 123, 41-49.

Marine Cornelis, (2022), How to avoid a Renoviction Wave, Report on the social impacts of the Renovation Wave, FEANTSA.

Marine Cornelis, (2023), Social safeguards: the key to a successful renovation wave, European Commission <https://sustainable-energy-week.ec.europa.eu/news/social-safeguards-key-successful-renovation-wave-2023-03-06_en>

Meijer, F., Itard, L., & Sunikka-Blank, M. (2009). Comparing European residential building stocks: performance, renovation and policy opportunities. Building Research & Information, 37(5-6), 533-551.

Mjörnell K., von Platten J., Björklund K., (2022), Balancing Social and Economic Sustainability in Renovation with an Affordable Option for Tenants? A Pilot Study from Sweden. Sustainability, 14(7), 3785.

Moussavi Nadoushani, Z. S., Akbarnezhad, A., Ferre Jornet, J., & Xiao, J. (2017). Multi-criteria selection of façade systems based on sustainability criteria. Building and Environment, 121, 67-78. doi:https://doi.org/10.1016/j.buildenv.2017.05.016

Muldur, U. Technical Annex on Structural Indicators. In Two Composite Indicators to Assess the Progress of Member States in their Transition towards a Knowledge-Based Economy; DG Research (Europäische Kommission): Brussels, Belgium, 2001.

Nardo, M.; Saisana, M.; Saltelli, A.; Tarantola, S. Tools for composite indicators building. European Commission, EUR 21682 EN. In Institute for the Protection and Security of the Citizen; JRC: Ispra, Italy, 2005.

Palacios-Munoz B., Peuportier B., Gracia-Villa L., López-Mesa B., (2019), Sustainability assessment of refurbishment vs. new constructions by means of LCA and durability-based estimations of buildings lifespans: A new approach. HAL open science.

POWERPOOR: D5.2 Energy poverty guidebook for energy planning (2021). Horizon 2020

Ramírez-Villegas R., Eriksson O., Olofsson T., (2019), Life Cycle Assessment of Building Renovation Measures–Trade-off between Building Materials and Energy. Energies, 12(3), 344.

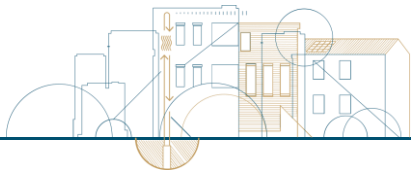
Singh R.K., Murty H.R., Gupta S.K. and Dikshit A.K., An overview of sustainability assessment methodologies, Ecol. Indic. 15 (2012), pp. 281-299.

Synnefa A., Vasilakopoulou K., Masi R. F. D., Kyriakodis G.-E., Londorfos V., Mastrapostoli E., Karlessi T., Santamouris M., (2017), Transformation through Renovation: An Energy Efficient Retrofit of an Apartment Building in Athens. Procedia Engineering, 180, 1003-1014.

Ülengin, B.; Ülengin, F.; Güvenç, Ü. A multidimensional approach to urban quality of life: The case of Istanbul. Eur. J. Oper. Res. 2001, 130, 361–374

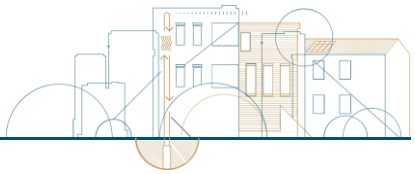
United Nations Environment Programme (UNEP), (2020), Guidelines for social life cycle assessment of products and organizations 2020

Vilches A., García-Martínez A., Sánchez-Montañés B., (2016), Life cycle assessment (LCA) of building refurbishment: A literature review. Energy and Buildings, 135.

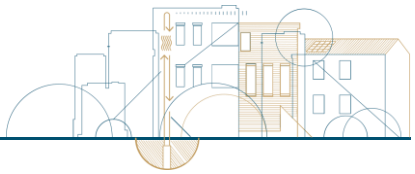


ANNEX I: QUESTIONNAIRE - PART A: GENERAL PERSONAL INFO

1. PLEASE SELECT YOUR GENDER	
Male	
Female	
Other	
2.PLEASE SELECT YOUR AGE RANGE	
from 21 to 30	
from 31 to 40	
from 41 to 50	
from 51 to 60	
over 60	
3. WHAT IS YOUR EDUCATION LEVEL?	
Primary school or no qualification at all	
Secondary school diploma	
Professional qualification	
High school diploma	
Degree	
Other	
4. WHAT IS YOUR EMPLOYMENT?	
Employment	
Unemployed	
Student	
Employee	
Retired	
other	
5. HOW LONG HAVE YOU BEEN LIVING IN YOUR CURRENT ACCOMMODATION?	
For more than 10 years	



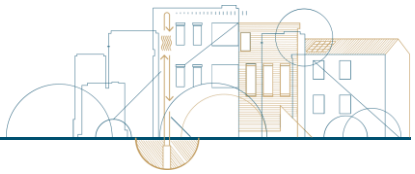
Between 5 and 10 years	
Between 2 and 5 years	
For one year or even less	
6. IN WHICH FLOOR IS YOUR APARTMENT?	
The base floor	
The last floor	
Not the base and nor the last floor	
7. WHAT IS THE POSITION OF YOUR APARTMENT RELATIVELY TO THE EXTERNAL BUILDING WALLS?	
Apartment/room has one external wall	
Apartment/room has two external walls	
Apartment/room has three external walls	
8. WHEN ARE YOU USUALLY AT HOME?	
In the morning	
In the evening	
All day long	
In the weekends	
9. HOW MANY PEOPLE STAY AT HOME DURING THE DAY?	
1 or 2	
3 or 4	
More than 4	



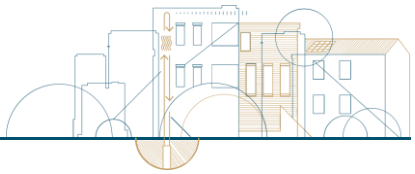
ANNEX II: QUESTIONNAIRE - PART B: SOCIAL ASSESSMENT QUESTIONNAIRE FOR EACH STAKEHOLDER CATEGORY

Social Assessment Questionnaire for the Users/Inhabitants.

STAKEHOLDER CATEGORY	SOCIAL TOPIC	INDICATOR	
USERS/ INHABITANTS	Convenience & Well-Being	**QUESTIONS**	**RANGE**
		How much has your living conditions been improved by the retrofitting?	Extremely Very Moderately Slightly Not at all
		Are you satisfied with the implementation time of the RP?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		How much has your lifestyle (everyday life) been affected during the construction phase?	Extremely Very Moderately Slightly Not at all
		How much did you have to change your daily routine to adapt to the new technology?	Extremely Very Moderately Slightly Not at all
		How easily have you accepted the new technologies?	Extremely Very Moderately Slightly Not at all
	Health and Safety	Please indicate your annoyance due to noise during the construction phase**.**	I heard it often and it was extremely annoying. I heard it often and it was very annoying. I heard it often and it was annoying. I heard it occasionally and it was annoying. I heard only occasionally, and it was slightly annoying.



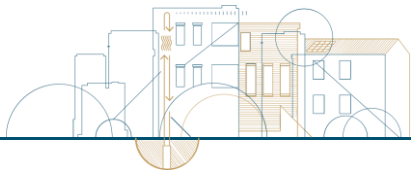
		Please indicate your annoyance due to dust in your apartment during the construction phase.	I was extremely annoyed. I was very annoyed. I was annoyed. I was slightly annoyed. I was not annoyed at all.
		How much has the humidity level improved in your apartment?	Extremely Very Moderately Slightly Not at all
		How much has the acoustic level improved in your apartment?	Extremely Very Moderately Slightly Not at all
		How much has the lighting improved inside your residence?	Extremely Very Moderately Slightly Not at all
		Are you satisfied with the thermal comfort-status (heating & cooling) of your dwelling after the renovation?	Very satisfied Satisfied Neither Dissatisfied Very dissatisfied
		Are you satisfied with the ventilation status of your dwelling after the renovation?	Very satisfied Satisfied Neither Dissatisfied Very dissatisfied
		Are you satisfied from the air quality inside the dwelling after the renovation?	Very satisfied Satisfied Neither Dissatisfied Very dissatisfied
	Economic	Have you ever encountered difficulties paying for energy supply to satisfy basic needs? ***(based on definition of energy poverty in France). *https://www.odyssee-mure.eu/publications/policy-brief/measuring-energy-poverty.html*	Not at all Once in my whole life Twice in my whole life Once annually More than once annually



		Do you agree that you can financially afford the operation and maintenance cost of the new technologies if the payment was your responsibility?	Strongly Agree Agree Neutral Disagree Strongly Disagree
	Environmental Protection/ Awareness	Are you interested in the benefits of ecological construction?	Extremely Very Moderately Slightly Not at all
		Have you noticed any reduction in your energy bills (electricity, Gas)? (Where applicable, otherwise proceed to the next question)	Extremely Very Moderately Slightly Not at all
	Increase asset value of the building	Do you agree that the renovation has improved the aesthetic of your building?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		Do you agree that the value of your building has increased after the retrofitting?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		How much are you satisfied by the Renovation solutions aesthetics?	Extremely Very Moderately Slightly Not at all
		Would you be interested to be involved in the future on the design phase of the building?	Extremely Very Moderately Slightly Not at all

Social Assessment Questionnaire for the Users/Inhabitants.

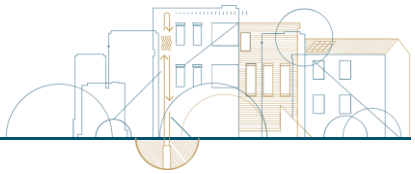
STAKEHOLDER CATEGORY	SOCIAL TOPIC	INDICATOR	
WORKERS	**Health and safety**	Does your employer cover your insurance contributions **(**during construction)?	YES NO
			YES NO



		Do you use Personal protective equipment (PPE) during construction work?	
		Do you have all the auxiliary equipment needed to deploy well your specific activities during the construction stage?	YES NO
	Working hours	Are the working hours dedicated in the installation of the RP in agreement with the contractual obligations?	YES NO
	Education/ Training	Have you trained or have you participated periodically (at least every year) in seminars in order to develop your skills?	YES NO
		Have you received any specific training in order to install the RP?	YES NO

Social Assessment Questionnaire for the local community & neighbours.

STAKEHOLDER CATEGORY	SOCIAL TOPIC	INDICATOR	
LOCAL COMMUNITY & NEIGHBOURS	**Health and Safety**	Have you felt any disturbance during the construction work?	Extremely Very Moderately Slightly Not at all
	Economic	Do you agree that the renovation activities have increased the local employment?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		Do you consider that the installation of new technologies in buildings decreases energy-related public expenditures?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		Do you agree with the integration of new technological attributes into existing buildings with the appropriate financial consideration?	Strongly Agree Agree Neutral Disagree Strongly Disagree



		Do you agree that your neighbourhood is more attractive to new buyers and/or tenants?	Extremely Very Moderately Slightly Not at all
	Cultural heritage (HU Demo)	In which level do you believe that the heritage building was protected during and after the retrofitting?	Extremely Very Moderately Slightly Not at all
	Aesthetics (design must fit with the surroundings)	Do you agree that the retrofitting works improve the attractiveness of the neighbourhood/city?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		Do you agree that the renovation of the building has improved the aesthetic of the neighbourhood/city?	Strongly Agree Agree Neutral Disagree Strongly Disagree
	Environmental Protection/ awareness	Are you aware of the benefits of the new innovative technologies to the environment?	Extremely Very Moderately Slightly Not at all
		How useful do you think the installation of environmentally friendly technologies is for the future of the city?	Extremely Very Moderately Slightly Not at all
		Do you agree that your neighbourhood will get improved due to the environmental interventions?	Strongly Agree Agree Neutral Disagree Strongly Disagree
		Do you think that the introduction of new environmentally friendly technologies in the building sector will increase the building value?	Extremely Very Moderately Slightly Not at all
	Community engagement	If you have not installed any innovative technology in your dwelling, would you be interested to install one?	Extremely Very Moderately Slightly Not at all