

LEVEL(S) IN ACTION: AN EXPLORATORY STUDY OF EU'S SUSTAINABILITY ASSESSMENT FRAMEWORK ON A PORTUGUESE SOCIAL HOUSING PROJECT

JOSÉ MIGUEL SIMÕES SILVA

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Supervisor: Prof. Maria Helena Póvoas Corvacho

Co-Supervisor: Fernando Pedro Fernandes Pereira

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MASTER IN CIVIL ENGINEERING 2020/2021

DEPARTMENT OF CIVIL ENGINEERING

Tel. +351-22-508 1901

Fax +351-22-508 1446

✉ miiec@fe.up.pt

Edited by

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉ feup@fe.up.pt

🌐 <http://www.fe.up.pt>

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To family and friends

Everybody's talking 'bout the stormy weather

S.Y

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ABSTRACT

In the past few decades, environmental sustainability has become a major goal across the globe. By joining the Paris Climate Accord, European countries have agreed to strive for overall net carbon neutrality by 2050. This ambitious goal is intended to mitigate the worst potential climate outcomes. One of the largest contributors to the overall carbon emissions of the European continent is the Construction Industry. In pursuit of higher levels of sustainability in the Construction Industry, the European Union released in October of 2020 an assessment framework for the sustainability of building projects, called Level(s). Level(s) aims to provide a common language for sustainability assessment, and in doing so, unite the broad field of BSAMs which currently exist throughout Europe. In using Level(s) as a consistent metric for construction sustainability across Europe, the EU will have a more viable way to measure and achieve its continent-wide environmental goals.

The following study performs an exploratory application of Level(s) to a proposed construction project in northern Portugal, which will convert an abandoned lumber yard into a social housing complex. The author goes through each Level(s) Indicator, providing contextualization and summaries for all 16 of them, detailing instructions for applying them to building projects, and applying them to Level 1 or Level 2 when possible. Certain limitations prevent the study from representing a true application in the field, but the application yielded fruitful results, especially with regard to pinpointing potential areas of improvement for the Level(s) framework. In particular, the author recommends that Level(s) becomes more unified and self-sufficient by not relying on third-party software systems and other existing assessment schemes. This exploratory study, one of the very first of its kind, will hopefully provide useful context to future Level(s) users, enabling them to more quickly understand the framework and apply the method more thoroughly to other building projects.

KEYWORDS: Level(s), sustainability, construction, European Union, social housing

RESUMO

Nas últimas décadas, a temática da sustentabilidade ambiental tem sido um dos principais tópicos de discussão global. Através da adesão ao Acordo de Paris, a Europa tem sistematicamente aplicado medidas que pretendem atingir a neutralidade nas emissões de dióxido de carbono em 2050. E é com tal meta incrivelmente ambiciosa que se pretende mitigar as piores estimativas de impactos climáticos projetados para o futuro. Um dos maiores contribuidores para tão preocupante situação ambiental é a Indústria da Construção.

Desta forma, e com o objetivo de promover a sustentabilidade nesta indústria, a Comissão Europeia lançou, em outubro de 2020, uma *framework* para a avaliação da sustentabilidade na construção – o Level(s). Este Método de Avaliação da Sustentabilidade da Construção (MASC) pretende implementar uma linguagem universal para a sustentabilidade e desta forma unir o vasto campo de MASC que atualmente operam na Europa. Uma utilização consistente do Level(s) na avaliação das construções dará à União uma metodologia comum praticável para medir e atingir os seus objetivos ambientais.

Este estudo desenvolve uma análise exploratória do Level(s) aplicada a um projeto de construção no Norte de Portugal, que irá reconverter uma antiga instalação fabril num complexo de habitação social. São percorridos os 16 indicadores do método, sendo fornecidas contextualizações, resumos individuais, instruções de aplicação em projetos de construção e, quando possível, aplicando-os no Level 1 ou no Level 2. Algumas limitações impediram este estudo de apresentar uma aplicação completamente realista, mas os resultados obtidos foram úteis ao especificar áreas de melhoria e desenvolvimentos académicos futuros para este ainda recente MASC. Em específico, é recomendado que o método se torne mais unificado e autossuficiente ao deixar de depender de softwares terceiros e de critérios delineados por outros MASC. Através das várias análises efetuadas, este estudo, um dos primeiros do seu tipo, fornece uma contextualização mais clara para os futuros utilizadores do Level(s), permitindo-lhes compreender de forma mais rápida a sua estrutura e mais eficazmente aplicá-lo a outros projetos de construção.

PALAVRAS-CHAVE: Level(s), sustentabilidade, construção, União Europeia, habitação social

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ABBREVIATIONS AND SYMBOLS

A _{eq}	Equivalent Sound Absorption Area
BIM	Building Information Modelling
BoM	Bill of Materials
BoQ	Bill of Quantities
BRE	Building Research Establishment
BREEAM	Building Research Establishment's Environmental Assessment Method
BSAM	Building Sustainability Assessment Method
CDW	Construction and Demolition Waste
CE	Circular Economy
CMR	Carcinogenic, Mutagenic, or toxic for Reproduction
D _{2m,Nt,w}	Weighted Standardized Level Difference for Traffic Noise
D _{nT,w}	Weighted Standardized Level Difference
EN	European Standards
EPC	Energy Performance Certificate
EPD	Environmental Product Declaration(s)
GHG	Greenhouse Gas
GPP	Green Public Procurement
GWP	Global Warming Potential
IAQ	Indoor Air Quality
iiSBE	International Initiative for a Sustainable Built Environment
IPMS	International Property Management Standards
JRC	Joint Research Centre
L' _{Nt,w}	Weighted Standardized Impact Sound Pressure Level
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LiderA	<i>Liderar pelo Ambiente</i>
LoW	List of Waste
MO	Macro-Objectives
NZEB	Nearly-Zero Energy Buildings

PVGIS TPY	Photovoltaic Geographical Information System - Typical Meteorological Year
REH	<i>Regulamento de Desempenho Energetico dos Edificios de Habitacão</i>
RGEU	<i>Regulamento Geral das Edificacoes Urbanas</i>
T	Reverberation Time
VOCs	Volatile Organic Compounds
WEI+	Water Exploitation Index plus
WMP	Waste Management Plan

1

INTRODUCTION

1.1. MOTIVATION

The need for sustainable development to guarantee the future availability of resources is of fundamental significance today, as the Earth approaches a population of 7.7 billion people, whose needs have risen steadily in the course of recent years (Mhatre et al. 2021). And given the fact that Earth possesses a finite amount of resources, optimizing their expenditure is essential in order to avoid exceeding the Earth's natural capacity for replenishing its biodiversity. In the past few decades, the human race has been urged to radically reduce its ecological footprint due to the magnitude of the pending environmental crisis.

One of the major contributors to our current ecological footprint is the Construction Industry - accounting for 35% of total energy consumption, 38% of greenhouse gas (GHG) emissions, and 17% of freshwater consumption, while also producing between 45% and 65% of solid waste (Programme 2020). Therefore, buildings are still an enormous untapped source of efficiency potential, and controlling their environmental impact has become a major challenge for the world's economies. Interest has therefore been growing in concepts that aim to avoid irreversible damages, like Life Cycle Assessment and Circular Economy (Geissdoerfer et al. 2017).

Building upon these two concepts, the European Commission, under its Circular Economy Action Plan and Green Deal policies, developed Level(s). This framework aims to deliver a much-needed consistency in the method of assessing building sustainability across national boundaries in Europe, while providing flexibility of use and much vital information for their efficient development.

Moreover, in line with the environmental, economic, and social agendas of the European Union, Social Housing continuously attracts attention as a dynamic field in the construction sector. It is a theme closely connected to urban regeneration processes and to investment policies, and is an opportunity to improve the quality of life of citizens with the highest levels of need (Coscia et al. 2020).

Since Level(s) attempts to assimilate the vast scenery of sustainability assessment tools available, it is a complex and multi-faceted framework. Therefore it is essential to examine, in concrete terms, its capacity to serve as a key instrument in promoting sustainable construction. Applying the European Commission's novel method to the projected conversion of an old Portuguese lumber yard into a Social Housing complex will serve as an appraisal of the framework's ability to accommodate both the characteristic creativity of the construction industry and the tight deadlines created by many social emergencies.

1.2. EU'S RENOVATION WAVE STRATEGY

The COVID-19 pandemic made the world aware of how important our buildings are, and how their fragilities are usually overlooked. Throughout the larger part of 2020 and early 2021, quarantines and lockdowns confined the daily lives of millions to their homes, bringing up social and health concerns related to the safety, environmental, and health conditions of many houses.

In part because it is such a symbol of European pride—due to its individuality and heterogeneity, showcasing the vast history and cultural diversity of the continent—the EU's building stock is resistant to dramatic changes. Aggregated data provided by the European Commission's "2019 Commission Recommendation on Building Renovation (EU)" show that more than 220 million building units, which represents 85% of EU's building stock, were built before 2001, and the report projects that around 85-95% of the building stock in the year 2050 is already standing today (European_Commission 2020b).

It is no revelation that the bigger part of those buildings fails to meet our current standards of efficiency, often because they remain completely dependent on fossil fuels for heating and cooling. The same report from the European Commission acknowledges that even across the building stock that has recently undergone deep renovation, measures to reduce the energy consumption by at least 60% only met that goal in 0.2% of cases, and some regions have practically negligible energy renovation rates. It is a pace that would make the building sector's goal of net-zero carbon emissions take centuries to accomplish.

Therefore, with a declared intention to break down the barriers to energy- and resource-efficient renovation, the European Commission launched its Renovation Wave Strategy, with the objective to *"at least double the annual energy renovation rate of residential and non-residential buildings by 2030 and to foster deep energy renovations."* The Commission estimates that *"these goals will result in 35 million building units renovated by 2030"* (European_Commission 2020b). That rate is to be maintained even after 2030 in order to achieve carbon neutrality in the construction sector by 2050, in accordance with the European Green Deal ambitions.

According to the Renovation Wave Communication, which defines the Strategy, the main focus for building renovation towards 2030 and 2050 must be to adhere to the following principles: energy efficiency; affordability; decarbonization and integration of renewables; life cycle thinking and circularity; high health and environmental standards; tackling the twin challenges of the green and digital transition together; and respect for aesthetics and architectural quality.

As later chapters of this study will demonstrate, many of the stated principles correlate with those of Level(s). In fact, the novel assessment framework is one of the EU's main tools to pave the way for the Renovation Wave to achieve its ambitious goals. It is crucial that an improved building stock is based on life cycle and circularity principles, and it is within those terms that this novel framework has been built.

In the Social Housing sector, the importance of a major renovation is paramount since inefficient buildings are often synonymous with social problems. Each year, 800,000 social housing units require renovation and nearly 34 million Europeans cannot afford to maintain their homes warm (Lieve Fransen and Reviglio 2018)(Figure 1.1). People with low incomes who live in such houses have almost no ability to heat them and, when aggressive weather makes it vital, the low yield of the insulation results in high energy bills, rent debt and aggravated social problems. Ultimately, the lack of baseline conditions of wellbeing and comfort, such as appropriate indoor temperature, adequate air quality, and nonhazardous building materials, results in both a higher mortality rate and a lower rate of economic engagement in such families. Families in these situations too often become trapped in a vicious cycle of poverty and sub-optimal living conditions.

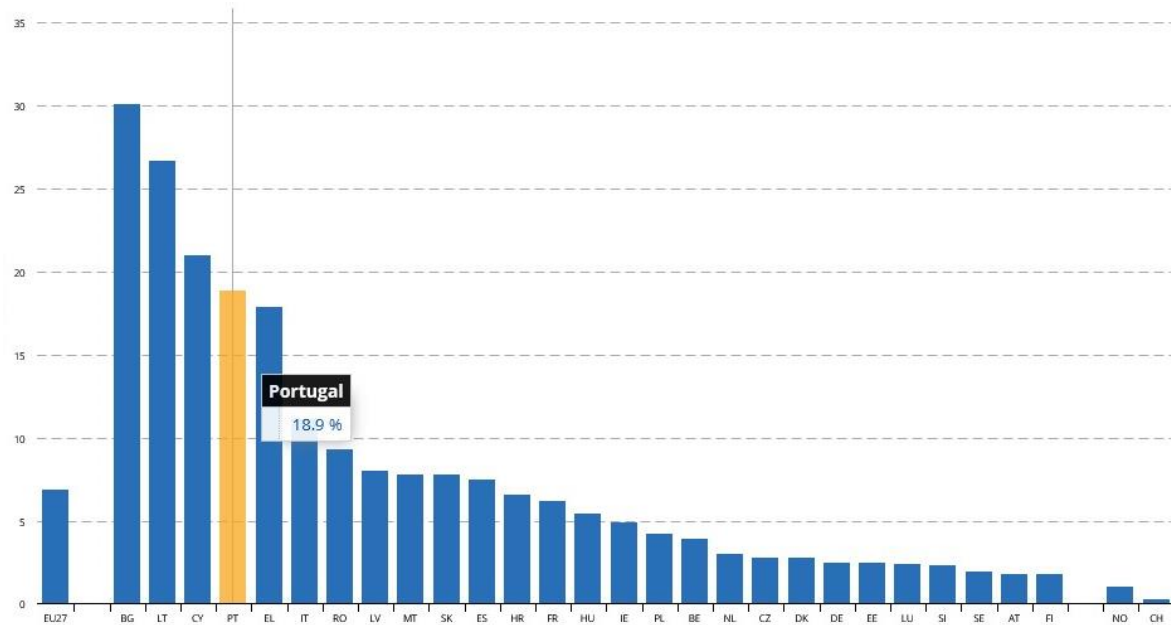


Figure 1.1 – Percentage of European countries' population unable to keep their home adequately warm (eurostat 2021a)

1.3. PURPOSE

The European Union is constantly developing new tools and incentives to respond to the Paris Agreement's goals of decarbonizing the construction sector by 2050. This investigation intends to appraise one of those tools, the newly released Level(s) common framework for assessing the sustainability of European buildings.

More specifically, this study aims to explore and evaluate Level(s) usability on the Portuguese construction sector, by applying it to a social housing complex project. To do so, the following steps were developed:

- Contextualizing Level(s), by understanding its main concepts and surrounding policies and by comparing it to other well established local and international Building Sustainability Assessment Methods (BSAM)
- Interpreting the Levels's framework structure and its different macro-objectives and indicators, providing the groundwork for what information must be gathered for its application;
- Performing an experimental application of Level(s) to a case study, encompassing all of its indicators with either assessments or commentaries.
- Explaining the operation of the method by providing application guides based on the indicators and the pertinent regulatory documents;
- Reflecting on the results obtained, the strengths and weaknesses of the method, and its adaptability to the Portuguese panorama.

1.4. DOCUMENT STRUCTURE

The following study is organized in 5 chapters, with respective sub-sections.

The first chapter introduces the main topics of the thesis. In this chapter, the reader will learn the motivation for this exploratory study and will become familiar with the European sustainability context. The information presented will help to frame the rest of the study.

Chapter two adds further context to the case study by surveying fundamental concepts of the field of sustainability assessment, and by introducing other methods that currently exist. The breakdown of these other methods will form a starting point for the comparison to Level(s), so that readers will be able to conceptualize what makes it unique in the spectrum of building sustainability assessment methods (BSAMs).

The scope is narrowed in the third chapter, which is completely focused on introducing Level(s) to the study, providing an extensive summary of its structure and main components. A further analysis is also performed by placing it side by side with the methods introduced in the previous chapter, so that readers may get a sense of what it might look like to integrate Level(s) into the European construction field. The chapter is completed by a quick guide on how to start applying Level(s) to building projects, which prepares the reader for the next chapter.

The fourth chapter is the application of Level(s) to the case study. Here the guide previously summarized is followed in order to perform a complete exploration of Level(s) as a framework and of all the 16 Indicators that the framework contains. The sub-sections of this chapter each summarize, apply, and provide instructions for an Indicator. The case study is useful in providing some real data inputs for the method; however, the focus is primarily on elaborating the different goals of each Indicator and what would be needed to perform a real time application.

The fifth and last chapter is reserved to the exposition of some of the conclusions of this study. The author discusses the challenges and successes of the project, as well as the shortcomings and strengths of the Level(s) framework itself. The chapter and this thesis are then completed by the formulation of some suggestions for future studies that this study deems critical for the improvement of Level(s) as a method to be applied across Europe as a whole, and in the Portuguese construction industry more specifically

2 SUSTAINABILITY ASSESSMENT IN THE CONSTRUCTION INDUSTRY

2.1. HISTORICAL PERSPECTIVE

Performance evaluations and environmental assessments of buildings have generated intense research since the 1970s (Cole 1998), in tandem with the development of the concepts of sustainable building and development, and motivated by the growing focus of major industrial sectors on the environmental effects of human action. But due to the complexity and novelty of these concepts, whose definitions deviate among academics, and due to the different interests of the actors – e.g., stakeholders interested in economic performance, residents focused on health and comfort – a major attempt to establish a standard framework to assess the comprehensive environmental performance of a building only appeared in 1990. This framework was the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom.

Nowadays the concept of sustainability is undergoing a boom of popularity, having become almost omnipresent in our daily lives. Such popularity is also reflected in the range of new assessment methods. The selection of systems now range from LCA-based tools, rating systems, technical guidelines, assessment frameworks, checklists, and certificates (Castanheira and Bragança 2014). Driven by increasingly ambitious environmental policies and by a strong and vocal public support, especially in the age of social media, institutions and industries have now fully incorporated sustainability into their agendas. Aside from this more politically-driven preference, future homeowners will be enticed by the substantially reduced use stage operation and maintenance costs, while investors will benefit from improved marketability and increased market valuation through time of energy-efficient buildings. In addition, European governments are taking the top-down approach of relaxing taxation for buildings that follow sustainable guidelines, supporting builders that choose to be on the frontline of this progressive but almost inevitable change.

The eurostat (2020) study presented in Figure 2.1 illustrates the annual growth of key economic indicators since the beginning of the millennium. The last year data (2017) shows the clear growth of environment-related activities when compared to the overall economy. Such performance can be taken as a sign of the potential of this still relatively new industry, and it can serve as a forecast for the growth of sustainability assessment as a major frontier for the Construction Industry.

The environmental economy encompasses activities and products that serve either of two purposes: ‘environmental protection’ — that is, preventing, reducing, and eliminating pollution or any other degradation of the environment or ‘resource management’ — that is, preserving natural resources and safeguarding them against depletion. (eurostat 2020)

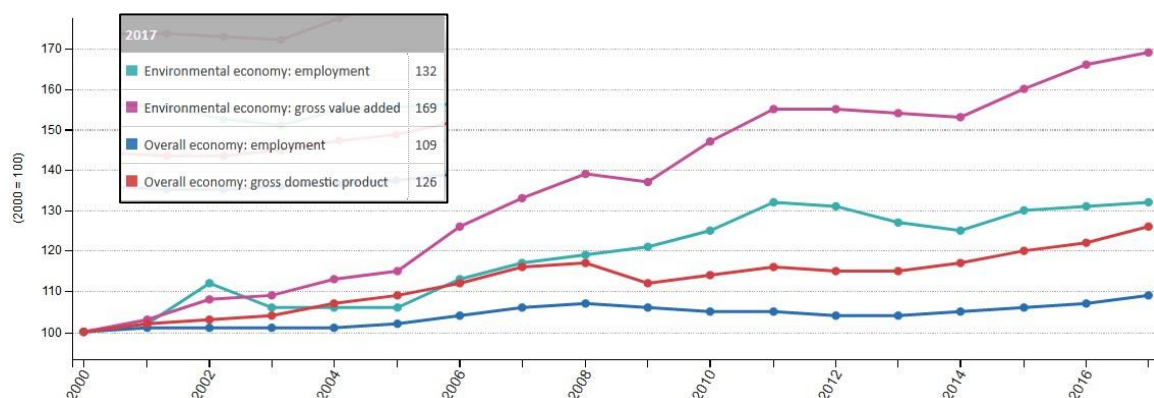


Figure 2.1 – Annual trends in employment and economic share of environment-related activities, EU-27, 2000-2017 (eurostat 2020)

2.2. MAIN CONCEPTS (CIRCULAR ECONOMY AND LIFE CYCLE ASSESSMENT)

Intrinsically connected to the assessment of a building's sustainability, and fundamental to the Level(s) framework structure, are the concepts of Circular Economy (CE) and Life Cycle Assessment (LCA). The importance of describing them together comes from the fact that CE provides a strategic framework for looping material flows and LCA complements it by focusing on assessing the related environmental effects of different impact categories and ultimately producing data essential for efficient decision making.

The **Circular Economy** approach can be simplified to the creation of a self-regenerative system where waste or end-of-life products are recycled and/or reused as the input for another process, leading to a considerable reduction of the use of raw materials. This approach comes as a very welcome shift away from the typical linear path of consumption and production models, also known as take-make-use-dispose (Camana et al. 2021). This nearly obsolete approach to construction materials was based on the assumption introduced by the Industrial Revolution that resources are abundant, easy to find and cheap to dispose of. A dramatic change of mindset is now being incorporated by some of the world's leading economies as one of the many policies that intend to make the human world more sustainable. In the European Union, the 2020 Circular Economy Action Plan, a prerequisite to achieve the Union's milestone of climate neutrality by 2050, introduced legislative and non-legislative measures aiming to reduce pressure on the continent's natural resources. The construction industry, being responsible for half of the total extraction of natural resources in the European economy, will bear particular responsibility to accommodate these measures (European_Commission 2020b).

The **Life Cycle Assessment (LCA)** (standardized in the ISO 14040) permits a building's environmental impacts, from the extraction of the raw construction materials to the disposal of waste, to be measured (Nematchoua, Asadi and Reiter 2020). LCA methodologies, with a particular focus on the one adopted by Level(s), are based on a few key notions essential for their approach (Dodd, Donatello and Cordella 2021a):

- Life cycle stages: the different stages of a building's life. The standardized version used by Level(s) is depicted in Figure 2.2;
- Impact categories: the different categories of environmental impacts, spread across the different life stages, that will be quantified and reported in their own units of measurement;

- Hot spots: the points in the life cycle of a building that produce the greatest environmental impact. They can be related to stages of the building's life (e.g. use stage), building processes (e.g. concrete mixing, steel manufacturing), or specific building components (e.g. rooftop insulation, facade).

Application of these notions also reduces the “burden shifting” factor – which refers an impact appearing later in a project because it was avoided (but not solved) at an earlier stage – simply by associating and keeping track of all the data variations of the building's different life cycle stages. As European legislation shifts the new construction panorama towards the highly energy-efficient Nearly-Zero Energy Buildings (NZEB), LCA will also see a reconfiguration of the stages' relative impacts – the use stage environmental impact will be minimized, while the early stages impacts related to the construction materials take a bigger percentage. These considerations make LCA an important tool to monitor innovations, making sure the steps being taken are indeed moving the Construction Industry forward.

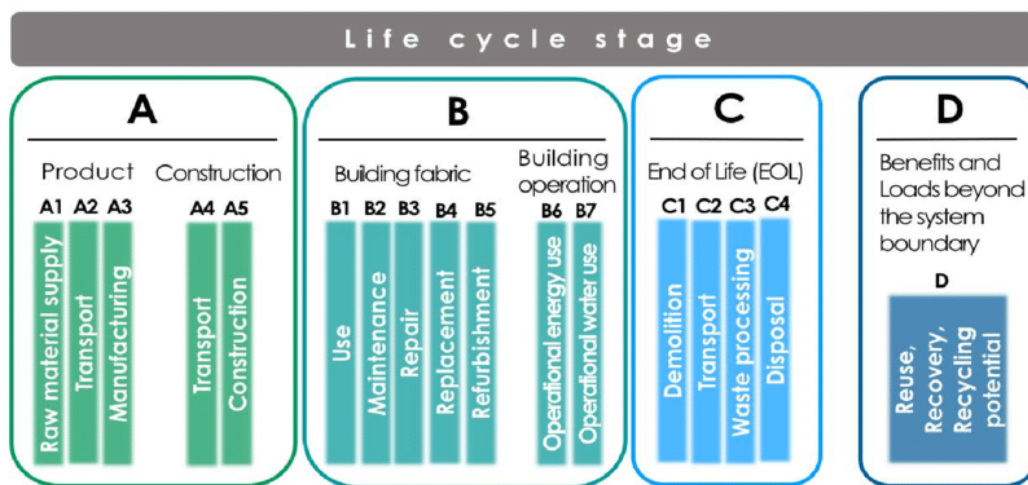


Figure 2.2 – Stages in a building's life cycle, adopted from the EN 15978:2011 standard (Cadorel and Crawford 2019)

The joint concepts of Circular Economy and Life Cycle Assessment both work at their best when applied in concert to the same systems, buildings, and projects. Such is the case for Level(s); the framework takes a holistic approach to the environmental impact of the full life cycle of buildings, and on this account, it communicates exceptionally well with the European policies that aim to make the continent more sustainable. As illustrated in Figure 2.3, the first three macro-objectives of the method comprise a full LCA of a given building in defined impact categories, so that a starting point for improvement can be identified and reviewed. The macro-objectives of Level(s) are defined in much more detail in [Chapter 3](#).

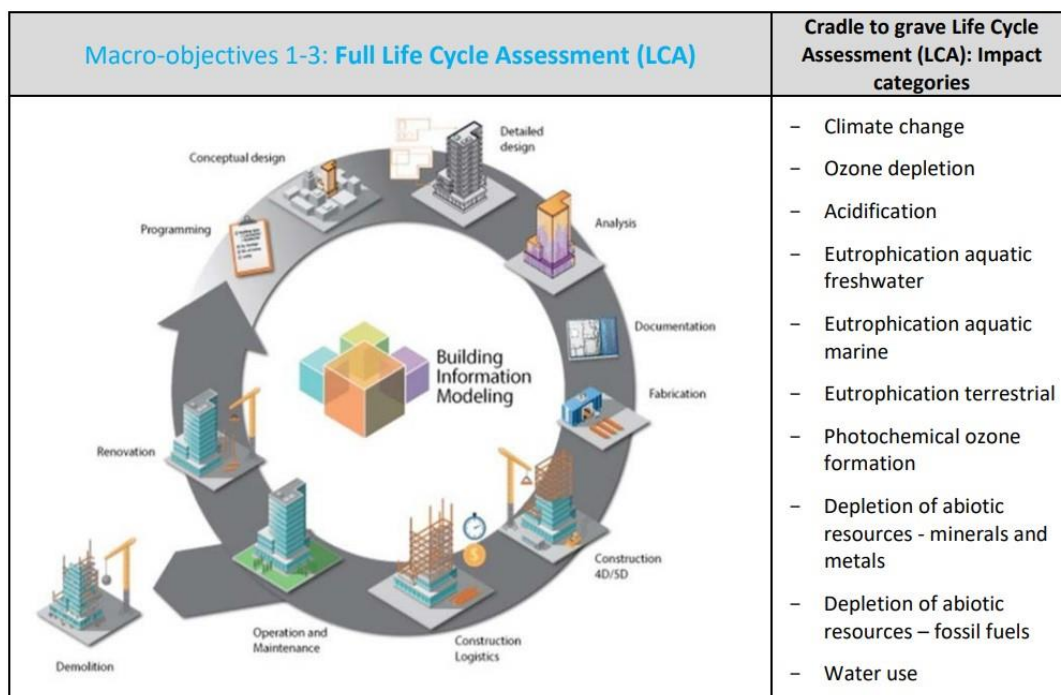


Figure 2.3 – Level(s) take on CE and LCA, and its impact categories (Dodd, Donatello and Cordella 2021a)

2.3. BUILDING SUSTAINABILITY ASSESSMENT METHODS (BSAM)

2.3.1. INTRODUCTION

Fueled by the need to determine how sustainable a building was, countries and stakeholders started promoting systems that assessed the environmental performance of buildings – the BSAM. An apparent consensus among academic papers is that a sustainable building must be highly efficient in its use of energy, water, and materials, and must show reduced impacts on health and on the environment throughout its life cycle. And this congruence is one of the few factors that connects the vast field of BSAM.

In Europe, country-specific or international adaptations of some of the field's most notorious methods (BREEAM and LEED in particular) have proliferated in the market, creating a heterogeneous mix that very much reflects a culturally and technically diverse continent like Europe – see Figure 2.4. To better place Level(s) inside this highly particular field, a survey of current methods were chosen to be summarized, including BREEAM, LEED, LiderA, and SBTool^{PT}. They stand as some of the most prominent and well-developed systems in the European Union, where Level(s) is targeted, and in the Portuguese Construction Industry, where the present essay's case study is located.

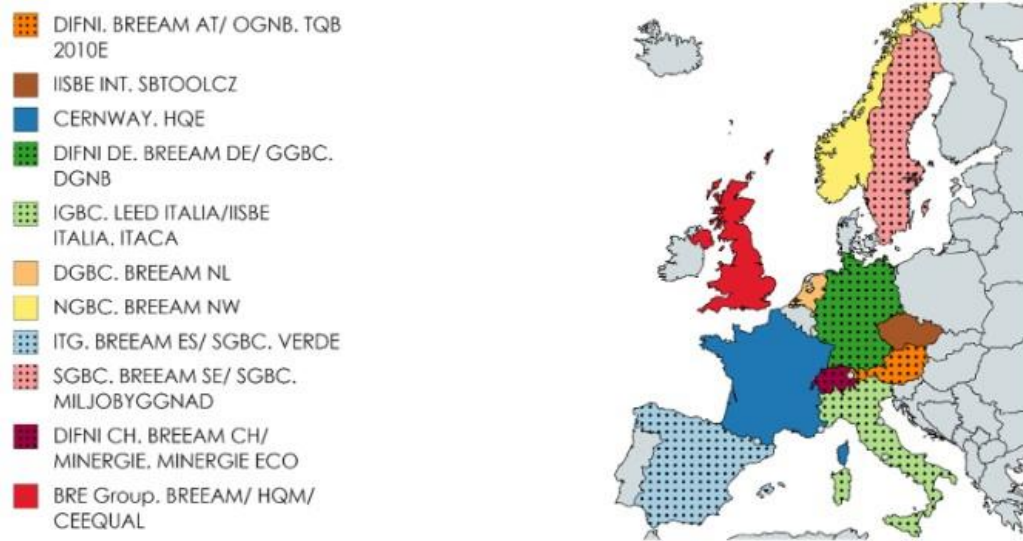


Figure 2.4 – Most Representative BSAM in the European Union (Cordero, Melgar and Márquez 2019)

2.3.2. BUILDING RESEARCH ESTABLISHMENT'S ENVIRONMENTAL ASSESSMENT METHOD – BREEAM

BREEAM is today's leading and most commonly applied environmental assessment method for buildings. Created in 1990 by the Building Research Establishment (BRE), it holds the longest continuous tenure of all building environmental assessment methods. Despite being initially only applied in the United Kingdom, it was an early pioneer in the field, and has seen countless adaptations following the release of the BREEAM International version in 2008. Today, the international version also contains a group of different schemes aimed towards different types of projects – Communities; Infrastructure; New Construction; In Use; and Refurbishment and Fit Out. Additionally, and where the number of certified buildings is sufficiently high, BRE promotes cooperation with local institutions to adapt its international version to the local conditions, regulations and language (Cordero, Melgar and Márquez 2019). Due to its proximity to the scope of this case study, the scheme and version referenced here is the BREEAM International New Construction 2016 SD233 v2.0 (BREAM INT NC).

The basic conceptual unit of BREEAM INT NC is the Criteria, which is a performance standard which must be met in order to receive a rating; the Criteria are grouped under Issues, of which there are 57; and those Issues are classed under the ten Categories, nine of which are environmental, while the last relates to Innovation (Figure 2.5). Like many other BSAM that followed, the minimum sustainability performance Criteria are the preconditions to being rated, and do not award Points for compliance. The assessment process itself starts with a checkup for those Criteria; if even one of them is not met, the building will receive a zero rating for the respective Issue, regardless of its other accomplishments.

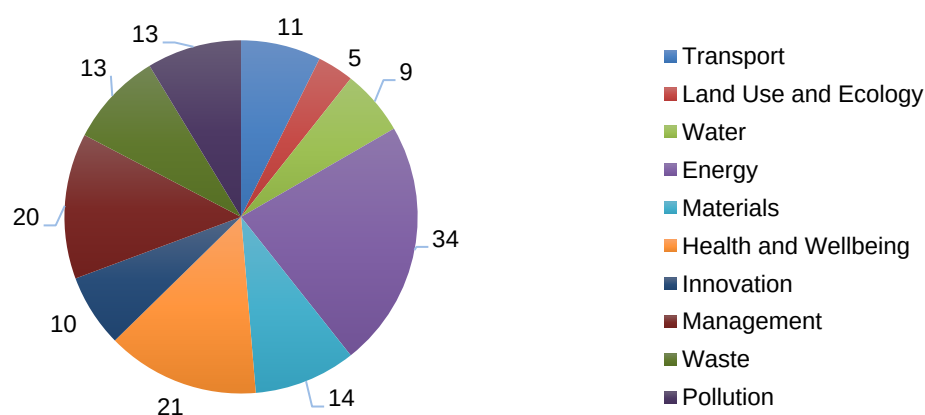


Figure 2.5 – BREEAM INT NC Points per Categories (BRE 2017)

To obtain the final certification, BREEAM INT NC uses a bottom-up calculation method. Each Category's Points (awarded by the performance of their respective Issue) is divided by the total Points of the Category and multiplied by its weighing factor (i.e., Category Points divided by 150, the total possible Points), resulting in a percentage score. Those percentages are then summed to record a total assessment for the building, and a rating is then awarded according to Table 2.1.

Table 2.1 – BREEAM INT NC assessment ratings (BRE 2017)

BREEAM Certification Level	SCORE (%)
Outstanding	≥ 85
Excellent	≥ 70
Very Good	≥ 55
Good	≥ 45
Pass	≥ 30
Unclassified	< 30

2.3.3. LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN – LEED

Developed and released by the United States Green Building Council in 1998, LEED is a rating system that measures the sustainable performance of various types of buildings or clusters, throughout their life cycle and regardless of their use. The LEED certification system has since expanded to encompass more than 93,000 registered projects in over 163 countries, sticking out not only as a BSAM but also as a positive indicator of construction and residential quality, high standards, and environmental responsibility. It is today one of the field's most used and adapted assessment tools (USGBC 2021b). Like BREEAM, the most recent version of LEED (v4.1) offers different schemes that can be used to perform assessments in any type of project: Building Design + Construction; Interior Design + Construction; Operations + Maintenance; Residential; Cities and Communities; and Recertification. This study will review the Building Design + Construction scheme (LEED BD+C), which most closely resembles the new construction project at the focus of this study.

As described in Figure 2.6, LEED BD+C projects can earn points in 8 Categories, and by conduct a LEED Integrative Process (awarding 1 point). In each Category, a total of 62 Credits and respective Requirements provide at least 1 point, whereas the minimum level of sustainable practice merely fulfil obligatory Requirements and are awarded no points.

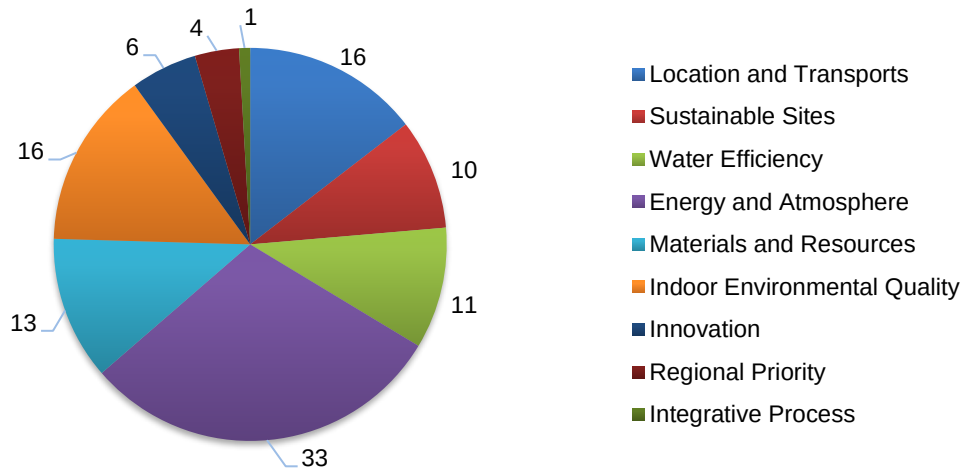


Figure 2.6 – LEED BD+C achievable points (USGBC 2021a)

Also applying a bottom-up scoring system, but removing the weighing factor that BREAM uses, final LEED BD+C scores can be obtained by simply adding the points obtained in each Credit. There is a maximum of 110 possible points (100 for the basic Categories + 10 possible points awarded for the special Category Regional Priority and Innovation, for exceptional performance of the overall building). Based on these guidelines, projects can achieve one of the following certifications:

Table 2.2 – LEED BD+C Certification and scores (USGBC 2021a)

LEED BD+C Certifications	SCORE
Platinum	80-110
Gold	60-79
Silver	50-59
Certified	40-49

These certifications are valid for a period of 5 years, requiring new performance evaluation afterwards, using the LEED Recertification scheme, which is more focused on the management of the facility.

2.3.4. LIDERAR PELO AMBIENTE – LIDERA

LiderA, created in 2005, is a Portuguese sustainability assessment and certification method with the purpose of supporting the search for sustainability in the construction industry. Like many other country-specific methods, LiderA is loosely inspired by BREEAM and adapted to better fulfill the standards of the Portuguese construction industry.

Its structure is composed of 6 main Threads that are divided into 22 Areas with corresponding Criteria. These Criteria, all of equal weight, are examined and placed within a qualitative qualification bracket –

G, F, E, D, C, B, A, A⁺, A⁺⁺, from inferior to superior performance – respective to standard or reference values, which are represented by bracket E. Figure 2.7 exposes the weight distribution by percentage of the 6 main Threads of the method.

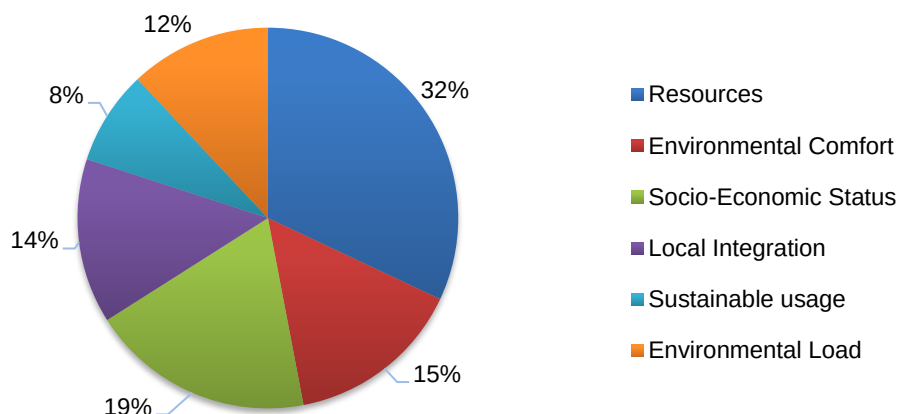


Figure 2.7 – LiderA's Threads percentual distribution (Pinheiro 2011)

In a procedure very similar to the one described for BREEAM, the different Criteria scores are aggregated, according to their different weights, into qualifications for the 22 Areas, for the 6 main Threads, and then ultimately for the last score and LiderA's final certification - clarified in Table 2.3.

Table 2.3 – LiderA certification and scores (Pinheiro 2011)

LiderA Certification Rating	SCORE
A ⁺⁺	10 times the performance than the reference value
A ⁺	4 times the performance than the reference value
A	2 times the performance than the reference value
B	1.60 times the performance than reference value
C	1.33 times the performance than reference value
D	1.14 times the performance than reference value
E	Equal performance to the in practice or standard value
F	0.89 times the performance than reference value
G	Less than 0.80 times the performance than reference value

2.3.5. SUSTAINABLE BUILDING TOOL PORTUGAL - SBTTool^{PT}

SBTool^{PT} was launched in 2009 and is the Portuguese version of SBTool – a flexible framework for rating the sustainability performance of buildings, designed to be easily adapted to different regions and building types. Likewise, this country-specific method was developed and tailored to the Portuguese

scene by the joint forces of 3 Portuguese entities: the construction company ECOCHOICE, the International Initiative for a Sustainable Built Environment Portugal (iiSBE Portugal), and the *Laboratório de Física e Tecnologias da Construção da Universidade do Minho* (iiSBE 2009).

Unlike LiderA, which is a single version (V2.00c) since 2011, SBTool^{PT} has seen continuous development and today there are multiple versions, or schemes, for assessing different projects and realities. Some of them are SBTool^{PT}-H, for residential buildings; SBTool^{PT}-T for touristic projects; SBTool^{PT}-S, for service buildings; and the SBTool^{PT}-UP, for Urban Planning assessments. Although they have similar structures, these methods differ on the number and type of indicators assessed as well as on how that assessment is performed and their respective standard practices (Castanheira and Bragança 2014). For the purposes of this study, the summarized scheme will be the SBTool^{PT}-H, developed by Mateus and Bragança (2011b) which is the one that more closely resembles Level(s), the case study, and the previously analyzed BSAM.

The structure of SBTool^{PT}-H consists of 9 Categories divided into a total of 25 Indicators to be individually evaluated. Figure 2.8 summarizes the different Categories of the method, with respective percentage weights.

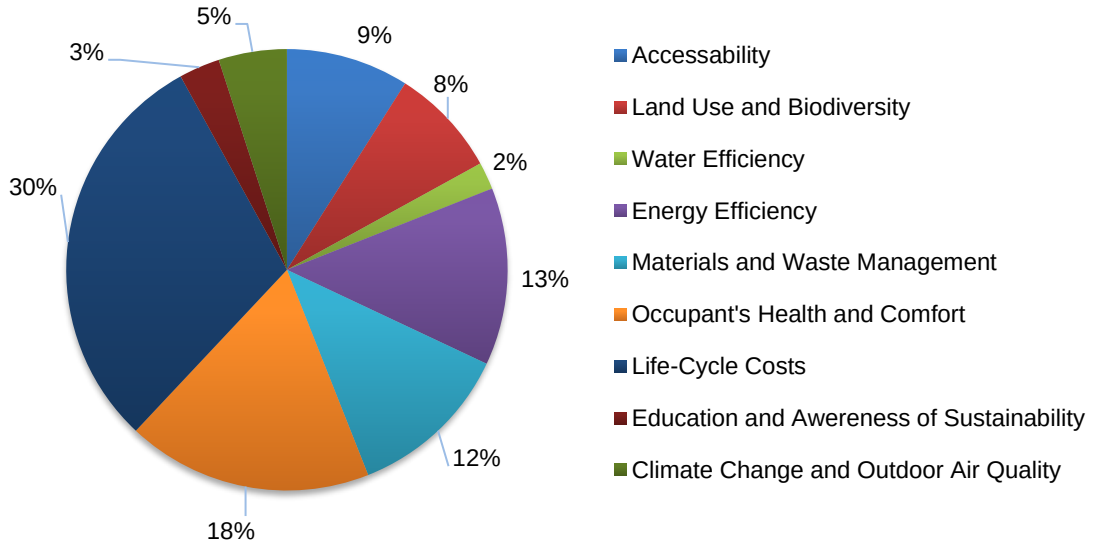


Figure 2.8 – SBTool^{PT}-H Categories and percentual weights (Mateus and Bragança 2011b)

Their assessment, much like LiderA, is strongly connected to reference values, but is calculated using a simple equation of normalization. Here, and in order to defuse a common problem of some indicators being of the type “higher is better” or “lower is worse”, the normalized value of the i th indicator ($\bar{P}_i$) is obtained by comparing the assessed value (P_i) to the best (P_i^*) and worst (P_{*i}) values in use in the Portuguese building sector (Mateus and Bragança 2011b).

$$\bar{P}_i = \frac{P_i - P_{*i}}{P_i^* - P_{*i}} V_i \quad (1)$$

Ultimately, after obtaining the performance of the different indicators and considering the weight of both the method's Categories and Indicators, a final value for $\bar{P}$ is obtained and project is graded

according to Table 2.4. This calculation process is identical across all subsystems of the SBTool network.

Table 2.4 – SBTool^{PT}-H grades and scores (Mateus and Bragança 2011b)

SBTool ^{PT} -H Grades	SCORE
A ⁺	$\bar{P} > 1.00$
B	$0.70 < \bar{P} \leq 1.00$
C	$0.40 < \bar{P} \leq 0.70$
D	$0.10 < \bar{P} \leq 0.40$
E	$\bar{P} < 0.00$

3

UNDERSTANDING LEVEL(S)

3.1. METHOD INTRODUCTION

The many voluntary sustainability certification or assessment tools already in operation throughout Europe, with thousands of project assessments already done, indicates the maturity and knowledge of the building sector for this type of initiative. But on the other hand, the differences between these diverse processes cause logistical issues for efforts to comply with the European and National legislation and with the goal of carbon neutrality by 2050. This factor creates the widespread need to continuously adapt each main BSAM to individual countries (e.g. BREEAM ES, BREEAM NL, BREEAM DE, SBToolPT, SBToolCZ, LEED Italia) or even to create new, country-specific, methods (e.g. LiderA in Portugal, Minergie-ECO in Switzerland, Miljoyggnad in Sweden). The whole European picture amounts to more than 500 BSAM indicators (Cordero, Melgar and Márquez 2019) working at the same time, resulting in a confusing and hard to manage situation for both policy makers and stakeholders, and slowing down the construction industry's efforts to adapt to the growing standards of environmental friendliness. Kestutis Sadauskas, the Director for the Circular Economy and Green Growth at the European Commission's Directorate-General for the Environment, signaled his understanding of this continent-wide issue. He stated that "to truly achieve sustainable transformation in the building sector, we need a common language that not only could be used across the building chain, but also help with data comparison across different countries" (European_Commission 2020a). Level(s) aims to sort out this puzzling picture by providing a simple structure of indicators established completely within EU regulations, with its array of diverse national calculation tools, and on the field's major practices.

This brand-new European framework was pitched to the BSAM sector as the framework that will deliver the common reference language of sustainability to the European construction sector, allowing comparison on sustainable building growth and providing transparency and robustness to European Sustainability policies. Putting the same methodologies and language into practice in every country, Level(s) aims to further enable the creation of aligned European and National policies and boost the dissemination of sustainable construction. By taking a flexible and holistic attitude to building projects, the tool has the potential to efficiently, effectively, and realistically respond to the need to broadly adjust building practices to climate change.

It is important to note that Level(s) differs from the other major BSAMs as it is not a certification system, nor does it come with benchmarks. It simply sets out the methodology for how to work with a restricted number of indicators that collectively characterize the key attributes of a building's sustainability performance over its full life cycle.

3.2. DEVELOPMENT

The framework was proposed by the European Union, and it was developed and launched in beta form by the Joint Research Centre (JRC), also known as EU's Science Hub, in August of 2017. The official testing phase occurred between April 2018 and May 2020 and was made available to any organization interested in being part of Europe's shift towards circular and lifecycle thinking. Figure 3.1 illustrates the distribution of tests in Europe, amounting to 74 residential and 62 office building case studies. Figure 3.2 shows the mix of testers, ranging from the construction to the real estate sector; the diversity in the testing pool was a necessary factor in this phase, so that a vast majority of opinions and ideas would be represented in the assessment. During this phase, Kestutis Sadauskas and his team reportedly found that “the building sector sees the common language and metrics, and the fact that different stages of the building chain came together to find a common solution, as an important added value of this framework. In a way, we are not just harmonizing data and metrics: we are also harmonizing the built environment's vision of a sustainable future” (European_Commission 2020a).

According to the JRC team and a final test survey, more than 60% of the testers' project leaders and teams had extensive previous experience making environmental or sustainability performance assessments of buildings, focused on the use of different LCA tools, BREEAM, LEED and others, while close to 20% had limited to no experience on this field (Nicholas Dodd 2020).

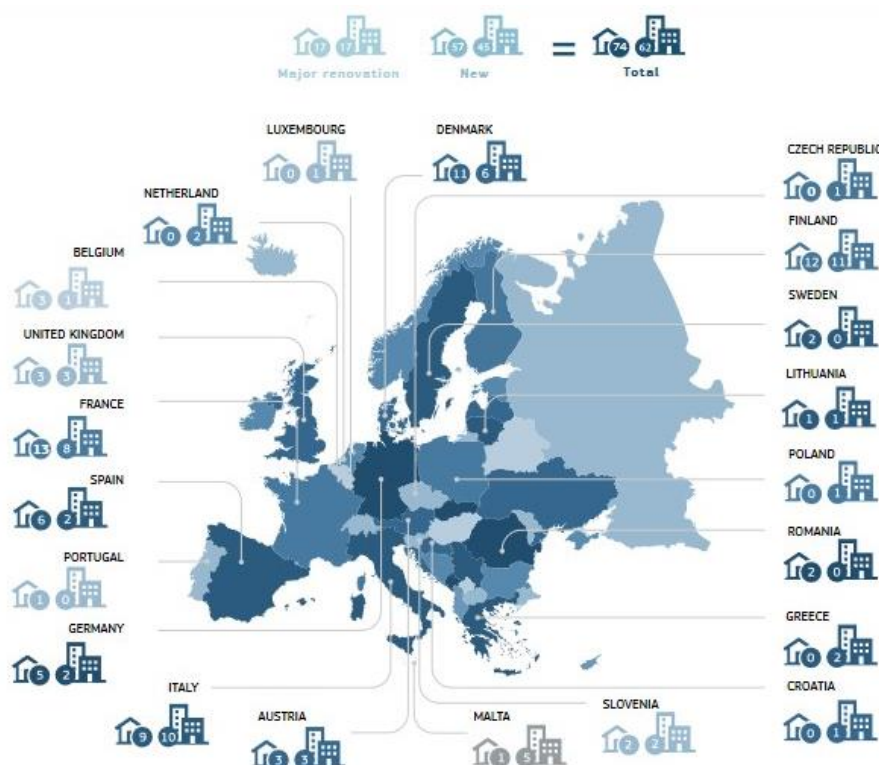


Figure 3.1 – Distribution of Residential and Office tests (JRC 2019)

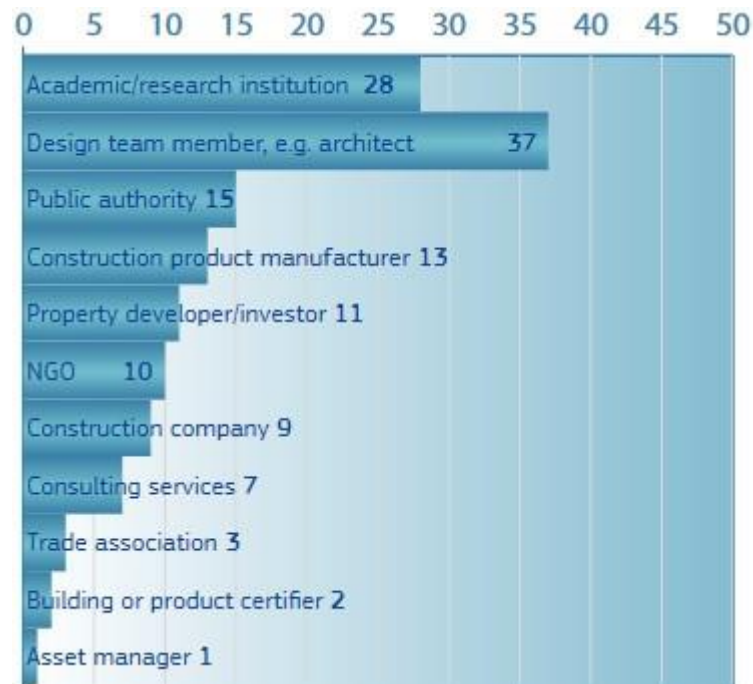


Figure 3.2 – Test's Project Leaders (JRC 2019)

The key aim of the testing phase was to understand the challenges associated with applying Level(s), and what barriers may inhibit Level(s) from becoming mainstream for all types of users across Europe, independent of their experience level in the field. After all the reports and suggestions were received, the end result saw major changes to the method's initial core structure due to the heterogeneity of the testers' field of operation, experience, and to the simple fact that the very concept of a sustainable building has morphed substantially in the past 4 years. A good example of this progress can be the emerging theme of social aspects, extensively brought up due to the COVID-19 pandemic, which was indeed among the last to be incorporated before the method's final version public launch, in October 2020 (Díaz-López et al. 2021).

However, as a project in active development and evaluation, Level(s) still has a few more imminent improvements. At the time this study is being carried out, the agenda available on Level(s) website has the following upcoming initiatives (JRC 2021a).

During the year of 2021:

- Web-based support tool to work with Level(s) and web-based training materials.
- New Public Private Partnership under Horizon Europe.
- Implementation of the “Sustainable Finance – tackling climate change” Delegated Act.

For June 2022:

- Green Public Procurement (GPP) criteria based on Level(s) for offices and schools – both new built and renovation.

In fact, this active development created the need to continuously update this thesis, due to releasing new official supporting material and updating some less advanced indicators.

3.3. STRUCTURE

The common framework structure contains 6 Macro-Objectives (MO) (see Figure 3.3) and 16 Indicators that can be applied on 3 distinct levels, corresponding to different stages of the full life of a building. This structure is based on the 3 key Themes of European Sustainability policies: environment (by performing a Life Cycle Analysis; MO:1,2,3), economics (by applying the Circular Economy philosophies; MO:5,6) and social wellbeing (by including distinct health and comfort analysis; MO:4).



Figure 3.3 – Macro-Objectives (Dodd, Donatello and Cordella 2021a)

The structure of the method's extensive environmental ambitions is deeply connected to the definition of these 6 main categories. In fact, the Indicators are simply a separation of those goals into subcategories that allow for a more organized impact assessment and comprehension. Likewise it is important to present a summary of each MO that reflects the official definitions presented by Dodd, Donatello and Cordella (2021a) on Level(s) User Manuals.

- MO1 aims to reduce the carbon footprint of buildings along their full life cycle and considers both energy emissions occurring during the use phases and the embodied energy expenditures.
- MO2 seeks to control the generation of waste by optimizing the building design to allow lean and circular methodologies. It tries to defeat common linear theories by boosting deconstruction and recycling as opposed to demolition.
- MO3 has the sole goal of improving water usage efficiency through minimization and reutilization, taking a particular focus on buildings located on areas with current or estimated future water shortages.
- MO4 focus on creating buildings that are great to live in. This is done through imposing measures that control indoor environmental quality leading to comfortable, attractive, and productive buildings that are healthy to live in.
- MO5 takes the climate change projections into consideration and imposes measures to futureproof the buildings' performance and minimize possible risks to the property values and investments, as well as occupier's safety and comfort.
- MO6 is completely set on the economic aspect of the building's life and provides an extended overview of the whole life costs as well as guidelines on how to increase market valuation by integrating sustainability practices and features.

Recapping the above information, Table 3.1 compiles the method's **Themes** and **Macro-Objectives**, and introduces its **Indicators**.

Table 3.1 – Overview of Level(s)

Themes	Macro-Objectives	Indicators			
Resource use and environmental performance	1. Greenhouse gas emissions along a building's life cycle	1.1 Use stage energy performance (kWh/m²/yr)	1.2 Life cycle Global Warming Potential (CO2 eq./m²/yr)		
	2. Resource efficient and circular material life cycles	2.1 Bill of quantities, materials, and lifespans	2.2 Construction and Demolition waste and materials	2.3 Design for adaptability and renovation	2.4 Design for deconstruction, reuse, and recycling
	3. Efficient use of water resources	3.1 Use stage water consumption (m³/occupant/yr)			
Health and comfort	4. Healthy and comfortable spaces	4.1 Indoor air quality	4.2 Time outside of thermal comfort range	4.3 Lighting and visual comfort	4.4 Acoustics and protection against noise
Cost, value, and risk	5. Adaptation and resilience to climate change	5.1 Protection of occupier health and thermal comfort	5.2 Increased risk of extreme weather events	5.3 Sustainable Drainage	
	6. Optimized life cycle cost and value	6.1 Life cycle costs (€/m²/yr)	6.2 Value creation and risk exposure		

Level(s) projects can employ the above structure to assess two kinds of buildings – **Offices** or **Residential Buildings** – in two project types – **New Construction** or **Major Renovation**. Differences in the execution of those assessments are minimal and can only be observed within the few Indicators that provide distinctive instructions for each project type.

The 3 Levels within the framework, which give the system its name, reflect the depth of the assessment stage and are one of the great innovations introduced by the method. Ideally, a project would be assessed at every level to provide the most accurate picture possible of the building's degree of sustainability. However, the individual Levels are not required to be employed in concert. This structure provides users with a choice on how complex their project's sustainability assessment will be, and it corresponds to the following stages of the project execution:

- **Level 1 - Conceptual design:** The simplest level, requiring mostly qualitative assessments of the advancements made during the early stages of the project and on the concepts meant to be applied.
- **Level 2 – Detailed design and construction:** Matching regulated units and methods, quantitative assessments of the design performance and examinations of the construction start to be applied on this intermediate level.
- **Level 3 – As-built and in-use:** The last and most advanced level is done after handover of the completed project to the client and showcases the complete building performance. It requires both monitoring and surveying of the activity on the construction site and of the complete building's first tenants.



Figure 3.4 – The Levels of Level(s) (Dodd, Donatello and Cordella 2021a)

Some indicators go a step further in providing instructions for assessment activities that should only be performed after a certain stage of development is completed. Table 3.2 illustrates the suggestive project stages associated with each of the 3 Levels.

Table 3.2 – Suggestive project stages associated with each level.

Level 1	Level 2	Level 3
L1a. Project definition and brief	L2a. Outline design (spatial planning and permitting)	L3a. As-built design
L1b. Concept design	L2b. Detailed design (tendering)	L3b. Commissioning and testing
	L2c. Technical design (construction)	L3c. Completion and handover
		L3d. Occupation and use

As this study will show in [Chapter 4](#), various combinations of Levels can be applied to different Level(s) indicators for a vast number of reasons. According to the user's priorities, needs or skills they have, for example, the options to:

- Work only at one Level;
- Work up to a specific level (e.g. from Level 1 to Level 2);

- Combine different Levels (working only with Level 1 and later on monitoring the performance at Level 3);
- Apply different alternatives to each indicator.

This organization comes as one of the main strengths of Level(s) since it permits a flexible and progressive adaptation of the tool to the distinct phases of the building's life and to the user's main objectives, urgency, and competences. Major implementation, which for many new projects like Level(s) comes as one of the main difficulties, is then facilitated.

The method is also intended to be applied by a **full team of distinct specialists**, especially created and accountable for their respective tasks. The overarching structure of Level(s) requires an efficient flow of information and data, covering many specializations and involving strong application coordination by a team leader. This phase, although not of major importance for the present single-author case study, is one of the main components for a successful real-life application of the method.

The greatest value can be added by integrating the framework into the building's project roadmap, since by doing this, sustainability will in fact become a key priority apace with other factors such as cost and timing. Table 3.3 displays the planning required by Level(s) for an effective full-scale application. Producing answers for these questions before the initial steps of the building's design will allow for efficient preparation and initiation of this complex assessment, leading to its complete assimilation in the project developments.

Table 3.3 – Initial project planning (Dodd, Donatello and Cordella 2021b)

Workflow Items	Planning Required
Level(s) Performance Assessment	Has the team received a briefing on Level(s) and how it will be used?
	Have milestones been established by the team for each indicator assessment?
	To whom will responsibilities for making each indicator assessment be assigned?
	Who will co-ordinate the Level(s) indicator assessments?
	Does the team have the training and expertise to make all the Level(s) assessments? If not, how will the gaps be bridged?
Information and Data Management	How will the flow of information and data required to make each indicator assessment be managed?
	Will BIM be used and if so, how could it support Level(s) assessments?
Renovation Baseline	Will it be a major renovation project? - If so, how comprehensive is it planned to be?
	How will the baseline survey of the building and its fabric be carried out?
	What information will be needed from the baseline survey in order to make the indicator assessment?
Property Market Valuation	How will Level(s) indicator performance aspects be taken into account in the building's market valuation?

	How and at what points in the project will dialogue be established between the project team and the valuer?
External Verification	Will third party verification of the Level(s) assessment results be required? If so, by whom and at what point in the project?

Ultimately, an essential component for the viability of this method is the **comparability factor**. Each indicator has specific instructions that allow a minimum comparison to a functionally equivalent building. A **principle of equivalence** is also followed, meaning that national and private tools can sometimes be used if they are explicitly supported by the rules of each Level(s) indicator. This aims to serve as a clever way to motivate users of other BSAM to start working with Level(s) without having to completely change their usual procedures. The following list was extracted from the method's first User Manual (Dodd, Donatello and Cordella 2021a) and describes how compatibility is supported by the framework:

- Use of common units of measurement.
- Completion of the Level(s) building description.
- Use of the cited reference standards and methods.
- The required reporting on key parameters, assumptions, and data quality, in order to ensure transparency.
- The rules stipulated that are specific to Level(s) and which:
 - Fix key parameters,
 - Provide default data,
 - Define calculation assumptions.

3.4. LEVEL(S) IN THE BSAM SPECTRUM

After exploring the structure of Level(s), it is important to introduce a comparison of the novel framework to a set of commonly used BSAMs, already presented in [Chapter 2.3](#). The early stages of the method's public version, and its current development roadmap, will in fact lead to further developments in the distinct indicators and on the way some assessments are completed. Additionally, updated versions of BREEAM, LEED, LiderA and SBTool^{PT} may be released, targeting the methods to either approximate or distinguish themselves from Level(s). It is therefore necessary to explicitly announce the various method's versions being used to perform this comparative survey – see Table 3.4. All the versions or schemes used are the most recently published ones available at the time of this thesis elaboration.

Table 3.4 – Surveyed method's information

BSAM	Version	Published	Documents URL
Level(s)	V1.1	2021	Level(s) Documents
BREEAM	International New Construction SD233 2.0	2016	BREEAM NC
LEED	LEED V4.1 Building Design and Construction	2021	LEED V4.1
LiderA	V2.0	2011	<i>Documentação</i> LiderA

SBTool ^{PT}	SBTool ^{PT} -H	2011	Mateus and Brangança Article
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Comparing these methods side by side can sometimes be a confusing endeavor due to the variety of concepts applied by each. It is also not an advantage that each User Guide is extensive and sometimes rather ambiguous. Understanding the Structure of each method is a great initial step to begin their individual comprehension. But to accurately compare the data between them, it is necessary to establish a group of denominations that aggregates the different method's hierarchies. This thesis suggests a **Category**, **Subcategory** and **Benchmark Enabler** hierarchy to fulfill this necessity. Categories and Subcategories are the main branches of each method, and the ones that weigh the different environmental impacts. What this study calls Benchmark Enablers are measures or values that allow the performance of a building to be evaluated by each method. A fourth category, named Themes and taking the top position of the hierarchy, could have been added, but since its components (Economy, Environment, and Society) are shared between the 5 methods, it was deemed unnecessary for this comparison. Table 3.5 uses these suggested denominations, organized with the data compiled in the previous chapters, to place the methods together.

Table 3.5 – Side by side BSAM placement.

BSAM	Category System	Subcategory System	Benchmark Enabler
Level(s)	Macro-Objective (6)	Indicator (16)	-
BREEAM	Category (10)	Issue (57)	Criteria
LEED	Category (8)	Credit (62)	Requirements
LiderA	Thread (6)	Area (22)	Reference Value
SBTool ^{PT}	Category (9)	Indicator (9)	Reference Value

It is hard to ignore the particularity of Level(s) not providing Benchmark Enablers that would allow projects to achieve a sustainability score. Still, it is the method's main aim to introduce planning, debates, and sustainable decision-making from the early stages of the project, eventually leading to full integration of the method on project developments. The intended lack of Benchmarks allows the concentration of workforces on applying Level(s), ensuring the sustainability of the project throughout its life cycle, and establishing a future-proof building. Following this complete process can, in the right conditions, defeat the need for ranking and certification.

However, there a lot of advantages to certifying performances, and some of the methods stated were able to elevate their certificates to reflect the highest standards that a construction project can attain. In this vein, the lack of certification within Level(s) also opens the way for other methods to include its guidelines within their respective certification schemes. This possible general adaptation of the framework to the different broadly used BSAMs would indeed help fulfill one of Level(s)' main objectives – instating a common language of sustainability assessment.

It is therefore quite interesting to assess the influence that Level(s) would impose on these methods. Their distinct scoring systems – percentages, points/credits, and grades – makes them hard to fully compare under the same conditions. Nevertheless, results can be obtained if a system normalization is imposed. To calculate this influence, this study performed a group of normalizations and associations with the intention of attributing a percentage score to each BSAM Category and Subcategory and in the

end uniting them with Level(s). This process, based on the author's interpretation of the different methods' characteristics, is described as follows.

- Aggregating the different Categories and Subcategories.
- Calculating Approximated Percentage Weights for the different Categories and Subcategories scores (to permit comparison between the different scoring systems) – Results described in Annex A:.
- Comparing every method Category and Subcategory with Level(s)' Macro-Objectives (MO) and Indicators, learning which ones bear most resemblance.
- Associating Categories to the Level(s) MOs and attributing them their respective percentual scores – shown in Table 3.6 and compiled on Figure 3.5.

In Table 3.6, Level(s) is delineated by its MOs and by their respective number of Indicators (I). Beneath every other BSAM, the left column describes how much influence (in percentage) Level(s) would impose in the method's scoring system, while the right column displays what Category/Thread – presented by its Reference name – corresponds to each MO. In the special cases where this arrangement was not accomplished, an explanatory note was added to the bottom of the table. Refer to [Annex A](#): for more information on the different percentages and Category's Reference names.

Table 3.6 – Level(s) possible influence on common BSAMs assessment schemes (BRE 2017; USGBC 2021a; Pinheiro 2011; Mateus and Bragança 2011b)

Level(s)		BREEAM		LEED		LiderA		SBTool ^{PT}	
MO	I	%	Category	%	Category	%	Thread	%	Category
1. Greenhouse gas emissions along a building's life cycle	2	31.14	Ene + Pol	33	EA	19	(**)	13	EE
2. Resource efficient and circular material life cycles	4	17.37	Wst +Mat	13	MR	8	(**)	12	MWM
3. Efficient use of water resources	1	6	Wat	11	WE	8	(**)	2	WE
4. Healthy and comfortable space	4	14	Hea	16	IQ	15	EC	18	OHC
5. Adaptation and resilience to climate change	3	0.67	(*)	-	-	6	(**)	5	CC
6. Optimized life cycle cost and value	2	-		-	-	3	(**)	30	LCC
Totals		69.38		73		59		80	

(*) Partial fulfilment by the "Adaptation to Climate Change" Issue, of the Waste Category. The weight of said Issue was removed from the MO2 estimation, which also included the Waste Category.

(**) Due to the structure of LiderA, associating full Threads to the MOs was not always viable. Likewise, the following association of Criteria was then chosen: MO1 – "Energy" and "GHG Emissions"; MO2 – "Materials" and "Waste"; MO3 – "Water"; MO5 – "Environmental Management"; MO6 – "Life Cycle Cost".

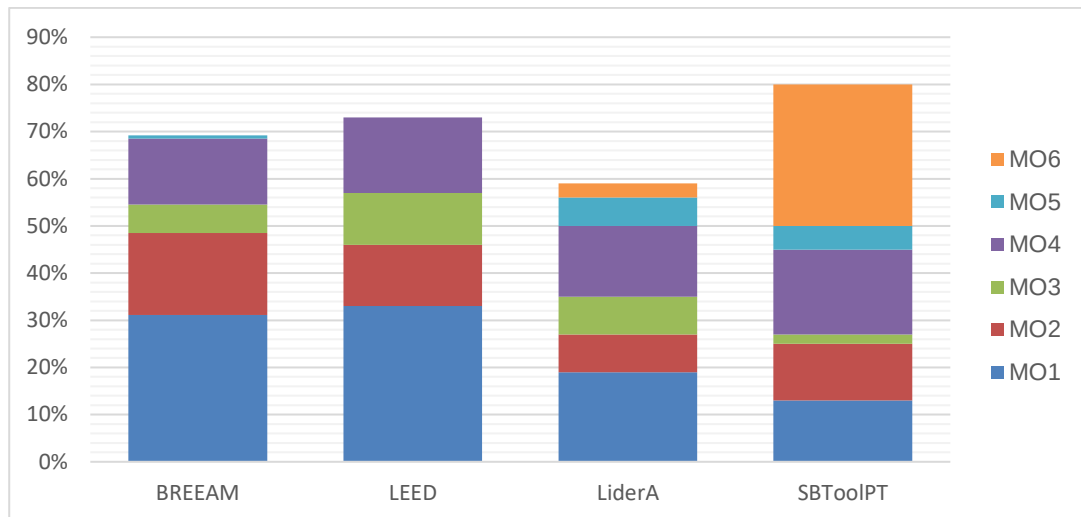


Figure 3.5 – Breakdown of Level(s) influence on each assessment scheme

Because of the different structures of this group of BSAMs, each would be affected differently and to different extents by integrating the Level(s) framework into its assessment scheme. Data shown in Figure 3.5 state that Level(s) produces the most overall influence over SBTool^{PT} (80%) followed by LEED (73%), BREEAM (69,38%) and LiderA (59%).

The preeminence of the influence on SBTool^{PT} can be attributed almost exclusively to the outsized role of its parallel with MO6, compared to the absence or near absence of effect in that category for the other assessment schemes. SBTool^{PT} is the only method that effectively provides extensive Life Cycle Cost (LCC) assessments (MO6), which constitutes an important factor for the holistic approach to sustainability found in Level(s). Moreover, SBTool^{PT} provides the most straightforward association with Level(s) since it is possible to connect single Categories to the different MOs.

The influence breakdown for LiderA demonstrates that it, among all the BSAMs surveyed, would bear the most evenly distributed influence across the Categories, rather than being disproportionately impacted along the axis of one or another MO. This could indicate that LiderA would be most accommodating to an incorporation of the Level(s) framework within its existing assessment scheme.

It is interesting to see that the biggest discrepancy in overall influence is between the two Portuguese BSAMs. It might be expected that two methods tailor-made around the same year for the same country would present similar performances. However, LiderA seems to be more aimed to the true environmental impacts of the projects, while SBTool^{PT} performs a more holistic assessment, which is in fact what Level(s) also aims to do. The small weight attributed by LiderA to MO6 (LCC) in contrast with SBTool^{PT} is an indication of this distinction.

BREEAM and LEED bear a rather similar amount of influence, both on their total influence scores, and on the discrete MOs associated. The qualities of these two field pioneers seem to be aimed to a more exclusive assessment of environmental impacts, leaving behind the economic concepts contained in LCC. However, all the BSAMs consider impacts related to Land Use and/or Transportation, which Level(s) does not directly include. This incongruity is one of the reasons that the influence of Level(s) is capped at a certain value.

Ultimately, the previous data also suggests that future versions or schemes of BREEAM, LEED, LiderA, and SBTool^{PT} can very well be adjusted to increase synergy with Level(s). In fact, its alignments with European policies and goals, its lack of a certification scheme (which allows it to avoid appearing as a competitor), and all its comparability factors and principles of equivalence can only be seen, taken

together, as an open call for implementation in and unification of the many partakers of the Building Sustainability Assessment field. And if such call is accepted, Level(s) will succeed in unifying the Union under a common language for sustainability.

3.5. BRIEF APPLICATION GUIDE

The following guide is based on the first two manuals of Level(s) official documentation (Dodd, Donatello and Cordella 2021a, 2021b) and aims quickly describe some of this study's steps and interpretations of the method, when applied to Residential Buildings. It is divided in three parts.

The first part is entitled “**Part 1 – Establishing a Level(s) Project Plan**”. It concerns the first steps of the planning phase of the assessment and is intended to provide an overview of all the information that will be necessary, as well as the team members that will participate in it. For the present study, there will be no need to decide on team members since every assessment will be performed by the writer. The following list compiles the initial steps to be taken:

- Decide on the Macro Objectives and Indicators to report;
- Select the Level each of the chosen Indicators will have;
- Complete the project planning matrixes with the previous information;
- Plan the workflow requirements to make the assessment, and gather all the information needed to the work.

The second part is entitled “**Part 2 – Complete Building Description**”. The Building Description is an important component of working with any BSAM. In Level(s) it is a crucial part, especially in quantitative assessments (Levels 2 and 3) since its information standardizes the results of various indicators. Additionally, it provides a transparent basis for comparing the performance of different buildings. The following list shows the information that Level(s) requires for the Building Description, as well as a few authorial suggestions regarding how to obtain precise data:

- **Location:**
 - Country and Region;
 - Heating and Cooling degree days:
 - Also known as HDD and CDD;
 - Easily calculated with JRC's PVGIS TPY (Photovoltaic Geographical Information System - Typical Meteorological Year) tool.
 - Climate Zone:
 - To be chosen from Figure 3.6's Climate Zone, corresponding to the project's closest representative city.

Climate zone	Parameters		Representative cities
	Heating degree days	Cooling degree days	
Zone 1	<1500	>1200	Athens - Larnaca - Luga - Catania - Seville - Palermo
Zone 2	<1500	>800 - 1200	Lisbon - Madrid - Marseille - Rome
Zone 3	>1500-3000	400-800	Bratislava - Budapest - Ljubjana - Milan - Vienna
Zone 4	>1500-3000	<400	Amsterdam - Berlin - Brussels - Copenhagen - Dublin - London - Macon - Nancy - Paris - Prague - Warszawa
Zone 5	>3000	<400	Helsinki - Riga - Stockholm - Gdansk - Tovarene

Figure 3.6 – Climate Zones for Level(s) assessments (Dodd, Donatello and Cordella 2021b)

- **Building typology and age:**
 - New building or major renovation:

- Level(s)' assessed projects are considered a Major Renovation if the cost of renovation is higher than 25% of the total value of the building, excluding the value of the land or more than 25% of the surface of the building undergoes renovation.
- **Year of construction**
- **Market segment:**
 - By form of tenure, choose between: Owner occupation - Leasehold, social - Leasehold, market rental - Leasehold, student - Leasehold, seniors - Other (to be described).
- **How the Building will be used:**
 - Conditions of use:
 - Default conditions of use are provided in Annex C of the EN 16798-1;
 - Parameter usually defined by the national calculation method for assessing the building's energy requirements.
 - Intended or required service life:
 - Reference study period for all the Level(s)' assessed buildings is 50 years;
 - It is possible to additionally report on the performance of the building for the clients' intended service life.
- **The building model and characteristics:**
 - Building form:
 - To be chosen from: Free standing, detached house – Semi-detached house – Row or terraced house – Multi-family house or apartment block (up to 5 floors; 5-9 floors; more than 9 floors).
 - Total useful floor area:
 - Basic reference to be used: one square meter of useful internal floor area;
 - Using International Property Measurement Standards (IPMS): Standard 3B;
 - INCLUSIONS:
 - Area in exclusive occupation, including the floor area of internal walls and columns;
 - Floor area measured to the internal dominant face and the finished surface of all full-height internal walls;
 - Fully glazed partitions are not regarded as permanent internal walls.
 - EXCLUSIONS:
 - Patios;
 - Unenclosed parking areas, which may be measured or defined by the number of spaces;
 - Staircase openings;
 - Voids where the area, including the enclosing wall, is greater than 0.25 m².
 - Scope of building elements to be assessed and the categorization system used:
 - Minimum scope of the building parts and associated elements must be defined. Level(s) provides a suggestive categorization system, which will be used in this study and can be found in Figure 3.7.

Building parts	Related building elements
Shell (substructure and superstructure)	
Foundations (substructure)	Piles Basements Retaining walls
Load bearing structural frame	Frame (beams, columns and slabs) Upper floors External walls Balconies
Non-load bearing elements	Ground floor slab Internal walls, partitions and doors Stairs and ramps
Facades	External wall systems, cladding and shading devices Façade openings (including windows and external doors) External paints, coatings and renders
Roof	Structure Weatherproofing
Parking facilities	Above ground and underground (within the curtilage of the building and servicing the building occupiers) ⁹
Core (fittings, furnishings and services)	
Fittings and furnishings	Sanitary fittings Cupboards, wardrobes and worktops (<i>where provided in residential property</i>) Ceilings Wall and ceiling finishes Floor coverings and finishes
In-built lighting system	Light fittings Control systems and sensors
Energy system	Heating plant and distribution Cooling plant and distribution Electricity generation and distribution
Ventilation system	Air handling units Ductwork and distribution
Sanitary systems	Cold water distribution Hot water distribution Water treatment systems Drainage system
Other systems	Lifts and escalators Firefighting installations Communication and security installations Telecoms and data installations
External works	
Utilities	Connections and diversions Substations and equipment
Landscaping	Paving and other hard surfacing Fencing, railings and walls Drainage systems

Figure 3.7 – Level(s) categorization of building parts and respective elements (Dodd, Donatello and Cordella 2021b)

The third part of the guide is entitled “**Part 3 – Apply the indicators.**”

After completing the elaboration of the project plan and evaluating the categorization of the building, the user has all the initial steps necessary to start applying the indicators. Due to the extensive works and uniqueness of each of the 16 indicators, the guidelines stating how the author understood each indicator and how their assessment was performed will be presented in the Method Application chapter.

4

METHOD APPLICATION

4.1. INTRODUCTION AND LEVEL(S) PROJECT PLAN

Following the guide elaborated in the previous chapter, the initial step in applying Level(s) is the elaboration of the Project Plan. This study will address all the six macro-objectives and the 16 corresponding indicators. However, the extent of the Indicator applications will vary according to the case study information available, and the time constraints imposed on this dissertation.

Level(s) is intended to be applied by a team of different specialists, triggering conversations and debates between the project's team leaders, beginning in the early days of the project. The qualitative and quantitative assessments made in the course of these debates are to be seen as the foundation for deeper changes in some of the project categories that ultimately lead to a more efficient building. To allow that, an initial Project Plan of a true Level(s) application should include the planning of workflow requirements (previously described in Table 3.3), attributing individual roles and responsibilities to experts, specific training (if required) and imposing deadlines for key activities to be completed. Since a single person elaborated this study, such a step could not be performed, and the assessments were performed to the best of the author's abilities.

Some assessments require data that is either not customarily calculated in Portugal (and would therefore require extensive calculations that are not possible in the time window available for this dissertation) or that involves precise information that was not available at the project's current stage. In some such cases, the author used standard values to estimate missing components. In other cases, where no reliable data was available for the building project, a commentary section elaborates how the Indicator would have been applied if more information had been at hand, and thus may serve as guides to future researchers applying the framework to a building project with more complete data. Each indicator assessment will signal the extent that an application was possible, and the approach taken to bring it to fruition.

The building project is still in a preconstruction phase (corresponding to Level 2), which will not allow Level 3 assessments to be fully performed on this analysis.

The compilation of the Levels applied to each indicator, together with some relevant additional information is described in Table 4.1. There, and for each Indicator, the assessment level applied is displayed on the second leftmost column. The next three columns state if the writer provided summaries for each level instructions with the intent of exploring what they entail (n.a. means that official guidelines are yet not available for users). And rightmost column provides additional information that the write deemed relevant for the comprehension of each application.

Table 4.1 – Overview of the Assessments

Indicator	Assessment	Inst.L1	Inst.L2	Inst.L3	Additional Information
<u>1.1</u>	L2	Yes	Yes	Yes	-
<u>1.2</u>	-	Yes	Yes	Yes	Delineation of a projected L2 application
<u>2.1</u>	L2	Yes	Yes	Yes	Full L2 application with illustrative data
<u>2.2</u>	-	Yes	No	No	-
<u>2.3</u>	L1	Yes	No	No	Overview of L2 and L3 instructions
<u>2.4</u>	-	Yes	No	No	Overview of L2 and L3 instructions
<u>3.1</u>	L2	Yes	Yes	Yes	Full L2 application with a standard value
<u>4.1</u>	-	Yes	No	No	Overview of L2 and L3 instructions
<u>4.2</u>	-	Yes	No	No	-
<u>4.3</u>	L1	Yes	n.a.	n.a.	-
<u>4.4</u>	L1	Yes	n.a.	n.a.	Additional reporting on quantitative measurements
<u>5.1</u>	-	Yes	No	No	-
<u>5.2</u>	L1	Yes	n.a.	n.a.	-
<u>5.3</u>	L1	Yes	n.a.	n.a.	-
<u>6.1</u>	-	Yes	No	No	Overview of L2 and L3 instructions
<u>6.2</u>	-	Yes	n.a.	n.a.	-

An important part of this section is to organize and manage the information that will be used in the course of applying different indicators, both for understanding how much information gathering must be done, and to create a baseline for comparison with other buildings undertaking a similar analysis.

The data, corresponding to the preliminary design phase of the project – was cordially provided by the project's team to be used as a case study in this dissertation. The following list outlines the information accumulated. Throughout the application of the method, the source of the data used will be indicated, and the author will reference one of these documents.

- Water Supply Project
 - Project description and water supply calculations
 - Drawings
- Gas Supply Design
 - Design description and licensing
 - Drawings
- Acoustics Performance Project
 - Project description
 - Calculations
- Architecture Designs
 - Project description

- Drawings including topography, floor plans, construction details, facades, and views
- Rainwater Drainage System Design
 - Design description including hydraulic calculations
 - Drawings
- Greywater Drainage System Design
 - Project description including hydraulic calculations
 - Drawings
- Electrical Designs
 - Design description, quantities, and specifications
 - Electronic installation drawings (including switchboards, and sourcing)
- Portuguese Energy Performance Certificate (EPC)
 - Energy performance calculations
 - Description with the calculation's results
- Fire Safety Design
 - Design description and licensing
- Telecom Design
 - Drawings containing the wiring network

4.2. BUILDING DESCRIPTION

The project under assessment is a refitment of an abandoned industrial lumber yard into a social housing complex in the northern region of Portugal (Figure 4.1). It is part of the *Plano Operacional Regional do Norte* (or NORTE2020), a Portuguese financial instrument (backed by the European Regional Development Fund) for supporting the development of the northern region. One of its purposes – to preserve and protect the environment and promote efficient use of resources – describes a priority of “adopting measures to improve urban environments, revitalize cities, recover and decontaminate abandoned industrial zones, reduce air pollution, and promote noise reduction” (CCDRN 2020). This priority aligns with the refitting of abandoned industrial spaces and units into multifamily housing or public use spaces, which is an approach with vast potential to support the purposes of the program and contribute to a sustainable use of resources and land and preventing urban expansion.

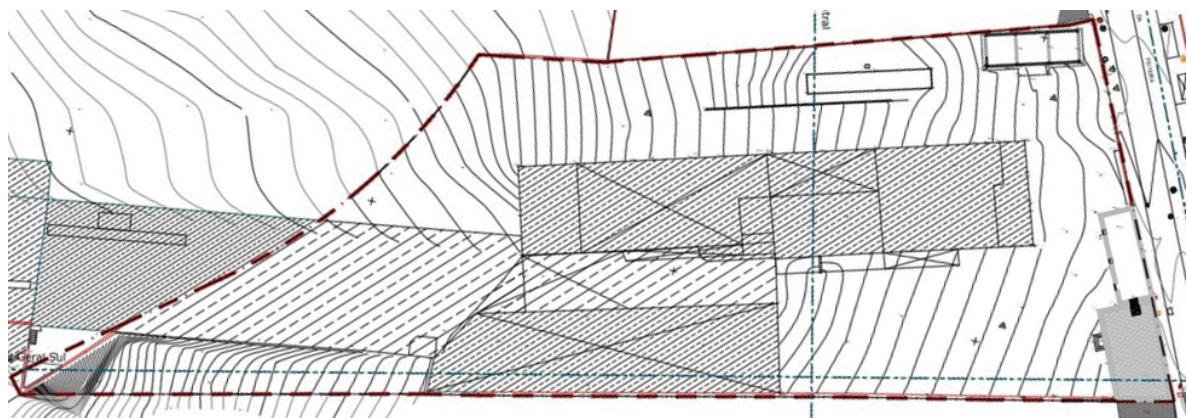


Figure 4.1 – Site Plan, current state (taken from the Architectural Design)

The intended tenants of the project are three different communities with a total of 31 families (115 individuals) of a socially and economically marginalized population, currently living in different nuclei of precarious constructions (tents). The early project stages defined three building blocks of multi-

family houses composed in total by 12 two-bedroom apartments (T2), 16 three-bedroom apartments (T3) and six four-bedroom apartments (T4) (34 total apartments).

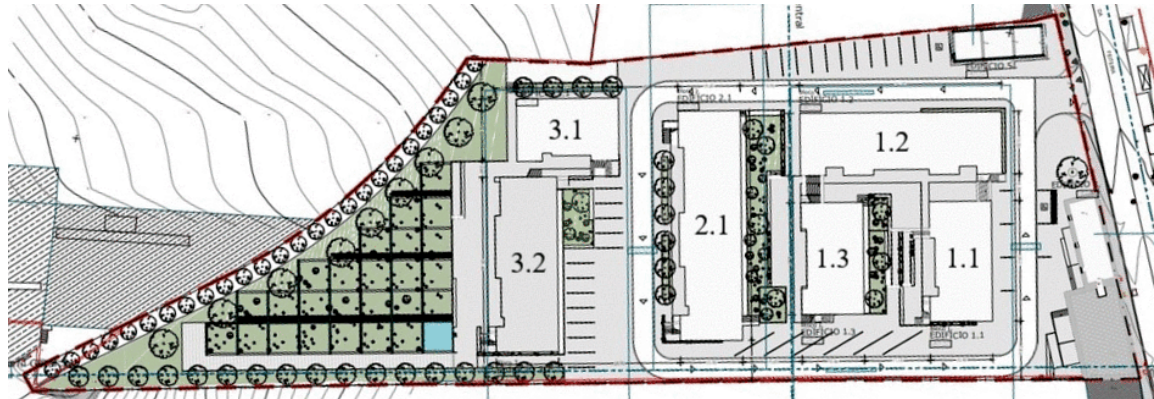


Figure 4.2 – Site Plan Proposal (taken from the Architectural Design)

The three blocks have a total of six two-story residential buildings (Figure 4.2), of identical volume and typologies with the goal of creating equal living conditions for the various families of future tenants and to maintain social status. This uniformization of construction solutions, appliances and dimensions also leads to considerable reduction of operational costs, a major factor in such a large project. For the objectives and methods of the present study, said uniformization permitted a singular focus on only one of these residential buildings – **Building 1.1** located on block number 1 and composed by two T2 and two T4 apartments – since the results can very well showcase the whole picture of the complex. The Building Description of that building, in accordance with this thesis guide ([Chapter 3.5](#)) and Level(s) requirements, is as follows.

▪ **Location:**

- Country and Region:
 - Portugal, northern region.
- Heating and Cooling degree days:
 - HDD: 1020
 - CDD: 0

Provided inputs:	
Location [Lat/Lon]:	~~41.153, -8.623~~
Horizon:	Calculated
Period:	2007 - 2016
Simulation outputs:	
Average temperature [°C]:	15.13
Heating Degree Days:	1020
Cooling Degree Days:	0

Figure 4.3 – HDD and CDD results for the project location (PGIS – TMY)

- Climate Zone:
 - Zone 2 (according to Level(s) designations set on Figure 3.6)
- **Building typology and age:**
 - New building or major renovation:

- New building.
- **Year of construction;**
 - Estimated completion in 2022.
- **Market segment:**
 - Leasehold, social.
- **How the Building will be used:**
 - Conditions of use:
 - Temperature set between 18°C and 25°C, ventilation rate of 24h per day. Assessed for the two cooling and heating seasons (Summer and Winter)
 - Intended or required service life:
 - 50 years, corresponding to the Level(s) reference period.
- **The building model and characteristics:**
 - Building form:
 - Multi-family apartment block with 2 floors.
 - Total useful floor area:
 - 316.02 m², obtained by adding the useful floor area of the building's four apartments: $98.14 + 98.14 + 59.87 + 59.87 = 316.02 \text{ m}^2$
 - Scope of building elements to be assessed and the categorization system used:
 - Due to the length of this part of the building description, the scope will be delineated in a new list, below.

To present a consistent way of describing the building, this study will follow the suggested minimum scope of building parts and elements, described in Figure 3.7. External Works are not defined on the project and will likewise not be described here. Since the available information about the project still does not have an extensive Structural Design available, most of the information was gathered by examining the drawings of the Architecture Design.

In terms of the **Shell** (substructure and superstructure) the building is composed by:

- Foundations:
 - Reinforced concrete footing with waterproofing coverings.
 - Reinforced concrete piling walls with waterproofing coverings.
 - No basements.
- Load Bearing Structural Frame
 - Reinforced concrete columns.
 - Reinforced concrete beams .
 - Concrete rib and hollow block slabs.
- Non-load Bearing Elements:
 - Ground floor slab made of reinforced screed, *tout-venant*, and gravel over compacted soil.
 - Internal walls
 - Partition walls: single brick (30x20x22cm, 30x20x17cm or 30x20x7cm) walls with rock wool insulation.
 - Separating Apartments: double brick (30x20x7cm) wall with mineral wool insulation.
- Facades:
 - Apartment doors: wooden panel doors
 - External walls: concrete hollow brick (50x20x25cm) with external ETICS solutions
 - Window spans: Aluminum frames with thermal cut and double glass. Equipped with exterior blinds inserted in high density polystyrene roller blinds boxes.

- Roof:
 - Pitched roof, with a metallic structure (I beams) and sandwich panels.

In terms of the **Core**, the building is composed by:

- Fittings and furnishings:
 - Sanitary fittings: Single-flush toilets, showers, baths, bidets, and sinks.
 - Cupboards, wardrobes, and worktops: not described.
 - Wall finishes: painted sanded plaster, ceramic baseboards.
 - Ceiling finishes: painted sanded plaster.
 - Floor coverings: ceramic over a screed layer.
- In-built lighting systems:
 - Light fittings: LED technology, 3000°K color temperature
 - Control systems and sensors: *Quadro 45* – Siza Viera series (Efapel).
- Energy system:
 - Heating plant and distribution: not described/available.
 - Cooling plant and distribution: not described/available.
 - Electricity generation: outsourced and distributed by an underground PEAD 63 tube.
- Ventilation system:
 - Air handling units: centrifugal plug fan.
 - Ductwork and distribution: made with galvanized steel.
- Sanitary systems:
 - Cold Water distribution: polypropylene tubing.
 - Hot Water distribution: polypropylene tubing.
 - Water treatment systems: not described/available.
 - Drainage system:
 - Rainwater: rooftop steel gutters and downspouts.
 - Greywater: polypropylene tubing
- Other systems:
 - Firefighting installations: fire hydrant outside of the building.
 - Telecoms and data installations: wired network and maneuvering boxes.

In addition to what is required by the Level(s) Building Descriptions, the following denominations for the four apartments of the building are announced in Table 4.2. These denominations will be used to better understand the assessments, since most of the building's available data is calculated or described for each of its dwellings. Figure 4.4 shows the distribution of the ground floor, repeated on the first floor.

Table 4.2 – Building Apartments.

Apartment	Area	Typology	Floor
A	98.14	T4	Ground
B	59.87	T2	Ground
C	98.14	T4	1 st
D	59.87	T2	1 st



Figure 4.4 – Building 1.1 ground floor disposition (taken from the Architectural Design)

4.3. USE STAGE ENERGY PERFORMANCE (INDICATOR 1.1)

4.3.1. DEFINITION AND SCOPE OF THE APPLICATION

The first Level(s) indicator reports on the **primary energy use**, which is perhaps the industry's most frequently assessed metric. This indicator measures the energy and fuels (including natural gas and biomass) consumed in the processes of generating and supplying the energy necessary for heating and cooling, for running technical building systems such as security and elevators, and for heating water. Linked to a growing awareness of their economic and environmental advantages, renewable energy generators are a growing technology in almost every major building. Likewise, the indicator also allows reporting on the quota of primary energy demand that is supplied by this source, a factor that will be present in this study. This indicator is regulated and instructed by the Level(s) User Manual 3: Indicator 1.1 (Dodd, Donatello and Cordella 2021c).

The unit of measurement is **kilowatt hours per square meter per year (kWh/m²/yr)**. The energy demand must be assessed for the total useful floor area of the building, already calculated in the Building Description.

For evaluating this Indicator, a **Level 2** assessment of the design data will be performed. The project's available information allows a quick adaptation of the Portuguese preliminary energy performance calculations to this intermediary level. Neither Level 1 nor Level 3 assessments are relevant to this

application due to the project's already completed design phase and it's not yet started construction phase, respectively. To define the scope, Figure 4.5 showcases the activities related to the different Levels of this Indicator.

Level	Activities related to the use of indicator 1.1
1. Conceptual design (following design principles)	✓ Design, material selection and detailing according to principles for cost-optimal minimum requirements and Nearly-Zero Energy Buildings (NZEB). ✓ Selection of tailored solutions for major renovation works.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ Calculated building permitting assessment: design or tailored ✓ Calculated EPB assessment sub types: as built
3. As-built and in-use (based on commissioning, testing and metering)	✓ Construction quality testing: air tightness and building fabric integrity ✓ Commissioning: functional performance testing and seasonal testing. ✓ Measured EPB assessment sub types: climate corrected, use corrected or standard

Figure 4.5 – Review of the activities related to the Use-Stage Energy Performance Indicator (Dodd, Donatello and Cordella 2021c)

In order to complete said activities for a Level 2 assessment, the following steps were performed:

- Complete the reporting table that identifies systems to be used to obtain the necessary data.
- Gather the data related to the energy performance of the building and the primary energy factors needed.
- Calculate the values of the building's energy needs.
- Convert the calculated energy needs into total primary energy by applying each primary energy factor.
- Complete the final Level(s) reporting tables with the previous calculations.

The **information necessary** for this indicator was found on the project's verification of the *Regulamento de Desempenho Energético dos Edifícios de Habitação* (REH) which issues the Portuguese national Energy Performance Certificate (EPC). This national calculation method is in accordance with Annex 1 of the Directive 2010/31/EU (energy performance of buildings), as required by Level(s) to ensure comparability.

4.3.2. RESULTS

The assessment begins by completing the first reporting table, to identify the assessment that will be performed.

Table 4.3 – Indicator 1.1 assessment identification

Level 2 Reporting Item	Information
Type of assessment	Building Permit
Calculation method	REH, Portugal
Energy needs included in the calculation method	Heating, Cooling, Hot Water, Ventilation
Unregulated energy needs assessed	None

Following this contextualization, the different types of energy needs were then calculated for each apartment, according to the stated energy carrier.

Heating is provided by the forced circulation of hot water, heated by an electric system.

Table 4.4 – Heating delivered energy needs in kWh/yr

	A	B	C	D	Total
Electricity	3188.45	1910.41	3119.42	1880.46	10098.74

The total primary energy needs for Heating are calculated for the building's total floor area, considering a primary energy factor of 2.5 for electricity use.

$$\text{Primary Energy for Electricity} = 10098.74 \times 2.5 \div 316.02 = 79.89 \text{ kWh/m}^2/\text{yr} \quad (2)$$

Cooling systems were deemed unnecessary for the majority of the building's fractions. However, the high solar exposure of fraction C (oriented towards the south), required the consideration of some cooling energy needs.

Table 4.5 – Cooling delivered energy needs in kWh/yr

	A	B	C	D	Total
Electricity	0	0	153.66	0	153.66

$$\text{Primary Energy for Electricity} = 153.66 \times 2.5 \div 316.02 = 1.22 \text{ kWh/m}^2/\text{yr} \quad (3)$$

The building will have natural **Ventilation**, processed by self-adjusting grids (FLATAIR-EPC). The delivered energy needs for this process are null.

Hot Water is produced by solar panels (renewable energy) and supported by an electric resistance system (electricity) blended into the solar panel's reservoirs. The final energy needs for these systems are:

Table 4.6 – Hot water delivered energy needs in kWh/yr

	A	B	C	D	Total
Renewable	1923.00	1009.00	1923.00	1009.00	5864
Electricity	1127.53	832.22	1127.53	832.22	3919.5

The total primary energy needs for Hot Water are calculated for the building's total floor area, considering a primary energy factor of 1 and 2.5 for renewable energy and electricity usages, respectively.

$$\text{Renewable} = 5864 \times 1 \div 316.02 = 18.56 \text{ kWh/m}^2/\text{yr} \quad (4)$$

$$\text{Primary Energy for Electricity} = 3919.5 \times 2.5 \div 316.02 = 31.01 \text{ kWh/m}^2/\text{yr} \quad (5)$$

Although required by Level(s), the Portuguese national calculation method still does not account for the **Lighting** parcel of energy demands, and no data was offered that made reliable estimates possible. For calculation purposes, a factor of 2% was added to the total primary energy value to account for this

parcel, in accordance to European estimates for this parcel's share in total energy consumption (European_Commission 2013).

Table 4.7 – Delivered energy needs.

Energy Needs	Fuel or Energy carrier	kWh/yr
Heating	Electricity	10098.74
Cooling	Electricity	153.66
Ventilation	Natural	0
Hot Water	Electricity	3919.5
Lighting	-	Estimated
Other	-	-

Lastly, the **Total Primary energy** of the building is calculated by joining parcels, with a 2% increment corresponding to the lighting demands estimate. Renewable energy, as a neutral impact on this concept, is not included.

$$Total\ Primary\ Energy = (79.89 + 1.22 + 0 + 31.01) * 1.02 = 114.36\ kWh/m^2/yr \quad (6)$$

4.3.3. COMMENTARY

The application of this indicator did not produce many difficulties since variations of the required assessment are commonly found on any type of preconstruction project. However, Level(s) is structured to consider the complete building and has no mention of how to proceed in cases when there are individual apartments composing a building, as in this case study, whereas the data available and the energy performance calculations present in the REH were calculated for the individual apartments, as is usual for REH's approach to multi-family buildings.

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the energy design concepts described in Figure 0.1 (Annex B) were introduced into the design process, and if so, in what way.

For a **Level 3** assessment, a complete and final Energy Performance Certificate would be needed, complemented with real-time measures. These would be accomplished by installing meters prior to handout, which would record air tightness and thermal integrity. Data would start to be collected after a pre-defined minimum time and for pre-defined minimum duration. New calculations for the measured delivered energy needs and primary energy use would then be performed and a reporting table (Figure 0.1 – Annex B) equal to the one used for Level 2 is to be completed.

4.4.LIFE CYCLE GLOBAL WARMING POTENTIAL (INDICATOR 1.2)

4.4.1. DEFINITION AND SCOPE OF THE APPLICATION

The main contributor to climate change is the carbon that is released by human activity into the atmosphere. Once released, carbon functions as a “greenhouse” gas, resulting in rising global temperature and sea level. Because of the large share of carbon emissions claimed by the Construction Industry (Programme 2020), it is necessary to take real steps to understand and to limit the amount of carbon that the industry is responsible for releasing.

For this reason, Level(s) considers the Global Warming Potential (GWP) of a building project's entire life cycle. A building's GWP, measured in **kg CO₂ equivalents per m² of useful floor area over 50 years**, considers all the direct and indirect emissions of greenhouse gases throughout the entire projected lifespan of the building project. This cradle-to-grave analysis includes four separate life stages, for any project: production stage (A1-5), use stage (B1-6), end-of-life stage (C1-4), and benefits and loads beyond the system boundary (D). These were previously portrayed in Figure 2.2.

A major part of this Indicator consists in **planning and modeling out the expected GHG emissions** associated with each stage of a project's lifespan. This roadmap of GHG emissions is to be holistic, so that it may capture both the GHG emissions directly relating to the heating, cooling, electrical, and gas needs of the building, as well as the embodied GHG emissions of the project, which are more tied up with the materials used in construction, repair, and maintenance. This indicator is regulated and instructed by the Level(s) User Manual 3: Indicator 1.2 (Dodd, Donatello and Cordella 2021d).

Time constraints and lack of detailed information related to the material inventory of the building did not allow a complete application of this indicator. However, a plan of tasks was set to better understand how this assessment would be performed for the different Levels (described in Figure 4.6).

Level	Activities related to the use of indicator 1.2
1. Conceptual design (following design principles)	✓ Aspects of the building that contribute most to GHG emissions, or ‘hot spots’, along a buildings life cycle can be identified in order to improve design concepts;
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ The greenhouse gas emissions associated with a building design and each life cycle stage can be calculated and modelled. The emissions from different design scenarios and future life cycle scenarios can be tested;
3. As-built and in-use (based on commissioning, testing and metering)	✓ The building materials used and assumptions made in order to calculate the life cycle greenhouse gas emissions can be validated against the as-built information as it becomes available.

Figure 4.6 – Review of the activities related to the Life Cycle Global Warming Potential Indicator (Dodd, Donatello and Cordella 2021d)

4.4.2.COMMENTARY

A **Level 1** qualitative assessment would require the elaboration of a reporting table by the design team, stating whether or not the life cycle design concepts described in Figure 0.2 (Annex B) were introduced into the design process, and if so, in what way.

Simplified instructions to apply a **Level 2** assessment are presented below. However, these do not dispense with the necessity of using the respective User Manual for further detailed guidance.

- Study the architecture drawings or other documents with detailed coverage of the construction products planned for use (specific quantities required). With this, elaborate a material inventory for the building.

- Decide on an LCA software with tools to calculate life cycle impacts associated with GWP (in the four separate life stages that Level(s) considers), in compliance with EN15978. Choose a sufficiently broad LCA database for Environmental Product Declarations (EPDs) related to material inventory.
 - In initial preparations for this assessment, this thesis had planned to use OneClickLCA software on this indicator. Besides being a pioneer in already offering an interactive structure for Level(s) assessments (based on the beta versions of the method), it comes with extensive built-in LCA material databases. It was, at the time of this study, a paid software, but academic versions were available upon request.
 - A great source of EPD information for the Portuguese Construction Industry is also “*Avaliação do ciclo de vida dos edifícios : impacte ambiental de soluções construtivas*” by Mateus and Bragança (2011a).
- Within the program, set up a prototype of the building based on the information of the Level(s) Building Description elaborated for the project (intended use and conditions, useful floor area, reference study period, scope of building elements). The assessment life cycle stages must also be defined here.
- Run the software and calculate the impacts associated with the GWP impact category. The Level(s) reporting table on Figure 4.7 must then be filled in with the compiled information and assumptions. At the design stage, design teams should consider making changes or adjustments after defining the hot spots and interpreting the results. Additional assessments should be performed for new designs until the impacts are reduced, and always accounting for the “burden shifting” factor.
- The note sections of the table must be completed with observations relating to the quality of the data introduced (LCA database, material inventory, EPDs).

A **Level 3** assessment of this indicator would require the same procedure, but the design data would be exchanged by the correct material inventory applied after the construction or renovation of the building.

Indicator	Unit	Product (A1-3)	Construction process (A4-5)	Use stage (B1-7)	End of life (C1-4)	Benefits and loads beyond the system boundary (D)
(1) GWP - fossil	kg CO ₂ eq					
(2) GWP - biogenic	kg CO ₂ eq					
GWP – GHGs (1+2)	kg CO ₂ eq					
(3) GWP – land use and land use change	kg CO ₂ eq					
GWP – overall (1+2+3)	kg CO ₂ eq					
Notes:						

Figure 4.7 – Reporting Table. Level 2 and 3 assessment – Indicator 1.2 (Dodd, Donatello and Cordella 2021d)

Even with LCA tools, calculating the life cycle GWP is still a time-demanding and complex task, in large part due to the lack of data and access to professional training. Taking this into consideration, Level(s) provides two incomplete life cycle reporting options for simplified assessments (Figure 4.8). These options encourage users or professionals with less formal training to conduct a more user-friendly GWP analysis. Both of these options narrow the GWP focus in order to assess the tradeoffs between the embodied impacts of construction materials (A1-3) and achieving a Net Zero Energy Building (NZEB) performance (B6). From this baseline, a user taking the first option would provide the service life impacts of maintenance and replacements (B4 and B5), whereas a user taking the second option would

report the end-of-life stage (C3-4) and the net benefits of recovering/recycling/reusing materials at the end of service (D).

Simplified reporting option 1: 'incomplete life cycle: product stage, calculated energy performance and projected service life'	• The product stage (A1-3) • The use stage (B4, B5, B6)
Simplified reporting option 2: 'incomplete life cycle: product stage, calculated energy performance and the building material bank'	• The product stage (A1-3) • The use stage (B6) • End of life stage (C3-4) • Benefits and loads beyond the system boundary (D)

Figure 4.8 – Simplified life cycle options for GWP assessments (Dodd, Donatello and Cordella 2021d)

In summary, for a detailed quantitative assessment of this indicator, the following tools and data would be needed:

- An LCA calculation software (and basic training in its use).
- An LCA material database.
- A complete bill of quantities for the building elements.

4.5. BILL OF QUANTITIES, MATERIALS AND LIFESPANS (INDICATOR 2.1)

4.5.1. DEFINITION AND SCOPE OF THE APPLICATION

The Construction Industry has a high demand for extracted materials. While the use-stage energy efficiency of buildings is predicted to increase substantially in the coming years (NZEB designs), the materials required for the construction and renovation of a building have a less flexible bottom limit. Accounting for the materials used will therefore play an increasingly important role in evaluating the overall environmental impact of any building project.

By considering all of the materials expected to be used during the construction and renovation stages over the life course of a building, this Indicator produces a detailed excel spreadsheet that **indexes the anticipated and real costs, the specific lifetimes of each material element, and the materials disposed of during renovations and demolition.**

The materials are first broken down into the aspect of the building (i.e., whether it is the shell, the core, or an external component), and then further into the material type. The basic units of measurement in this indicator are **tons and percentage of total building mass**. If a Level(s) user inputs further optional data, there will also be outputs in terms of Euros (rounded to nearest thousand), which can then be broken into **€/ton** and **€/m²**.

Because this Indicator collects the material and lifespan data for the whole of the building project, this Indicator goes hand-in-hand with other Level(s) Indicators, namely 1.2 (Life Cycle Global Warming Potential), 2.2 (Construction and Demolition Waste and Materials), and more broadly with MO 6 and the Cost Analysis of the building (Figure 4.9). Combined with Indicator 1.1 (Use Stage Energy Performance), this Indicator is a necessary step in weighing resource cost against the energy needs of a building in order to optimize its environmental impact.

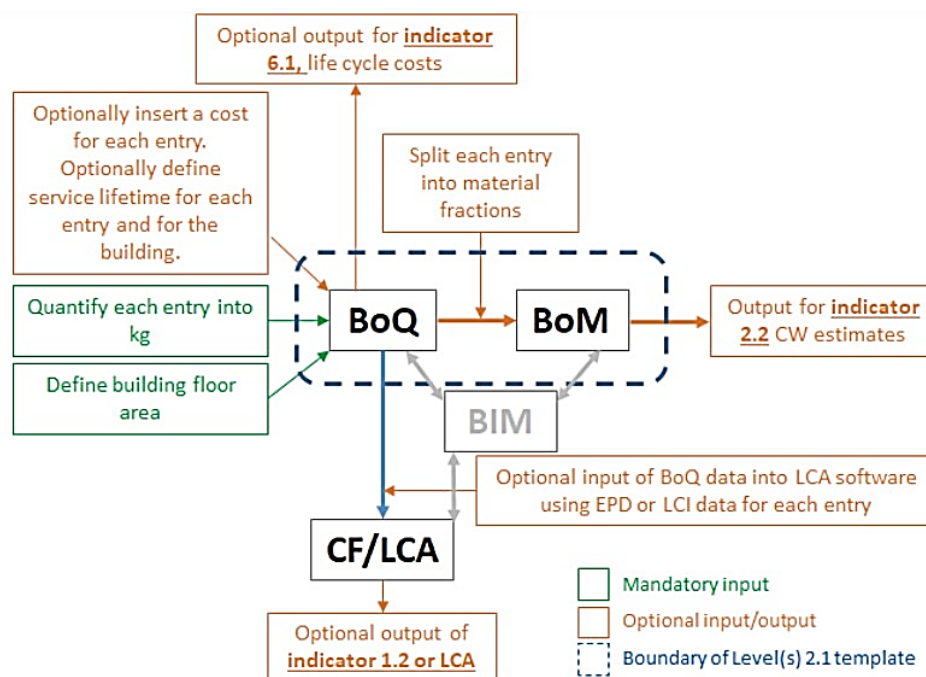


Figure 4.9 – Possible outputs and inputs of Indicator 2.1 (Dodd, Donatello and Cordella 2021e)

This Indicator is also accommodating to the auxiliary software that already exists in the Construction Industry, such as Building Information Modelling (BIM) and LCA tools, mentioned above. Building Information Modelling (BIM) can replicate the associations described above, producing similar results to this indicator. Level(s) leaves it up to the user to choose whether to continue using BIM, or to adapt the BIM data to the excel spreadsheet provided with this Indicator. Most LCA tools also require a complete material inventory to operate, and such information can be adapted to successfully populate the Indicator spreadsheet.

The case study under assessment did not provide data from any of the previously mentioned software, nor estimations for the quantities of different materials to be used. Likewise, this study will not be able to offer precise conclusions related to the Building 1.1. However, to further explore this Indicator, a test application for **Level 2** will be performed using simplified values. Simplified guidelines for assessing the other Levels will also be given. The description of the activities associated with each of the Levels can be found in Figure 4.10

Level	Activities related to the use of indicator 2.1
1. Conceptual design (choice of building form and main construction materials, elements and methods)	✓ For the conceptual design, information is provided to prompt discussion and decision making for the project about aspects that will directly or indirectly influence the choice of building structure and the main materials to use in the shell and core.
2. Detailed design and construction (based on drawings and estimations)	✓ During the detailed design and construction stages, estimates of BoQ can be compiled in an inventory following the Level(s) excel template.
3. As-built and in-use (based on invoices and site records)	✓ The material footprint of the as-built building can be calculated by compiling the real Bill of Quantities. Any replacement of building components (as they reach the end of their service lives, or for other reasons) can be recorded as part of monitoring in-use performance.

Figure 4.10 – Review of the activities related to the Bill of Quantities, Materials and Lifespans indicator (Dodd, Donatello and Cordella 2021e)

To completely perform this assessment, a user would need extensive building documentation and specifications (including at least the Structural Design, Architecture Design, and associated element quantities and descriptions). A complete BIM model could be used either to perform the same indexation or to extract the required data. The following trial was performed with the official Bill of Quantities, Materials, and Lifespans excel template, downloaded from the Level(s) documentation website.

4.5.2.RESULTS

Once the complete building materials spreadsheet is at hand, users can start filling in the first table of the Bill of Quantities (BoQ) - Figure 4.11. From this point on, only the green and beige fields are to be edited by users. The user first introduces the building floor area, reported in the Building Description, and then adds the different products/materials to the tool. Drop-down menus allow an organization of inputs similar to the one performed on the Building Description (and summarized in Figure 3.7). Quantities and unitary weights (kg/unit) must then be added to each element. If the user intends to perform life cycle cost analysis with MO6, unitary costs (€/unit) must also be provided here. The products used in this assessment do not represent the Building 1.1 and were only added for calculation purposes.

Bill of quantities organised by the main building parts and elements.								Building floor area (m2)		316,02
Tier 1 building element	Tier 2 building element	Tier 3 building element	Optional further description of the product/material being purchased	Bill of Quantities (number of units)	Unit	Conversion factor (kg/unit)	TOTAL (kg)	Cost €/unit	Cost €/kg	TOTAL cost €
Shell	Foundations_substructure	Piles	Reinforced concrete pile foundations with rebar at 130kg/m3	30	m3	2600	78000	150,0	0,1	4500
Shell	Loadbearing_structural_frame	Frame (beams, columns and slabs)	Reinforced concrete slabs and columns with rebar at 120kg/m3	400	m3	2400	960000	125,0	0,1	50000
Core	Fittings_and_furnishings	Floor coverings and finishes	Laminate flooring with foamed plastic underlay	316,02	m2	7,5	2370,15	12,0	1,6	3792,24

Figure 4.11 – Bill of Quantities (Indicator 2.1 spreadsheet)

Although the first goal of assessing this indicator is the indexation of materials into a BoQ, it is also aimed at converting that data into approximated material splits (in %), and generating a Bill of Materials (BoM) that can be used for assessing Construction and Demolition Waste - Figure 4.12. Better certainty on these divisions can be obtained by studying each material's EPD. Then, it is important that users with an intention to obtain life cycle results introduce in years the intended building life (same as in the Building Descriptions) and estimations for material/products life. This Indicator's User Manual provides suggested lifetimes for each Tier 3 element, in the event that said information is not otherwise available to the user.

Bill of Materials by material type (% weight). Enter the approximate % split by material according to the options below											Assumed building life (yrs)	50	Normalised weight of materials needed over lifetime	Normalised cost of materials needed over lifetime
Concrete, brick, tile, ceramic etc.	Wood	Glass	Plastic	Bituminous mixtures	Metals	Insulation materials	Gypsum	Mixed	Electrical and Electronic Equipment	Total % (should be 100%)	Assumed lifetime of product/material (years)	Normalised requirement factor over building lifetime		
95,0%					5,0%					100,0%	75	0,666666667	78000	4500
95,0%					5,0%					100,0%	50	1	960000	50000
	95,0%		5,0%							100,0%	15	3,333333333	7900,5	12640,8

Figure 4.12 – Bill of Materials (Indicator 2.1 spreadsheet)

The spreadsheet automatically assimilates the inputs and provides outputs for the quantities of materials expected to be used, both for the construction/renovation and, if life estimations were added, also for the full lifetime of the building – Figure 4.13. On these outputs it's possible to examine that due to the estimated life of the Shell elements outpacing the intended building life, no additional materials will need to be acquired during the project's planned lifetime.

Automatically calculated Bill of Quantities / Materials (in kg) (for construction)									
Concrete, brick, tile, ceramic etc.	Wood	Glass	Plastic	Bituminous mixtures	Metals	Insulation materials	Gypsum	Mixed	Electrical and Electronic Equipment
74100	0	0	0	0	3900	0	0	0	0
912000	0	0	0	0	48000	0	0	0	0
0	2251,643	0	118,5075	0	0	0	0	0	0

Automatically calculated Bill of Quantities / Materials (in kg) (for planned building lifetime)									
Concrete, brick, tile, ceramic etc.	Wood	Glass	Plastic	Bituminous mixtures	Metals	Insulation materials	Gypsum	Mixed	Electrical and Electronic Equipment
74100	0	0	0	0	3900	0	0	0	0
912000	0	0	0	0	48000	0	0	0	0
0	7505,475	0	395,025	0	0	0	0	0	0

Figure 4.13 – Material quantities in kg, for construction and for the building planned lifetime (Indicator 2.1 spreadsheet)

Aggregating the previous calculations, Figure 4.14 displays the reporting format generated for this Indicator. The units reported, as previously stated, are tons and the percentage of total building mass. Due to the conversion of the BoQ into a BoM, these units are also broken down by material type on the left section of the table. Since the previous steps of providing unitary costs were also performed, the additional units of measurement – total cost in (€/m² and €/ton) – are also calculated. These will be essential to estimate life cycle costs on MO6.

It can be noted that the planned building lifetime reporting table has an error connecting the material quantities from the previous tables and converting it into tons – the metals are displayed as insulation materials. Since this is an exploratory assessment, the writer did not perform the simple programming change necessary to correct that problem in the template. Caution is advised to the readers intending to use this Indicator, since similar errors may exist in other non-used cells.

Bill of Quantities/ Materials (for construction)						
Breakdown by material type			Building floor area (m ²)	316,02	Totals check (should =0)	0
			Breakdown by building aspect			
	Material total (t)	Material total (%)	Shell	Core	External	Total
Combined total	1038	100,0%	1038	0	0	1038
Concrete, brick, tile, natural stone, ceramic	986,1	95,0%	100,0%	0,0%	0,0%	100,0%
Wood	0	0,0%	54,5	0	0	54,5
Glass	0	0,0%	100,0%	0,0%	0,0%	100,0%
Plastic	0	0,0%	Total cost €/m2		Total cost €/t	
Bituminous mixtures	0	0,0%	172,5		52,5	
Metals	51,9	5,0%				
Insulation materials	0	0,0%				
Gypsum	0	0,0%				
Mixed	0	0,0%				
Electrical and Electronic Equipment	0	0,0%				

Bill of Quantities/ Materials (for lifetime)						
Breakdown by material type			Building floor area (m ²)	316,02	Totals check (should =0)	0
			Breakdown by building aspect			
	Material total (t)	Material total (%)	Shell	Core	External	Units
Combined total	1230	100,0%	1230	0	0	1230 tonnes
Concrete, brick, tile, natural stone,	1168,5	95,0%	100,0%	0,0%	0,0%	100,0% mass %
Wood	0	0,0%	64,5	0	0	64,5 000 €
Glass	0	0,0%	100,0%	0,0%	0,0%	100,0% € %
Plastic	0	0,0%	Total cost €/m2		Total cost €/t	
Bituminous mixtures	0	0,0%	204,1		52,4	
Metals	0	0,0%				
Insulation materials	61,5	5,0%				
Gypsum	0	0,0%				
Mixed	0	0,0%				
Electrical and Electronic Equipment	0	0,0%				

Figure 4.14 – Full breakdown of the building materials and costs, for construction and for the building planned lifetime (Indicator 2.1 spreadsheet)

Additionally, the elaboration of the BoM allows the excel tool to display a very simplified estimate for expected Construction Waste - Figure 4.15. To obtain these values, the user must only display (in the beige cells) estimations for what percentage of each material type will go to waste. This percentage would be composed by over-orders of materials and expected waste generated by construction actions. Level(s) already associates to each of the material types a very simplified single “assumed” waste type and code on the European List of Waste (LoW) to allow the estimation to categorize waste in three main categories – inert, non-hazardous, and hazardous.

Simplified estimate for Construction Waste				
	Assumed wastage/ over-ordering rate	Assumed waste type	Assumed LoW code	Total CW (t)
Concrete, brick, tile, natural stone, ceramic	15,0%	Inert	17 01 01	147,92
Wood	20,0%	Non-haz	17 02 01	0,45
Glass	15,0%	Inert	17 02 02	0,00
Plastic	10,0%	Non-haz	17 02 03	0,01
Bituminous mixtures	5,0%	Non-haz	17 03 02	0,00
Metals	8,0%	Non-haz	17 04 07	4,15
Insulation materials	20,0%	Hazardous	17 06 05	0,00
Gypsum	22,5%	Non-haz	17 08 02	0,00
Mixed	10,0%	Non-haz	17 09 04	0,00
Electrical and Electronic Equipment	10,0%	Hazardous	16 02 XX or 20 01 XX	0,00
	Inert	Non-haz	Hazardous	Total
Tonnes	147,92	4,61	0,00	152,53
% split	97,0%	3,0%	0,0%	100,0%

Figure 4.15 – Simplified estimate for Construction Waste (Indicator 2.1 spreadsheet)

4.5.3.COMMENTARY

The simplified inputs permitted a quick exploration of this indicator's main strengths. The excel spreadsheet provided is simple and effectively provides quick overviews of how materials influence the magnitude of building projects, both in size and cost. An extensive building material inventory is indeed necessary to allow accurate assumptions to be taken from it, but such a list is common in more advanced phases of project development.

Furthermore, performing a **Level 3** assessment would entail that the information provided on the Bill of Quantities is based on the actual records (usually provided by suppliers) of purchased and delivered materials and products. The excel tool provides an extra table that can be filled with purchase quotations and commentaries as a way to create an inventory as the different materials are delivered to the construction site. That information would then be copied and pasted into the Bill of Quantities. This is an optional step since users can opt to directly fill the main input tables.

A **Level 1** qualitative assessment would require the elaboration of a reporting table by the concept design team, stating whether the six relevant aspects for optimizing the consumption of construction materials and products described in Figure 0.4 (Annex B) were introduced into the design process, and if so, in what way.

4.6. CONSTRUCTION AND DEMOLITION WASTE AND MATERIALS (INDICATOR 2.2)

4.6.1. DEFINITION AND SCOPE OF THE APPLICATION

The Construction and Demolition Waste (CDW) generated in Europe is one of the largest components of the continent's solid material waste (eurostat 2021b). For this reason, it is the goal of this Indicator to estimate and measure the quantities of material waste which are generated during construction, renovation, and demolition. This waste is disaggregated into categories of increasing environmental favorability, the least favorable being disposal offsite, and the most favorable being recycling and reusing the material waste.

By prompting discussion and conscientious decision making in the design phase of a building project, this Indicator enables a Level(s) user to make and deploy a Waste Management Plan (WMP). In this way, a building project's team can factor in the CDW recycling and reusing options from the earliest days of the project's lifespan.

The unit of measurement for this Indicator is in kilograms, which is then normalized into **kg/m²** for the entirety of useful floor area (insuring compatibility). It is regulated and instructed by the Level(s) User Manual 3: Indicator 2.2 (Dodd, Donatello and Cordella 2021f), and has the main activities described in Figure 4.16.

Level	Activities related to the use of indicator 2.2
1. Conceptual design (choice of construction/demolition methods and waste management planning)	✓ In the conceptual design, information is provided to prompt discussion and decision making for the project about aspects that will directly or indirectly shape the outline Waste Management Plan (WMP) and thus the quantities of CDW generated and their possible reuse, recycling and recovery.
2. Detailed design and construction (based on pre-demolition audit and/or draft Bill of Quantities)	✓ During the detailed design and prior to construction/demolition activity, estimates of CDW can be compiled in an inventory following the Level(s) excel template, which in turn will inform a more detailed WMP for the project.
3. As-built and in-use (based on invoices, delivery notes and site records)	✓ During and after the construction/demolition activity, actual data can validate performance when compared to estimates and project targets, both for quantities and outcomes for different types of CDW.

Figure 4.16 – Review of the activities related to Construction and Demolition Waste Indicator (Dodd, Donatello and Cordella 2021f)

4.6.2. COMMENTARY

Although having a WMP is already mandatory for public construction projects in Portugal, the documentation shared by the project team did not have any mention to the elaboration of this plan or to the compliance with other national minimum requirements for waste management. In fact, such lack of information related to these measures turns the analysis of this and other MO2 indicators into a task that would demand an incredible number of estimations to obtain understandable final results. The quantitative assessments for this Indicator are performed on a Level(s) CDW excel template. These require extensive planning, field surveys, cataloguing of materials, and sufficient knowledge of the concepts behind CDW. Such steps cannot be described in sufficient detail on such an all-encompassing research, without incurring data corruptions resulting from over-simplifications, thus eliminating its relevance. Likewise, this study will refrain from providing guidance for these Levels.

However, for a **Level 1** analysis, users should elaborate a reporting table together with the design team, stating whether the concepts aiming to optimize material management and reduce CDW, described in Figure 0.5 (Annex B), were introduced into the design process, and if so, in what way.

4.7. DESIGN FOR ADAPTABILITY AND RENOVATION (INDICATOR 2.3)

4.7.1. DEFINITION AND SCOPE OF THE APPLICATION

This Indicator also aims to limit the negative environmental impact of CDW, but in this case, its approach is not targeted at the CDW itself, but rather the ways in which a design can increase a building's longevity. When a building is demolished at the end of its service life, it incurs a great deal of energy consumption and generates a great deal of material waste. By promoting buildings that could adapt to changes in market conditions, this Level(s) indicator encourages designers to take a longer view on their building projects, and in this way aims to slow the rate of building demolition across Europe.

Two of the key ways that a building's adaptability can be assessed are with regard to how efficiently it uses space and its operational performance level. A highly adaptable building would be able to accommodate a growing number of occupants as their families or businesses grow, and it would allow for an easy transition to new energy-efficient technologies in its ventilation, temperature control, and energy generation systems.

This indicator renders a semi-quantitative unit of measurement, which is called the building's **dimensionless adaptability score**. There is a procedure for scoring each aspect of the building design's adaptability, and these sub-scores are aggregated for the dimensionless score. It is regulated and instructed by the Level(s) User Manual 3: Indicator 2.3 (Dodd, Donatello and Cordella 2021g).

A **Level 1** assessment of the key adaptability design aspects will be performed, leaving out the important step of debating with the design team. The information used on this assessment was based both on the conceptual description of the project that accompanied the Architectural Design and on some of its drawings. The summary of activities related to the different Levels of this Indicator is shown on Figure 4.17.

Level	Activities related to the use of indicator 2.3
1. Conceptual design (following design principles)	• Key design aspects for the architect and structural engineer to take into consideration • Value appraisal of the design aspects by the building promoter and cost surveyors
2. Detailed design and construction (based on drawings and dimensions)	• Spatial dimensions of the building and structural design, including bay widths, spans, ceiling heights, room sizes and accesses. • Servicing design of the building, including plant rooms, access ducts and distribution networks
3. As-built and in-use (based on final design features and inspection)	• Awareness and information relating to adaptable design features and their potential future value

Figure 4.17 – Review of the activities related to the Design for Adaptability and Renovation Indicator (Dodd, Donatello and Cordella 2021g)

4.7.2.RESULTS

Assessing a Level 1 Indicator should start with the analysis of the main design concepts that ensure its goals are considered on the early design phases - Figure 4.18. Level(s) provides a different set of concepts for Residential and Office builds, but the latter group will not be considered in this nor in other assessments of this residential case study.

Adaptability design concept	Specific design aspect to address	How the design aspect can contribute to adaptability
1. Changes to the internal space distribution	1.1 Wall systems that support layout changes	Internal wall designs that allow for ease of changes to floor layouts.
	1.2 Greater ceiling heights for surface routes	The use of greater ceiling heights will give more flexibility in the routing of services.
2. Changes to the buildings servicing	2.1 Ease of access to the building services	Location of services within the house or apartment building to ensure they are flexible to change.
	2.2 Ease of adaptation of the distribution networks and connectors	The internal layout of rooms, the distribution networks and connections can be adapted in the case of any layout modifications.
3. Change to the use of units or floors	3.1 The potential for a segregated home working spaces	The potential to segregate a space with adequate dimensions, light and services within the home will support teleworking.
	3.2 The potential for ground floor conversion to a contained unit	The potential for the ground floor to become a contained unit with bed space, kitchen, toilet and shower will support future changes in circumstances.
4. Changes in access requirements	4.1 Ease of access to each residential unit	Ease of access to residential units in cases of the need for pram or wheelchair mobility.
	4.2 Access to and manoeuvrability within rooms	Ease of access to and space to manoeuvre within living spaces, kitchens and bathrooms will support pram or wheelchair mobility.

Figure 4.18 – Adaptability design concepts for a Level 1 assessment. Residential Buildings (Dodd, Donatello and Cordella 2021g)

After the concepts are known, the reporting table for this assessment must be filled in – Table 4.8. The families that will be relocated to the Social Housing complex under consideration have a particular set of cultural characteristics that distinguish them from the Portuguese norm. These families are usually numerous and show a rapid variation in composition and structure through time, as the young members leave the house relatively early to start new families of their own. High natality is also predominant. These considerations require extra planning for the design teams.

Table 4.8 – Level 1 assessment of Indicator 2.3

Specific Design Aspect	Has it been addressed?	How has it been addressed during the building design process?
1.1 Wall systems that support layout changes	Yes	The conceptual description of the Architectural Design explains that the layouts were made to ensure that most rooms could be subdivided into two autonomous spaces, while keeping efficient ventilation and lighting conditions. Subdivision examples were also provided (Figure 4.19).
1.2 Greater ceiling heights for surface routes	Yes	Each apartment ceiling high was set to be 2.70m, which is relatively higher than the Portuguese minimum requirement* of 2.40m for residential buildings.
2.1 Ease of access to the building services	Yes	Building services are not located inside the apartments but are of easy outside access. Their

		maintenance will be performed periodically by city hall technicians.
2.2 Ease of adaptation of the distribution networks and connectors	No	No mentions are made on the different service designs to steps taken to ensure such adaptability if layouts are to be changed on the apartments.
3.1 The potential for a segregated home working space	Yes	Although it is not foreseen due the cultural characteristics of the occupants, divisions exemplified in Figure 4.18 can also be made to allow a separated home working space.
3.2 The potential for ground floor conversion to a contained unit	No	There are no mentions of measures allowing this type of conversions. This project was elaborated before/ during the early days of the global pandemic crisis of 2020; at that time, such precautions were not common practice for designers.
4.1 Ease of access to each residential unit	Yes	Each apartment access door is located outside of the building. Access to both ground floor and first floor apartments will be allowed by stairs and complimented by ramps to account for reduced mobility.
4.2 Access to and maneuverability within rooms	Yes	Apartments were designed to permit those tenants with reduced mobility to have no problem moving between the different sections. Additionally, the project team elaborated Accessibility Plans for the two typologies of Building 1.1 (Figure 4.20)

*According to Article 65 of the *Regulamento Geral das Edificações Urbanas (RGEU)*



Figure 4.19 – Layouts for apartments of T2 (left) and T4(right) typology. Red lines indicate possible subdivisions into autonomous rooms. (taken from the Architectural Design)



Figure 4.20 – Accessibility Plans for apartments of T2 (left) and T4(right) typology (taken from the Architectural Design)

4.7.3.COMMENTARY

A qualitative **Level 1** assessment for this Indicator was possible through the analysis of the already elaborated Architectural Designs. The project team seems to have given special care to create a flexible environment for the users, considering their distinct cultural costumes and applying much needed provisions for occupants with reduce mobility.

To allow **Level 2** and **Level 3** this Indicator requires users take the detailed designs of the building (including Structure and Servicing plans) and evaluate all the specific design aspects mentioned in the Level 1 assessment (Figure 4.18) and rating each of them with an Adaptability score. Level(s) applies a Transitional Methodology for the weighting system, adapted from the Building Flexibility Calculator provided by BREEAM Netherlands and the Dutch Real Estate Norm. During the period of this research, only an adaptation for Office Buildings was displayed by the User Manual – exemplified in Figure 4.21. It is to be expected that further developments of the Indicator include the complete adaptation of the BREEAM system to Level(s) Residential Buildings specific design concepts. Furthermore, Level 3 differs from Level 2 as it allows comparison between the early detailed designs to the final as-built ones.

Specific design aspect to address	How the design aspect can contribute to adaptability	Scoring system	Weighting factor
1.1 Column grid spans	Wider column spans will allow for more flexible floor layouts.	Column spacing: - < 5400 mm 0 points - 5400 mm < 8100 mm 1 point - > 8100 mm 2 points - free span 3 points	1.5
1.2 Façade pattern	Narrower bays will allow for more internal space configurations	Spacing between bays: - 1350 to >1800 mm 0 points - 1350 - 1800 mm 1 point - 1350 - 1800 mm, some bays 900 - 1350 mm 2 points - 900 - 1350 mm, some bays < 900 mm 3 points	1.5

Figure 4.21 – Weighting system for 2 specific design concepts. Office Buildings (Dodd, Donatello and Cordella 2021f)

4.8. DESIGN FOR DECONSTRUCTION, REUSE AND RECYCLING (INDICATOR 2.4)

4.8.1. DEFINITION AND SCOPE OF THE APPLICATION

The process leading up to a sustainable building renovation and demolition does not happen on its own. In order to recover a significant amount of CDW, sustainable practices and outlooks must be incorporated into the planning and design phases of the project. This Indicator provides a semiquantitative assessment of a project's reusability, considering factors like material type and size.

However, large barriers must be overcome in this effort, both at large scale and in any given project. These barriers are as follows:

- The time that elapses between the design phase and the demolition phase of any building. After several decades, it is likely that standard practices and preferred materials will have changed, making some of the building's materials obsolete and undesired.
- Imprudent building designs and structures. Much of the current building stock contains materials that have been exposed to hazardous substances, or that have been too closely integrated with the service systems, rendering them unusable in future projects.
- Hasty and uncareful demolition practices. Demolition is often done under tight time constraints. The most time-efficient demolition options tend to be the ones that destroy materials past the point of usability (e.g., using shears to cut and remove welded steel beams).
- A lack of logistical preparedness. Getting materials from one building site to another requires a system of logistics, such as where to store the materials until they are needed at the next site, or the process of modifying sections to be employed in the next project. These systems are underdeveloped.
- A low demand for reclaimed materials. Partially because this practice has not yet become standard practice across the continent, there is a lack of buyers for used materials. Without demand, any amount of recuperated CDW would serve little purpose.

Part of the role of this Indicator is to promote awareness in the Construction Industry about the potential in recovering CDW, both on the demand and on the supply side of the market. The indicator breaks down certain materials by their level of reusability, with steel beams and steel/concrete columns having the best reuse potential, and timber materials showing some promise of increased reusability in the future. The Indicator then uses these material reusability estimates to measure the **ease of disassembly** and the **ease of reuse and recycling** of the building's parts. The indicator renders a unit of measurement in a **dimensionless deconstruction potential score**. It is regulated and instructed by the Level(s) User Manual 3: Indicator 2.4 (Dodd, Donatello and Cordella 2021h).

Like mentioned on the previous MO2 indicators, the case study lacks mention to measures allowing a comprehensive assessment of its circularity. Quantitative assessments of this indicator require using the complete Bill of Quantities (2.1) and the Structure and Servicing plans to evaluate the different elements propensity to being recovered. Such documentation could not be gathered in order to provide results, likewise, this research will only include the general guidelines necessary to perform the activities of this indicator – Figure 4.22.

Level	Activities related to the use of indicator 2.4
1. Conceptual design (following design principles)	✓ Key design aspects for the architect, structural engineer, and contractor to take into consideration and to include in later specifications. ✓ Value appraisal of the design aspects by the building promoter and cost surveyors.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ Assessment of the structure, façade and building design and specification for deconstruction. ✓ Assessment of renovation building parts and fit out materials for their deconstruction potential on a shorter timescale.
3. As-built and in-use (based on commissioning and inspection)	✓ Awareness and information relating to circular design features and their potential future value.

Figure 4.22 – Review of the activities related to the Design for Deconstruction, Reuse and Recycling Indicator(Dodd, Donatello and Cordella 2021g)

4.8.2. COMMENTARY

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the deconstruction design concepts described in Figure 0.6 (Annex B) were introduced into the design process, and if so, in what way.

For **Level 2** and **Level 3**, Level(s) conveys users to a Transitional Methodology, outsourced from the German Sustainable Building Council to be used for assessing the same impacts on the DGNB System, a BSAM aimed to the German Construction Industry). This research will not explore this assessment, and suggests that users interested in learning more about how it is performed should download the user manual for DGNB Criteria “Ease of recovery and recycling” (TEC1.6). The conclusions and scorings taken for evaluating the ease of disassembly, reuse and recycling with that methodology are then to be extracted to the Levels reporting tables - Figure 4.23, Figure 4.24, and Figure 4.25. Level 3 differs from Level 2 as it allows comparison between the early detailed designs to the final as-built ones.

<i>Ease of recovery</i>	<i>Overall score obtained</i>	
<i>Building part</i>	<i>Design aspects checked/implemented</i>	
	<i>Ease of recovery aspect</i>	<i>Description of the design solution(s) used to facilitate recovery</i>
<i>Of the parts in table 2 list those that have been addressed</i>	<i>Aspect x</i>	

Figure 4.23 – Ease of Recovery reporting (Dodd, Donatello and Cordella 2021h)

<i>Ease of reuse and recycling</i>	<i>Overall score obtained</i>
------------------------------------	-------------------------------

<i>Building part</i>	<i>Design aspects checked/implemented</i>	
	<i>Ease of recycling/reuse aspect</i>	<i>Description of the design solution(s) used to facilitate recovery</i>
<i>Of the parts in table 2 list those that have been addressed</i>	<i>Aspect x</i>	

Figure 4.24 – Ease of Recycling reporting, plus final aggregated score(Dodd, Donatello and Cordella 2021h)

<i>Expert check carried out?</i>	<i>Yes/no</i>
Have any additional design aspects been identified and addressed?	<i>List any additional aspects identified and addressed:</i> – Aspects x – Aspects y – Aspects z

Figure 4.25 – Optional reporting option to identify if demolition and waste management experts were involved in the assessment (Dodd, Donatello and Cordella 2021h)

4.9. USE STAGE WATER CONSUMPTION (INDICATOR 3.1)

4.9.1. DEFINITION AND SCOPE OF THE APPLICATION

Fresh water is a finite resource, and controlling its consumption has been a sustainability practice adopted by many people in their daily lives since the beginnings of environmental awareness. Providing water for a building has embodied environmental impacts – in collection, treatment, transportation – that are worse for projects located in areas with high water stress and seasonal scarcity. Efficient sanitary fittings and water-using appliances can provide enormous assistance in reducing a building's consumption, and these have now become essential to new building designs. Besides reducing consumption, these components also affect life cycle costs, since water spending is one of the main continuous expenses during the use stage of buildings. Indicator 3.1 calculates this **total consumption of water for an average building occupant** with the unit of measurement being **cubic meters per**

occupant per year (m³/o/a). When applied to its full capacities, it aims to provide the user with several key pieces of understanding:

- How to conceptualize the sources of the building's water consumption.
- How to recognize the importance of water scarcity levels in the region where the building is located.
- How to envision the water saving potential of including greywater recycling and rainwater harvesting devices on the building's design.
- How to estimate the quantity of water to be saved by choosing water-efficient sanitary fittings/devices.
- How to measure and improve possible impacts that irrigating vegetated areas may produce.

It is regulated and instructed by the Level(s) User Manual 3: Indicator 3.1 (Dodd, Donatello and Cordella 2021i).

This assessment will be performed for **Level 2**. However, due to the fact that the design data available is not sufficient for a full calculation of the consumptions, this study will, for academic purposes, estimate the missing values in order to perform the complete assessment. These calculations are to be done with a Water Calculator excel file provided by Level(s). The summary of the activities related to each of the Levels is provided on Figure 4.26.

Level	Activities related to the use of indicator 3.1
1. Conceptual design (following design principles)	✓ In the conceptual design, information is provided to prompt discussion and decision making for the project about aspects that will directly or indirectly affect the consumption of water, especially potable water, during the use of the building.
2. Detailed design and construction (based on calculations, usage rates and occupancy rates)	✓ During the detailed design and construction stages, the influence of different design features and purchases of different devices on estimates of use stage water consumption can be made using the excel-based Level(s) water calculator.
3. As-built and in-use (based on product specifications, monitoring and metering)	✓ Awareness and information relating to circular design features and their potential future value.

Figure 4.26 – Review of the activities related to the Use Stage Water Consumption Indicator (Dodd, Donatello and Cordella 2021i)

The steps taken by the author to perform this assessment were:

- Gathering the available project data related to water usage and sanitary fittings.
- Downloading the Level(s) Water Calculator from the Document's website.
- Filling in the tables with the project's Location and Sanitary Fittings, Appliances, and Irrigation consumptions. Estimations were performed here to account for missing values.

The information necessary to perform this assessment was found on the Water Supply Project and on the Architecture Designs.

4.9.2. RESULTS

Starting this assessment, the project **Country** and **River Basin** should be defined. Level(s) provides an extensive list of options for European countries and its associated basins. Being located in northern Portugal, near the Douro River, the associated river basin for this project is the Douro (Figure 4.27). Besides providing the weather data that will be necessary in following actions, this initial step

automatically generates the summer Water Exploitation Index plus (WEI+), which measures the relative water scarcity of the region, and benchmarks it according to 105 other European river basins. Exploring the source data for this ranking, it is possible to learn that the top five European regions of higher water stress are located in the Iberian Peninsula, three of them being Portuguese – Sado and Mira (3rd, WEI+ 48.68); Guadiana (4th, WEI+ 41.19); and the Algarve Basins (5th, WEI+ 40.17). The Douro basin is also under high water stress, and its circumstances should not be overlooked on account of the southern basins' worse conditions. Facts like these reinforce the importance of controlling the Portuguese water resources consumptions. The Global Warming phenomena will only worsen these values, making the present day the best time to act on them.

Country:	Portugal_PT	
River basin:	WFD2_Douro	
Summer WEI+:	23,31	(WEI+ >20 is a region of water stress, WEI+ >40 is a region of severe water stress)
Summer WEI+ ranking:	17	(out of 105)

Figure 4.27 – Project River Basin. Level(s) Water Calculation Tool

Next, to calculate consumptions related to **Sanitary Fittings** and **Water Using Appliances**, Table 4.9 was elaborated. The Minimum Flow and Minimum Diameter columns were filled with the design data available on the Water Supply project of the building. No more precise data was found. The Consumption Rates column contains the estimations for each fitting/appliance consumption in the units required by the calculation tool. For the occupants daily Usage Factor (o/day), this study considered the default rates suggested by Level(s). A list was added at end of the table to explain the estimations performed.

Table 4.9 – Water Consumption Rates and Usage Factors for Sanitary Fittings and Appliances.

Sanitary Fitting	Minimum Flow (L/s)	Minimum Diameter (cm)	Consumption Rates	Usage Factor
Toilet	0.10	12.7	6L/flush ^[1]	4 flushes/o/day
Bathroom tap	0.10	19.1	6 L/minute	75 seconds/o/day
Shower	0.15	19.1	9 L/minute	360seconds/o/day
Bathtub	0.25	19.1	120 L/bath ^[2]	0.11 baths/o/day
Kitchen tap	0.20	19.1	12 L/minute	240seconds/o/day
Water Using Appliances				
Dishwasher	0.15	19.1	14 L/cycle ^[3]	0.4 cycles/o/day
Washing machine	0.20	19.1	62 L/cycle ^[4]	0.3 cycles/o/day

- ^[1] Estimated consumption of 6L per full flush on an average toilet (Rodrigues et al. 2021). No mentions to a dual system toilet were found on the designs.
- ^[2] Estimated consumption per average bath of 120L (Matos et al. 2017)
- ^[3] Estimated consumption of 14L/cycle for an average dishwasher (Brunzell and Renström 2020).

- ^[4] Estimated consumption of 62L/cycle for an average washing machine (Botha, Jacobs and Terblanche 2018)

To perform the estimation for the **Irrigation consumptions**, a separate assessment is to be performed. The river basin data introduced will automatically provide the rainfall and evapotranspiration data (Figure 4.28) necessary to start calculations.

	Rain (mm/month)	Actual ET (mm/month)	Balance (mm/month)
January	59,4	40,4	19,0
February	50,2	49,1	1,1
March	50,5	68,6	-18,1
April	56,8	76,8	-20,0
May	48,8	83,9	-35,1
June	28,8	74,7	-45,9
July	11,0	56,8	-45,8
August	15,1	40,1	-25,0
September	31,1	31,1	0,0
October	89,2	30,3	58,9
November	68,2	28,0	40,1
December	66,1	33,4	32,6
Total	575,2		-189,9

Figure 4.28 – Rainfall and Evapotranspiration data for the project location. Level(s) Water Calculation Tool

After this, estimations were made for the vegetation zones included in the complex. The Architecture Design includes a community garden where users would be able to grow their own crops. Additionally, these designs anticipate green areas populating the spaces between the different buildings that make up this complex. The Water Supply Project only mentions that a 50-millimeter extension tube is to be designed for the irrigation of the community garden. Likewise, estimations were made for these possible areas and added to the Water Calculation tool as described in Figure 4.29 and in the list that follows.

Area	Vegetation type	Water demand	K _{sp}	Microclimate / Heat island effect	K _M	Density of vegetation	Density (shading) factor (K _d)	Vegetated area coefficient K _{VA}
1000 m2	Mixed planting	High water demand	0,9	Low	0,5	Medium density	1,10	0,495
350 m2	Trees	Low water demand	0,2	Low	0,5	Low density	1,30	0,13
350 m2	Lawn grass	Low water demand	0,6	Low	0,8	Low density	1,00	0,48
0 m2								
m2								
m2								
m2								
m2								
1700 m2								

Net water balance without irrigation (mm/month)												Total			Irrigation system		Irrigation system efficiency
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	mm/yr	m ³ /m ² /yr	m ³ /yr			
0,0	0,0	-18,1	-20,0	-35,1	-45,9	-45,8	-25,0	0,0	0,0	0,0	0,0	-94,0	0,157	156,7	Manual or other		0,60
0,0	0,0	-9,0	-9,9	-17,4	-22,7	-22,7	-12,4	0,0	0,0	0,0	0,0	-24,7	0,041	14,4	Manual or other		0,60
0,0	0,0	-2,4	-2,6	-4,6	-6,0	-6,0	-3,3	0,0	0,0	0,0	0,0	-91,2	0,130	45,6	Sprinklers		0,70
0,0	0,0	-8,7	-9,6	-16,8	-22,0	-22,0	-12,0	0,0	0,0	0,0	0,0	0,0	#N/A				#N/A
												0,0	#N/A				#N/A
												0,0	#N/A				#N/A
												0,0	#N/A				#N/A
												0,0	#N/A				#N/A
												0,0	#N/A				#N/A
												0,0	#N/A				#N/A
												Total		216,7			

Figure 4.29 – Calculation of the Irrigation consumptions A. Level(s) Water Calculation Tool.

These spreadsheets are not excessively complex, but they are also not quite self-explanatory. The following notes explain the inputs provided:

- Only the cells with green shading are to be filled by the user.
- The first area added refers to the Community Garden (mixed planting). It was considered to have an area of 1000 m², with a high water demand and medium vegetation density.
- The second and third areas added are referring to the green areas around the complex. They were considered to have areas of 350m² each, low water demand and low density. Other options provided by the tool for the vegetation type included “bushes” and “creeping plants”.
- The microclimate / heat island effect was considered low since this complex will be built in a rural area with low population density.
- Assumptions for the irrigation systems were chosen to be “Manual or Others” for the community garden and the trees surrounding the Complex, and sprinklers for the lawn grass.
- The total annual consumption was automatically calculated considering the data previously introduced and the balances related to rainfall and evapotranspiration.

The last step for assessing the Irrigation component is converting the total annual consumption of water into a value reflecting the annual consumption of a single occupant. This is done by estimating the number of occupants that will populate the building area. The project estimation for the total number of residents of the Social Housing Complex is 115, and since the areas under consideration will be common spaces for all of them, this was the value introduced.

<i>Relevant number of occupants related to the building area (note that this may be higher than simply the occupants of the single residential building, office or office block in question in cases where vegetated spaces are common to multiple buildings).</i>	occupants	m3/o/yr
	115	1,884

Figure 4.30 – Calculation of the Irrigation consumptions B. Level(s) Water Calculation Tool

The **full compilation** of the previous calculations and estimations (Sanitary Fittings, Appliances, and Irrigation) is presented in Figure 4.31. The table used here is exclusive for Residential Buildings, and Level(s) provides a second one (with different requirements) for users wishing to apply this indicator to Office Buildings. Similar to the irrigation calculations, the green cells were the ones where information was introduced/chosen. After verification of the Greywater and Rainwater Disposal Projects it was possible to conclude that no devices were projected to recycle and/or reuse these disposed waters. This also applied for the Irrigation row since the natural rainwater fall was already previously considered. The building usage factor was considered to be 360 days per year. The suggested default value provided by Level(s) is 335 days per year, but the author of this dissertation deemed this provided value inferior to what is to be expected from Social Housing (the value chosen could have been 365 but, for academic purposes, 360 was chosen to differentiate from a full year). The building usage factor is used for Sanitary Fittings and Appliances, while for Irrigation a full year of 365 days is utilized. This calculation tool automatically converts all the data into Liters per occupant per day to estimate how much water a building resident will spend in a day.

Building use factor	360 days/annum				
Sanitary fittings	Consumption rates	Usage factor	Daily consumption per occupant	Providing greywater?	Accepting Greywater/Rainwater?
Toilet (full flush)	6 L/full flush	4 flushes/o/day	24 L/o/d	N/A	No
Toilet (small flush)	0 L/small-flush	0 flushes/o/day	0 L/o/d	N/A	No
Bathroom tap	6 L/minute	75 seconds/o/day	7,5 L/o/d	Yes	No
Shower	9 L/minute	360 seconds/o/day	54 L/o/d	Yes	No
Bath-tub	120 L/bath	0,11 baths/o/day	13,2 L/o/d	Yes	No
Kitchen tap	12 L/minute	240 seconds/o/day	48 L/o/d	Yes	No
Sanitary devices sub-total			146,7 L/o/d		
Water using appliances	Consumption rates	Usage factor	Daily consumption per occupant		
Dishwasher	14 L/cycle	0,4 cycles/o/day	5,6 L/o/d	Yes	No
Washing machine	62 L/cycle	0,3 cycles/o/day	18,6 L/o/d	Yes	No
Appliances sub-total			24,2 L/o/d		
Irrigation	526,6 L/d		4,579 L/o/d	N/A	No
Total			175,48 L/o/d	146,9	0,00

Figure 4.31 – Daily water consumption per occupant (Level(s) Water Calculation Tool)

To recapitulate, the Water Calculator Tool assimilates all the information on the table displayed in Figure 4.32 and converts it to the Indicator's unit of measurement, cubic meters per occupant per year (or annum). Although not influencing these results, the final breakdown also reports on the WEI+ of the basin, to better alert users to the region's water scarcity.

Summer WEI+ =	23,31	Total Water Consumption (m ³ /o/a)	Of which potable (m3/o/a)	Of which non-potable (m3/o/a)
Sanitary fittings and devices (e.g. toilets, taps, baths and showers).	Toilets	8,64	8,64	0,00
	Bathroom taps	2,70	2,70	0,00
	Showers	19,44	19,44	0,00
	Bath-tub	4,75	4,75	0,00
	Kitchen taps	17,28	17,28	0,00
	Sub-Total	52,81	52,81	0,00
Water using appliances (e.g. dishwashers and washing machines).	Dishwashers	2,02	2,02	0,00
	Washing machines	6,70	6,70	0,00
	Sub-Total	8,71	8,71	0,00
Irrigation	Irrigation	1,67	1,67	0,00
	TOTAL (m ³ /o/a)	63,20	63,20	0,00
	TOTAL (%)	100	100,0	0,0

Figure 4.32 – Full breakdown of the Building's Water Consumption (Level(s) Water Calculation Tool)

4.9.3. COMMENTARY

Through the usage of estimations and average values, it was possible to perform a successful **Level 2** assessment of Indicator 3.1. The final results provide a good starting point for estimating future water consumptions on this Complex, in the event that no additional water efficiency measures are applied. A quick search for Portuguese news articles suggests that individual daily residential water consumption averages 124 liters, which suggests that the estimated value of 175.48 liters is too high to reflect an efficient new building project (Gaudencio 2018).

Results aside, the flow of tasks required by the Water Calculator tool are exceptionally well defined, providing a straightforward way to insert data and obtain the intended overview of water consumptions and regional water scarcity. This simplicity allows users to play with the data in order to comprehend how improving some parameters could substantially reduce each occupier's water consumption and associated monetary costs. An additional feature of the Indicator that was tested but not included in this study is a tab to compare design option performances, with the intent of understanding how simple changes in fitting/appliance models could produce considerable results in the full frame of the building. The user would have to perform a variety of calculations, like those described above, and record the different results and what was changed in a table, enabling a clear comparison.

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the water consumption design concepts described in Figure 0.7 (Annex B) were introduced into the design process, and if so, in what way.

A **Level 3** assessment of this indicator would only include one additional input in the Water Calculator: meter readings in cubic meters per year (m^3/a). This operational stage measurement would be compared to the value estimated for the building's precise design options (in this assessment, 175,48 L/o/d) and multiplied by the building's correct number of occupants.

4.10. INDOOR AIR QUALITY (INDICATOR 4.1)

4.10.1. DEFINITION AND SCOPE OF THE APPLICATION

As the lives of most Europeans increasingly move indoors, the importance of indoor air quality (IAQ) also rises significantly. Current trends seem set to continue, with online shopping and working from home removing the need to leave home, particularly after the COVID-19 outbreak and the shifts in social behaviors it enacted. As a result, the importance of systems that can provide healthy air to breathe inside residential buildings is impossible to overstate.

The two measures of IAQ on this Indicator are the levels of various pollutants, such as Volatile Organic Compounds (VOCs), and the condition of the air itself, as evaluated in CO_2 and humidity levels. Effective ventilation is the most important factor in guaranteeing IAQ in both of these realms. Proper ventilation has the ability to filter pollutants originating both from within the building and from the air coming inside from outdoors; moreover, it plays a key role in managing healthy levels of CO_2 and humidity levels within an appropriate range by maintaining a minimum air exchange rate. Ventilation strategies become even more essential for IAQ when a building's design goal is to improve energy performance, since this goal tends to make living spaces more airtight and therefore decrease the margin of error for proper ventilation.

Keeping the humidity level of indoor air within an appropriate range is an important feature of air quality, both in its short- and long-term effects. Insufficient humidity can dry out the human body, causing health problems and discomfort, especially for the skin, eyes, nose, lips, and throat. On the other hand, not only does excessive humidity cause both hot and cold temperatures to feel more extreme and unpleasant, negatively impacting comfort and quality of life, but it also encourages the growth of mold within the building. Mold in buildings is a menace to occupant health, as it is highly allergenic and can threaten respiratory function. Controlling for excessive humidity is especially crucial around bathroom and kitchen areas. In Portugal, uncontrolled humidity is an especially important issue, as shown in Figure 4.33.

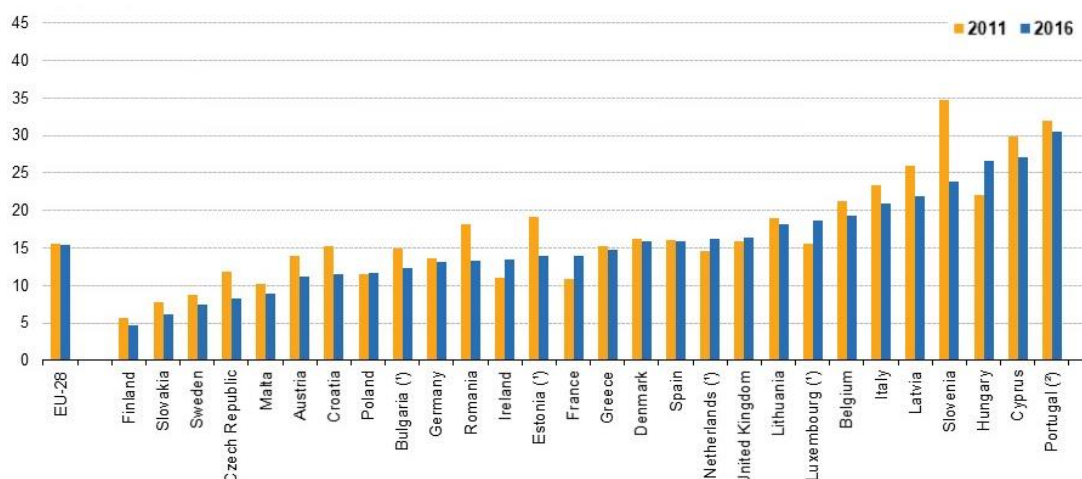


Figure 4.33 – Percent of population by country that lives in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor (eurostat 2018)

In addition to ventilation, other building features bearing a high impact on IAQ are proper building, outfitting, and renovation materials, as well as proper furnishing. The materials used in building or in furnishing a building can either inhibit or boost VOC production and can interact differently with varying levels of humidity. It is for this reason that design plays an important role in assuring that occupants have adequate IAQ. However, since occupants often utilize their spaces in ways that were not forecasted by the building's designers, it is necessary to continue monitoring IAQ throughout the use-stage of the building.

This Level(s) indicator outlines an approach to evaluate a building's IAQ by drawing the user's attention to the following performance aspects:

- How the building's ventilation system responds to and manages any changes in air quality, CO₂, and humidity.
- The ability of selected fit-out materials to mitigate air pollutants.
- The specifications for selected filters to regulate any air taken in from outdoors.
- Any risk for radon and mold over the life course of the building and its materials.
- Use-stage monitoring of IAQ, both in ventilation system function and in material performance.
- The occupant's observations of IAQ and ventilation effectiveness.

These performance aspects are evaluated by measuring several parameters, described in Figure 4.34. Additional instructions suggest that the ventilation rate can also be expressed on a per-person basis, which can be useful when preparing for situations of high occupation rates. The Indicator is regulated and instructed by the Level(s) User Manual 3: Indicator 4.1 (Dodd, Donatello and Cordella 2021j)

4.1.1 Indoor air quality conditions		4.1.2 Target pollutants			
		Mainly from indoor sources		Mainly from outdoor sources	
Parameter	Unit	Parameter	Unit	Parameter	Unit
Ventilation rate (air flow)	L/s/m ²	Total VOCs	µg/m ³ ³⁴	Benzene	µg/m ³
CO ₂	ppm	CMR VOCs*	µg/m ³	Radon	Bq/m ³
Relative humidity	%	R value	Decimal ratio	Particulate matter <2,5 µm	µg/m ³
Occupant survey	Not defined	Formaldehyde	µg/m ³	Particulate matter <10 µm	µg/m ³

Figure 4.34 – Parameters covered by Indicator 4.1 (Dodd, Donatello and Cordella 2021j)

- Carcinogenic, Mutagenic, or toxic for Reproduction VOCs (CMR VOCs)
- According to European Standards, the R value is the sum of each R_i value obtained during a test. R_i values are the ratio between the mass concentration in the air of the reference room the Lowest Concentration of Interest (substance specific value).

According to Level(s), to perform the main activities this indicator (Figure 4.35) users are required to at least have:

- Estimates for the occupation rate and schedule of the main building zones that are to be ventilated
- Ventilation filters' specifications, generally obtained from the suppliers
- Access and working knowledge of the design processes set out by the EN 16798 (indoor environmental criteria for the design of buildings);
- Emission data from products planned for use
- (for Level 3) A monitoring plan and the required equipment to perform it.

The case study project team did not provide any of this required information, nor did the available Designs mention specifications for the verification of minimum IAQ requirements besides simplistic estimations to the verification of each apartment ventilation requirements (part of the preliminary Energy Performance Certificate). This indicator's User Manual provides extensive instructions for the evaluation of each parameter, and therefore this research will not pursue this application, since it would require oversimplification without accurate data. Likewise, only a summary of each indicator activity and final results template will be displayed to allow readers a better understanding of what knowledge a full-scale application would provide.

Level	Activities related to indicator 4.1
1. Conceptual design	✓ Design of the building fabric and ventilation systems to meet target ventilation rates ✓ Control of potential sources of humidity by ventilation design ✓ Inspection of properties to be renovated in order to identify any problems relating to damp and mould. ✓ Design solutions for identified areas of cold bridging and damage from humidity in renovated properties ✓ Source control of target pollutants by selection of construction products/materials according to their tested emissions.
2. Detailed design and construction (based on as-built drawings)	✓ Verification that as-built and installed building fabric and services reflect those as designed.
3. As built performance	✓ In-situ measurement of the indoor concentration of target pollutants after completion and handover but prior to occupation. ✓ Functional performance testing of ventilation filters and their suitability for the building location.
3. In-use performance (testing after occupant entry and furnishing)	✓ In-situ measurement of the indoor concentration of target pollutants during occupation. ✓ In-situ measurement of the CO2 and relative humidity levels.

Figure 4.35 – Review of the activities related to Indoor Air Quality Indicator (Dodd, Donatello and Cordella 2021j)

4.10.2.COMMENTARY

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the main design factors influencing IAQ described in Figure 0.8 (Annex B) were introduced into the design process, and if so, in what way.

For **Level 2** and **Level 3**, quantitative assessments would produce results estimating the distinct parameters of Figure 4.34. The Level(s) documentation website offers a set of IAQ reporting tables, which must then be completely filled by the user, logging a complete overview of the project performance. They are displayed in Figure 4.36 and Figure 4.37 for a Level 2 (assessed with detailed design data) and on Figure 4.38 for Level 3 (requiring as built and in performance data).

4.1.1. Design indoor air quality conditions - general building level information							
Floor area (m2)	Method applied	Outdoor air quality (particulates)	Outdoor air quality (gaseous pollutants)	Supply air quality	Filter specification		
					1st	2nd	3rd

4.1.1. Design indoor air quality conditions - specific information for defined building zones								
Building zone/room	Floor area (m2)	Method applied	Ventilation performance category	Ventilation rate	Units	Design occupation rate (person/m2)	Upper CO2 limit (ppm above outdoor air)	Control range of relative humidity (%)

Figure 4.36 – IAQ conditions. Level 2 reporting tables (IAQ spreadsheet)

4.1.2. Target indoor air pollutants - general building level information								
Floor area (m2)	Indoor radon risk assessed?	Estimated exposure (Bq/m3)	Mould risk assessed?	Conclusion about mould assessment				
4.1.2. Target indoor air pollutants - specific construction products and materials								
Construction product/material	Product type or application	Total VOCs (µg/m³)	R value	Formaldehyde (µg/m³)	Certified by labelling scheme? If so, which one?	Other relevant information? (e.g. specific limits/results for other VOCs etc.)		
Ceiling tiles	All							
Paints and varnishes	walls and ceiling							
	floors and stairs							
	doors and windows							
Floor coverings	textile coverings							
	lamine and flexible coverings							
	wooden coverings							
	associated adhesives and sealants							
Renovation products	internal insulation							
	interior surface treatments (e.g. to resist damp)							
Other (please specify)	Other (please specify)							

Figure 4.37 – Target pollutants. Leve 2l reporting tables (IAQ spreadsheet)

Level 3 - 4.1.1 IAQ conditions								
Representative area tested and time/date of test	Floor area (m2)	Method applied	Ventilation performance category	Ventilation rate	Units	Occupation rate (person/m2)	CO2 (ppm above outdoor air concentration)	Control range of relative humidity (%)
Level 3 - 4.1.2 Target indoor air pollutants			Representative area tested			Representative area tested		
Nature of IAQ parameter	IAQ parameter		Design stage	Post completion (prior to)	During occupation	Design stage	Post completion (prior to occupation)	During occupation
Pollutants predominantly from outdoor sources	Radon (Bq/m³)							
	PM _{2.5} (µg/m³)							
	PM ₁₀ (µg/m³)							
	Ozone (µg/m³)							
	Benzene (µg/m³)							
Air quality aspects (from outdoor & indoor sources)	Relative humidity (%)							
	CO2 (ppm indoors)							
	CO2 (ppm outdoors)							
Pollutants predominantly from indoor sources	Total VOC (µg/m³)		n/a			n/a		
	Total CMR VOCs (µg/m³)		n/a			n/a		
	R-value		n/a			n/a		
	Formaldehyde (µg/m³)		n/a			n/a		

Figure 4.38 – IAQ Conditions and Target pollutants. Level 3l reporting tables (IAQ spreadsheet)

4.11. TIME OUTSIDE OF THERMAL COMFORT RANGE (INDICATOR 4.2)

4.11.1. DEFINITION AND SCOPE OF THE APPLICATION

Effective thermal controls in sustainable buildings have the potential to make a large difference in living standards. Inadequately regulated thermal conditions inside of buildings are a main reason why occupants consume more energy than would be required for their baseline operation. Thus, Level(s) has defined in this indicator a range of comfortable indoor temperatures, outside of which the occupants would be likely to heat or cool their buildings. The unit of measurement for this indicator is the **percentage of time, over a year of average weather in the building's area, that the interior of the building is outside of the range of 18°C and 27°C.**

This indicator focuses primarily on measuring summer days of excessive heat, honing more specifically into the solar gains during the months of exposure to more direct sunbeams. It emphasizes methods of cooling which do not require energy consumption, such as shading and passive cooling techniques.

However, warming buildings during the winter is also an important part of a building's annual energy consumption and in Portugal, around 19% of people are unable to afford to keep their homes warm through the winter (eurostat 2021a). This inability, in addition to high national energy costs and low per capita income, is often due to a combination of improper or insufficient insulation, outdoor air infiltration, and poorly operating (if at all) heating systems. While the climate is moderate in Northern Portugal, where this case study is located, it is not a region that allows for comfortable wintering without some method of heating.

The purpose of this indicator is to determine the **inherent thermal resilience** of the structure itself, and therefore only includes the temperature controls that are integrated with the envelope of the building. Likewise, it is to be applied both with and without the use of central cooling/heating systems, and it is to be applied to all spaces that account for more than 10% of useful floor area.

Weather conditions are projected to continue becoming more extreme in the upcoming phase of climate change. The implementation of this indicator should be performed in concert with Indicator 5.1. It is regulated and instructed by the Level(s) User Manual 3: Indicator 4.2 (Dodd, Donatello and Cordella 2021k).

Due to time constraints on this research, this Indicator and its counterpart (Indicator 5.1) will only be provided simple Level 1 instructions. The remaining activities can be seen on Figure 4.39.

Level	Activities related to the use of indicator 4.2
1. Conceptual design (following design principles)	✓ Thermal comfort risk assessment as part of the design of the building. ✓ Selection of tailored solutions for major renovation works.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ Calculated building permitting assessment - as part of an overheating assessment ✓ Consideration of different aspects of thermal comfort, including localised discomfort effects
3. In-use performance (based on commissioning, testing and metering)	✓ Measured EPB assessment sub types: climate corrected, use corrected or standard ✓ Commissioning: functional performance testing ✓ Comparison of estimated satisfaction levels with those obtained from occupier surveys.

Figure 4.39 – Review of the activities related to the Time Outside Thermal Comfort Range Indicator (Dodd, Donatello and Cordella 2021k)

4.11.2.COMMENTARY

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the design concepts allowing improvements to the building's thermal comfort conditions described in Figure 0.9 (Annex B) were introduced into the design process, and if so, in what way.

4.12. LIGHTING AND VISUAL COMFORT (INDICATOR 4.3)

4.12.1. DEFINITION AND SCOPE OF THE APPLICATION

The amount and quality of lighting available to the interior of a building is a main component of occupant satisfaction and overall wellbeing. A lack of natural lighting, for example, may lead to health issues relating to sleep and mood regulation. Moreover, the level of control that an occupant has over the type and amount of lighting supplied to their space at any given time corresponds to occupant satisfaction with their environment. This indicator takes these factors, as well as the views to the outdoors via windows or balconies, into consideration in order to determine and optimize the overall lighting and visual comfort of a building.

Regarding natural lighting, users of Level(s) should make plans in as much depth as possible in order to determine the amount of usable space to be illuminated by natural light. Important features to consider in this respect are the building's orientation, the geometry of the layout, the size of the windows, and the relative height of nearby buildings that might obscure direct light. Additionally, building designers and planners ought to keep in mind the possibility of glare, whether from reflective surfaces or from direct sunlight. Glare can result in higher energy use for otherwise unnecessary cooling demands, and it can be a major source of visual discomfort and dissatisfaction for a building's occupants.

In considering electric lighting options, a Level(s) user must consider the design and specifications for the light sources employed. Particular qualities of note, concerning the building occupant's satisfaction, are the hue of the lighting provided, the heat generated by prolonged usage, and the brightness or harshness of the light source. Occupant satisfaction should also be taken into account when planning measures of control such as dimmers and timers, so that an occupant can adjust lighting at his/her will.

To clarify the scope of assessment for this main factor of a building's comfort, the Level(s) framework expresses four main aspects of lighting to consider when applying this indicator:

- Daylight: does the building design maximize the useful contribution of sunlight? How does the building design account for glare?
- Light levels and distribution: are all parts of the building provided with quality lighting? Are parts of the building without windows provided with adequate lighting substitutes?
- Control: how much autonomy do occupants have in meeting their changing lighting needs? How much of the lighting process is automated to best optimize energy consumption and comfort?
- Light source quality: Do the electric lighting sources accord with the standard of living that the building aims to provide?

For the moment being, there are only instructions for Level 1 assessments of this Indicator. Because of its wide scope, future developments for quantitative assessments will measure a range of units already specified and enlisted in Figure 0.10 (Annex B). It is regulated and instructed by the Level(s) User Manual 3: Indicator 4.1 (Dodd, Donatello and Cordella 2021j).

This research will apply this Indicator at **Level 1** and evaluate the daylight performance of the building. Information for this application was gathered by reviewing the architectural plans for the site layout and the Electrical Designs. Current and future activities related to this method are displayed in Figure 4.40.

Level	Activities related to the use of indicator 4.3
1. Conceptual design (following design principles)	✓ At the <u>conceptual design</u> stage, the influence of building form and orientation on the daylighting performance can be considered as well as the supplementary electric lighting systems that will be necessary to provide the required illumination.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ <u>Detailed design and construction</u> : Prior to commencement of works on site and during the detailed design stage, more accurate lighting plans as well as sequences of operations for lighting controls can be made to ensure that the lighting system is capable of meeting the required lighting needs. Calculations will be made and verified by simulations.
3. As-built and in-use (based on commissioning, visual inspection and meter readings)	✓ <u>As-built and in-use</u> : The last stage should include a walk-through pre-occupation of the work/living spaces with in-situ measurements to identify and address any performance gaps and to ensure that the commissioned luminaires and systems meet the design criteria. A post-occupancy evaluation could be considered in order to understand the occupant impressions of the lighting conditions and installations.

Figure 4.40 – Review of the activities related to the Lighting and Visual Comfort Indicator (Dodd et al. 2021)

4.12.2.RESULTS

This **Level 1** assessment starts with the analysis of the lighting and visual comfort design concepts of Figure 4.41. Considering such topics in the early days of the conceptual designs can allow the subsequent engineering and architectural designs to be more accommodating of occupants' health, satisfaction, and visual comfort. Such an assessment should be accompanied by Figure 0.10 (Annex B), as it displays the many units of measurement that will be essential for assessing this indicator once fully operational. After this review as performed, the reporting should be done using this indicator reporting table – Table 4.10

Level 1 design concept	Brief description
1. Maximising the useful contribution of daylight	This aspect can be influenced by a number of architectural design decisions/concepts. Metrics for assessment would include daylight factor, sunlight exposure, spatial daylight autonomy and the use of automated shading. Potential trade-offs from excessive daylighting (e.g. glare, increased cooling energy) should also be considered as well as the design integration of shading devices.
2. Ensure that light levels and distribution are appropriate	Paying particular attention with this aspect to working planes for the visual tasks of the occupier. This should take into account both artificial and natural light as well as diffusion. Metrics should include task illuminance and colour rendering index.
3. Ability of occupants to tailor the lighting to their individual needs.	This aspect should include control over individual lighting levels and colour temperature (via manual or programmable controls for on/off and dimming).
4. Suitable quality of electric light fittings	This aspect should be defined by, for example, light efficacy, durability etc., whilst still minimising use phase electricity consumption

Figure 4.41 – Design concepts for lighting and visual comfort for a Level 1 assessment (Dodd et al. 2021)

Table 4.10 – Level 1 assessment of Indicator 4.3

Lighting and visual comfort concept	Has it been addressed?	How has it been addressed during the building design process?
1. Daylight - Maximize the useful contribution of daylight and minimize negative impacts on visual comfort	Yes	Each individual room as its own window span, protected with external blinds, to allow lighting capacities and daylight control. External views are generally unobstructed, due to the low urban density of the area. Common areas within the apartments were generally oriented to South/West to allow efficient daylight usage on this high occupation rate space.
2. Light levels and distribution for visual comfort	No	There are no mentions of steps being taken to measure light levels and light distribution within the areas in order to improve visual task illumination.
3. Automated and personalized control for visual comfort.	No	The Electric Design mentions no plans to install personalized or automated controls planned. Manual control will be limited to on/off switches.
4. Light source quality (for electric light sources)	No	The only metric displayed for the luminaries was a Color Temperature of 3000K.

4.12.3. COMMENTARY

The search for the inclusion of most of the lighting and thermal comfort design concepts within the conceptual design of the building did not produce many results. The overall assessment seems to prove that little to no precaution was given to assuring how light sources will influence the comfort of occupants. Since such assessments are not yet very common in the Portuguese Industry, such conclusion is not surprising. One concept that is more generally considered is the orientation of the building and its internal division layout. That aspect was thoroughly considered when allocating internal space, and when projecting window spans

4.13. ACOUSTICS AND PROTECTION AGAINST NOISE (INDICATOR 4.4)

4.13.1. DEFINITION AND SCOPE OF THE APPLICATION

A European Environment Agency report (2020) states that environmental noise remains a major environmental problem that affects the health and the wellbeing of millions. It also adds that European policy objectives aiming to reduce and control this issue have not been achieved and are unlikely to be in the coming years due to constant urban growth. Attempting to tackle this persistent issue, Indicator 4.4 measures the **acoustic performance** of buildings in order to introduce design solutions that would protect its users both from the outside acoustic climate, and from unwanted noise generated inside the building. This is of particular importance in apartment buildings, such as the case study project, so that groups of occupants can avoid hearing the nearby sounds of their neighboring families. This Indicator is regulated and instructed by the Level(s) User Manual 3: Indicator 4.4 (Dodd and Donatello 2021a).

To conduct this study, a **Level 1** assessment will be performed. This Indicator is still in a preliminary stage of development, and as such it does not provide instructions for Levels 2 and 3. Instructions for a

complete Level 1 qualitative assessment are already available, aiming to introduce considerations necessary to develop a quality acoustics environment in the early stages of a project's design. The activities associated with this Indicator are presented in Figure 4.42. Additional information is provided as to what measurements the future developments of this Indicator will enable.

Level	Activities related to the use of indicator 4.4
1. Conceptual design (following design principles)	✓ <u>Conceptual design</u> : The main considerations in creating a quality acoustic environment and for controlling noise can be used by designers to already assess the potential risks based on the building uses, the location and potential configuration of spaces within the building.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ <u>Detailed design and construction</u> : Upon moving into the detailed design of the building, the acoustic performance can be calculated and estimated for the main aspects addressed by the indicator. The design team can then focus on material selection and detailing required to achieve a specific level of technical performance.
3. As-built and in-use (based on commissioning, testing and measuring)	✓ <u>As-built and in-use</u> : Upon completion, it will become possible to carry out field surveys and measurements in order to determine the as-built performance of the building and its internal spaces.

Figure 4.42 – Review of the activities related to the Acoustics and Noise Protection indicator (Dodd and Donatello 2021a)

The steps taken to complete these activities were:

- Analyzing the Level 1 checklists provided by Level(s)
- Reviewing the building's Acoustic Project
- Reporting how the available data complies with Level(s) inquiries.

The **information necessary** for this assessment was found on the Acoustic Performance Project, which verifies the minimum acoustic insulation requirements of the building.

4.13.2. RESULTS

Being part of a social housing complex that will house a total of 115 residents, the design of Building 1.1 must comply with the acoustic requirements that will provide its residents with quiet daily life. To trigger the assessment of this criteria, Level(s) adds to this Indicator several questions that must be addressed by the conceptual design team working on the project, presented in Figure 4.43. They cover the five paramount acoustics and noise protection design aspects defined by the method.

Acoustic design aspects	Description	Considerations
1. Façade sound insulation	Protection from noise coming from the outside	Is exterior noise likely to adversely affect habitable rooms and by how much? Are there requirements that should be met in order to ensure there is adequate noise protection? Are external noise levels likely to be above WHO's suggested limit of $L_{den} = 55 \text{ dB(A)}$ outside habitable rooms?
2. Airborne sound insulation	Protection from airborne noise within adjacent rooms and spaces or buildings.	Is airborne noise from: - rooms outside the dwelling, - common areas, or - between other spaces Is it likely to adversely affect habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
3. Impact sound insulation	Protection from the sound of impacts within adjacent spaces or on an adjacent floor or wall.	Is impact noise from: - rooms outside the dwelling, - common areas, or - between other spaces Is it likely to adversely affect habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
4. Service equipment noise	Protection from noise generated by service equipment	Is service equipment for: - the building as a whole, - specific floors, or - individual dwellings Is it likely to adversely affect habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
5. Sound absorption in rooms and enclosed spaces	Control of the reverberation time, background noise level and speech intelligibility/privacy within spaces.	Has the reverberation time and sound absorption been considered in common areas adjacent to habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?

Figure 4.43 – Acoustic design aspects Level 1 considerations for Residential Buildings (Dodd and Donatello 2021a)

The instructions available to provide a Level 1 assessment are based on a checklist to see which of these aspects were considered by the team during the design phase. For this, a reporting table must be completed in the format of Table 4.11. To avoid having to produce results for every individual room of the building, this study chose to assess one of the bedrooms of fraction A (a T4 apartment on the ground floor of the building). This simplifying option was enabled by the homogeneity of the building construction solutions, and by the fact that bedrooms are one of the critical divisions that require better acoustic performances to allow tranquil rest.

Table 4.11 – Level 1 assessment of Indicator 4.4

Acoustics and noise protection design aspect	Has it been addressed?	How has it been addressed during the building design process?
1. Facade sound insulation	Yes	External concrete walls with an ETICS external solution that provides them a Weighted Standardized Level

		Difference for Traffic Noise (D2m,Nt,w) of 36,5dB (the minimum requirement is 33dB*)
2. Airborne sound insulation	Yes	Separating the fractions, Internal double brick walls and concrete slabs (with ceramic pavement and tinned ceiling) solutions provide a Weighted Standardized Level Difference (DnT,w) of 52,4dB and 56,3dB respectively (the minimum requirement is 50dB*)
3. Impact sound insulation	Yes	Vertically separating the fractions, concrete slabs (with ceramic pavement and tinned ceiling) solutions provide a Weighted Standardized Impact Sound Pressure Level (L'Nt,w) of 53.4dB (the maximum allowance is 60dB*)
4. Service equipment noise	No	No service equipment was described in the Acoustics Project and no verification was performed.
5. Sound absorption in rooms and enclosed spaces	Possible Yes	Calculations were made to estimate an Equivalent Sound Absorption Area (A_{eq}) of 1.0m ² and a Reverberation Time (T) of 4.67s

* Minimum requirements were set for this building Zone in accordance with Portuguese regulations (*Decreto-Lei n°96/2008 Artigo5°*)

4.13.3. COMMENTARY

Due to the Acoustic Project being somewhat detailed compared to other the types of reports available, it was possible to include in the Level 1 reporting table some quantitative information. Based on the description of Level 2 and 3 activities available on Figure 4.42, it is to be expected that future developments of this Indicator will include reporting on the performance data that was displayed for this assessment.

In the meantime, instructions provided for Level 1 were easy to follow and it was possible to verify that the building's design takes into consideration most of the acoustic aspects necessary to provide its future occupants some protection from unwanted noises.

4.14. PROTECTION OF OCCUPIER HEALTH AND THERMAL COMFORT (INDICATOR 5.1)

4.14.1. DEFINITION AND SCOPE OF THE APPLICATION

It is to be expected that over the course of the several decades of a building's use stage, the weather conditions in the building's zone will change substantially. The current climate change projections generally anticipate an increase in extreme weather conditions, manifesting in hotter summers and colder winters. This indicator considers the features of a building that can moderate the temperature inside and around a building, with an emphasis on what the EU refers to as "green infrastructure," that is, temperature control measures with low environmental impact.

This Indicator aligns with Indicator 4.2, and uses the same unit of measurement, i.e., **percentage of time outside of the range of comfortable temperatures (18 to 27°C)**. In line with Indicator 4.2, the emphasis here is on hotter temperatures rather than colder ones, accounting for the projected rise in global temperatures of 2°C by 2050 (estimated on Directive (EU) 2018/8441).

This Indicator differs from Indicator 4.2 in that it focuses on future projections of annual temperatures, whereas 4.2 focuses on recorded past temperatures. By projecting the thermal conditions of the building into the future, users of Level(s) will be able to assess the level of risk associated with changing temperatures and to identify steps that can be taken to protect the building's thermal environment from dramatic change in the face of emerging climate exigencies. It is regulated and instructed by the Level(s) User Manual 3: Indicator 5.1 (Dodd, Donatello and Cordella 2021l).

Due to time constraints on this research, this Indicator and its counterpart (Indicator 4.2) will only be provided simple **Level 1** instructions. The remaining activities can be seen on Figure 4.44.

Level	Activities related to the use of indicator 5.1
1. Conceptual design (following design principles)	✓ Thermal comfort risk assessment as part of the design of the building. ✓ Selection of tailored solutions for major renovation works.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ Calculated building permitting assessment - as part of an overheating assessment ✓ Consideration of different aspects of thermal comfort, including localised discomfort effects
3. In-use performance (based on commissioning, testing and metering)	✓ Measured EPB assessment sub types: climate corrected, use corrected or standard ✓ Commissioning: functional performance testing ✓ Comparison of estimated satisfaction levels with those obtained from occupier surveys.

Figure 4.44 – Review of the activities related to Protection of Occupier Health and Thermal Comfort (Dodd, Donatello and Cordella 2021l)

4.14.2. COMMENTARY

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the design concepts allowing improvements to the building's thermal comfort conditions described in Figure 0.11 (Annex B) were introduced into the design process, and if so, in what way.

4.15. INCREASED RISK OF EXTREME WEATHER EVENTS (INDICATOR 5.2)

4.15.1. DEFINITION AND SCOPE OF THE APPLICATION

Extreme weather events are not new, as they have shaped the building and settlement patterns of humans since prehistory. However, these events have often been proscribed to regions where their occurrence is somewhat predictable. Now, on the other hand, humankind faces an increasingly unpredictable climate, and the construction sector must prepare for an uptick in extreme weather events beyond the pale of what has been recorded in recent times. These extreme weather events can include unmanageably heavy precipitation, prolonged droughts, intense heat waves, windstorms, wildfires, landslides, and floods, which break into three main categories: fluvial, pluvial, and coastal.

A rising sea level appears to be one of the most consequential and inevitable manifestations of climate change. The cultures and populations of the European continent have been built up around its coasts and rivers, and therefore a great deal of effort must be made to mitigate the loss of economic and cultural value, and more importantly, the loss of life. This is certainly true in Portugal, the site of this case study, which is a highly coastal country.

However, a rising sea level manifests in many more climactic changes than mere flooding, since it throws off the balance of global atmospheric and weather patterns. Therefore, this Level(s) Indicator aims to promote increased readiness for a wide range of extreme weather events.

To compound the effects of a changing climate, the European continent is particularly vulnerable to extreme weather because of its pattern of development. The phenomenon of urban sprawl over recent decades, owing mostly to expensive real estate costs, has resulted in less geographically desirable locations undergoing rapid development. These zones often face higher exposure to extreme weather. (Smiraglia et al. 2021)

A building's ability to withstand dangerous weather conditions will become increasingly important for occupants and owners, both in the primary respect of safety, and in the secondary respect of insurance costs. Buildings that are poorly prepared to handle extreme weather conditions will likely cost its owners or occupants untold amounts in insurance premiums. Therefore, it is in the economic interests of building owners and occupants—and, for this reason, also for building designers—to future-proof buildings as much as possible with regard to extreme weather.

In evaluating a building's expected performance in these emergency situations, the Level(s) user should consider the following aspects of a building's construction, according to the geographic location of the building site:

Climatic actions	Level 1 – Conceptual design	Levels 2 & 3 – Detailed design and In-Use stages (Placeholder)
Fire exposure (from wildfires linked to drought conditions)	Layout on plot area, physical barriers on site perimeter, ground cover material (e.g. vegetation or hard paving), choice of materials for building envelope and structure.	Once the building structure and envelope is well defined, the following are considered: • Design values of actions; • Design values of material or product properties; • Design values of geometrical data; • Design resistance • Ultimate or serviceability limit states (EQU, STR, GEO, FAT)⁷
Snow loads	Pitch of roof, ease access for sweeping, roughness of roofing material.	
Wind actions	Choice of building form and surface roughness of building envelope.	
Thermal actions (daily and seasonal)	Building envelope design, cladding materials and fastenings. Temperature differentials on inner and outer surfaces of building envelope.	
Flooding	Building position on plot area if land is of different elevations. Potential elevation of ground floor slab. Installation of flood barriers.	The building structure should be able to withstand actions with defined probability (e.g. 0,02, which would mean a return period of 50 years).

Figure 4.45 – Extreme climate events considered on Indicator 5.2 (Dodd, Donatello and Cordella 2021m)

As indicated in Figure 4.45, this Indicator is only intended for application at Level 1 at this stage – and it is that assessment that will be performed on this research. New Eurocodes, anticipated soon, will announce quantitative measurements to be taken at Levels 2 and 3. This Indicator is regulated and instructed by the Level(s) User Manual 3: Indicator 5.2 (Dodd, Donatello and Cordella 2021m).

4.15.2. RESULTS

To perform the qualitative analysis of extreme weather event risks, the user is instructed to follow the steps listed in Figure 4.46. They were chosen to guarantee that extreme weather risks at the project's location are acknowledged and considered in the design options.

Level 1 design concept	Brief description
1. Preparing the ground for adaptation and resistance to extreme weather events.	Consult the following website, where any available national adaptation policies, strategies and plans should be available: https://climate-adapt.eea.europa.eu/countries-regions/countries Moreover, consider contracting specialists with skills and experience in the design and modelling of climate adaptation.
2. Assess the main risks of and vulnerabilities to extreme weather events at the building location (both now and in the future).	Consider historical extreme weather events in the area and consult any available risk maps, e.g. the national flood risk hazard map and the FRMP (Flood Risk Management Plan), the relevant drought management plan (if one available) and or RBMPs (River Basin Management Plans) For the specific site, consider factors such as exposure to high wind speeds, excessive solar gain and urban heat island effects, proximity of mountainous regions, proximity of steeply sloped land masses and proximity to the sea or watercourses (both in vertical and horizontal axes). Consult public reports, weather databases, climate change projections and experts if necessary. Insurance analysts may be especially helpful.
3. Identify possible adaptation actions.	Depending on the main risks identified in 2., check for relevant literature and case studies for climate adaptation for buildings. For example see the ClimateADAPT database: https://climate-adapt.eea.europa.eu/knowledge/tools/case-studies-climateadapt).
4. Assess the costs and benefits of adaptation actions.	Cost considerations should include the potential increased complexity of the construction works, increased capital costs and increased maintenance costs (especially relevant for certain nature-based solutions). Benefits to consider could include potentially lower insurance premiums and a reduced risk/cost of damage in the event of extreme weather events. In cases where the adaptation measures embrace nature-based solutions and aesthetically pleasing forms, benefits for biodiversity and occupant well-being may also be relevant.

Figure 4.46 – Concept designs for increased extreme weather events awareness (Dodd, Donatello and Cordella 2021m)

After reviewing these descriptions and consulting relevant national information about the risks associated with the location of the case study, Table 4.12 was elaborated to report the assessments.

Table 4.12 – Level 1 assessment of Indicator 5.2

Risk of extreme weather event design concept	Has it been addressed?	How has it been addressed during the building design process?
1. Preparing the ground for adaptation and resistance to extreme weather events.	Yes	National Adaptation Plan and Strategies are already in effect in Portugal (<i>Programa de Ação para a Adaptação às Alterações Climáticas - Resolução do Conselho de Ministros n.º 130/2019</i>)
2. Assess the main risks of and vulnerabilities to extreme weather events at the building location (both now and in the future).	Yes	Analysis of the region's Flood Risk Management Plan attributes no risks for this location. However, the Wildfire Risk Management Plan considers the location of moderate to high risk of fire. The different builds of the complex protect each other from excessive solar exposure and the low urban density of the location does not impose heat island effects.
3. Identify potential adaptation actions.	Yes	Fire Safety Designs were developed for the project, preparing the deployment of fire hydrants in strategic places around the complex

4. Assess the costs and benefits of adaptation actions.

No

No information was found confirming that these estimations were performed

4.15.3. COMMENTARY

The region where the case study is located is of relatively low risk considering the majority of extreme weather events. In the event that the predictions suggesting a general aggravation of these events come to full effect, the case study building and corresponding Social Housing complex are in good position to overcome difficulties.

4.16. SUSTAINABLE DRAINAGE (INDICATOR 5.3)

4.16.1. DEFINITION AND SCOPE OF THE APPLICATION

This Indicator focuses on the aspects of a building project that help to avoid major flooding incidents. Unlike Indicator 5.2, which focuses on what to do once an extreme weather event has already happened, this Indicator relates particularly to strategies that can prevent floods from happening in the first place. Of the three types of flood, the pluvial and fluvial floods are those which can most effectively be prevented with forward-thinking drainage design.

Because of urbanization, there are far fewer greenfield sites throughout most of Europe. These sites served a crucial drainage function for a given area. Now, concrete pavement has replaced soil, and there is a resulting increase in flood risk. The traditional approach to drainage has been to direct water away from the plot area and towards a shared city-wide drainage system, in the form of sewers. However, these sewer systems are prevented by a few limitations from meeting the drainage need expected over the next several decades. Made of heavy, inflexible materials and placed underground, it is nearly impossible to expand the pipes and therefore increase draining capacity; in the event of more frequent or severe flooding, the risk could be high for unsanitary and costly sewage back-ups that would further flood the streets.

Another consequence of current drainage systems is that, because of a lack of greenfield sites, an entire area's water rushes all at once into the river, rather than trickling slowly. When every municipality drains their water in this way, the effect is to raise the level of the river, which increases the likelihood of flooding for the communities downstream.

These issues are addressed in Indicator 5.3, which has the overall goal of promoting awareness of the methods and benefits of the sustainable alternatives to current drainage methods, which have been uncovered in recent research. It is regulated and instructed by the Level(s) User Manual 3: Indicator 5.3 (Dodd, Donatello and Cordella 2021n).

A single level is available at the current state of this Indicator development. Likewise, this research will assess this indicator on a **Level 1**. The information necessary for such task can be found on the Rainwater Drainage System Designs and respect descriptions. Activities related to this, and future levels are provided on Figure 4.47.

Level	Activities related to the use of indicator 5.3
1. Conceptual design (following design principles)	✓ information is provided to prompt discussion and decision making for the project about aspects that will influence pluvial flood risk directly at the site and that will indirectly influence fluvial flood risk downstream. The overall performance requirements of the drainage system should be agreed with planning authorities at this stage.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ <i>Prior to commencement of works on site and during the detailed design stage, the performance of the system shall be modelled against relevant design storms to estimate performance. The final design shall be adapted accordingly to meet any additional performance requirements or spatial constraints.</i>
3. In-use performance (based on commissioning, testing and metering)	✓ <i>The actual performance of the drainage system will be monitored by measuring runoff rates from the discharge point(s) and how closely water levels approach overflow points during real rainfall events and later determining how this compares to the predicted performance under an equivalent design storm determined in Level 2 estimations.</i>

Figure 4.47 – Review of the activities related to the Sustainable Drainage Indicator (Dodd, Donatello and Cordella 2021n)

4.16.2. RESULTS

The assessment of **Level 1** starts with the examination of the design concepts gathered by Level(s) to ensure that sustainable options are considered by designers - Figure 4.48.

Level 1 design concept	Brief description
1. Familiarise the core design team with the concept of sustainable drainage, its different components and how these can be linked together.	There is a wealth of literature available on the subject of sustainable drainage system thanks to work over the last 10-15 years. Some specific reference materials are recommended in the guidance section for consultation.
2. Assess the potential flood risk at the site.	Identify and contact the relevant authorities. Consider historical rainfall data and consult available flood risk maps for the local area (fluvial, pluvial and, if relevant, coastal). For the specific site, consider the current drainage system in the surrounding area (e.g. age, combined/non-combined etc.), the vertical drop to nearest discharge points, the extent of urbanisation in recent years and any concerns with pluvial flooding in recent years.
3. Consult relevant professionals and organisations at the beginning of the design process.	Gather urban planners, landscape architects, the concept architect, drainage engineers, the road authority and any other relevant parties around the table in order to collectively consider design and environmental aspects. This way, potential conflicts of interest can be flagged up and the roles, rights and responsibilities can be clearly understood before the design is completed and before the works begin.
4. Define the outline design and layout of the sustainable drainage system.	It is important here to define where storm water would be collected, where it would runoff to by gravity and how the runoff is conveyed to the ultimate discharge point(s). Overflows should also be clearly defined. At this stage it should be clearly agreed who takes ownership and responsibility for maintenance of the different components of the sustainable drainage system (i.e. the local authority or the building owner or a combination of both).
5. Assess the costs and benefits of sustainable drainage system.	Costs aspects should be determined by materials, works, landscaping and maintenance. Consideration could also be given to less tangible cost aspects such as increasing the risk of vector borne diseases (e.g. mosquitos) if the system includes a permanent pond where previously there was no permanent water in the immediate area. Benefits should focus on the four main pillars of sustainable drainage, which are: (i) water quantity; (ii) water quality; (iii) amenity value and (iv) biodiversity. Other benefits are also possible, including reduction of potable water demand (in cases where rainwater is harvesting for human uses) and the reduction of the urban heat island effect, thanks to evaporative cooling of standing water or evapotranspiration by vegetation.

Figure 4.48 – Design concepts for embracing sustainable drainage options on a Level 1 assessment (Dodd, Donatello and Cordella 2021n)

After getting familiarized with the sustainable drainage concepts, the reporting table for this assessment must be completed. For the application of this Indicator to the case study, Table 4.13 was elaborated.

Table 4.13 – Level 1 assessment of Indicator 5.3

Sustainable drainage design concept	Has it been addressed?	How has it been addressed during the building design process?
1. Familiarizing the core design team with sustainable drainage systems	No	Since the project does not contain many of the main sustainable drainage system components (such as rainwater harvesting, treatment systems and storage systems) it can be concluded that design teams did not were familiarized with such concepts.
2. Assess the potential flood risk onsite.	Yes	According to the region Flood Risk Management Plan, the site is not located in a zone where floods risk should be a problem. However, the designs estimate an area of around 1000m ² that will be converted into a community garden, downhill from the location of the buildings. Precautions to drain this area were taken in the Rainwater Drainage System Design (infiltration systems).
3. Consult relevant professionals and organizations at the beginning of the process.	Yes	Knowing that this is a Public Work, it is to be assumed that local authorities were aware of the environmental aspects related to this Indicator when allocating resources to elaborate the Designs
4. Define the outline design and layout of the sustainable drainage system.	No	The Rainwater Drainage System Designs do not mention any measures intending to apply sustainable drainage systems. Additionally, the system is already designed to operate solely with rooftop steel gutters and downspouts connected to public sewers.
5. Assess the costs and benefits of adaptation actions.	No	No mentions were found to the estimation of those benefits before making decisions related to the drainage systems.

4.16.3. COMMENTARY

Descriptions of the drainage systems that are to be applied to the complex showcase that most of the aspects that would create a sustainable drainage system were not performed on this project. These choices might have been taken due to the relative low risk of flood events in the region, both in present day and in estimations for the future.

4.17. LIFE CYCLE COSTS (INDICATOR 6.1)

4.17.1. DEFINITION AND SCOPE OF THE APPLICATION

An important factor that is currently slowing the rate of adoption of more sustainable construction practices is the high up-front cost of the project. While these costs are almost always over-compensated by the lower utility costs, the investors, stakeholders, property owners, and occupants can be discouraged by a higher price tag towards the beginning of a building's useful life. By promoting the philosophy of Life Cycle Cost (LCC), which measures the relevant costs for each stage of a building's life, this Indicator aims to correct for this bias in the market.

This Indicator begins in Level 1 by simply encouraging the users to take a long-term perspective on the costs associated with the building project. The Indicator's application becomes more in-depth as the project moves along, and requires verification, metering, and monitoring throughout the use stage of the building's life. Accurate data can then be collected on the cost distribution of the whole life cycle of the building.

This Indicator relies heavily on the inputs from Indicator 1.1 (use stage primary energy use), Indicator 2.1 (bill of quantities, materials, and lifespans), and Indicator 3.1 (efficient use of water resources). Increased thoroughness and accuracy in these previous Indicators will result in a more accurate assessment of the building's LCC in this step of the framework. The information output of this Indicator is in **Euros per square meter of useable floor area per year (€/m²/yr)**. It is regulated and instructed by the Level(s) User Manual 3: Indicator 6.1 (Dodd, Donatello and Cordella 2021o)

The activities for this indicator are described on Figure 4.49. This Indicator does not come with a built-in methodology that would allow direct quantitative calculations of LCC. Likewise, this Indicator will not be applied to the case study at hands since preparing such extensive calculations is not possible on the time window of this research. General guidelines for the indicators are provided next.

Level	Activities related to the use of indicator 6.1
1. Conceptual design (following design principles)	Life cycle thinking: Encouraging a longer-term perspective on design and specification decisions.
2. Detailed design and construction (based on calculations, simulations, drawings, and quotations)	Cost estimates and modelling: Based on the client's requirements and detailed designs.
3. In-use performance (invoices, meter readings and contractual agreements)	- Verification of as-built costs: Based on the final cost and the as-built specifications. - Metered utility costs: Real energy and water cost performance data. - Monitoring of maintenance and replacement costs: Refinement of projections over time as real performance data comes in.

Figure 4.49 – Review of the activities related to the LCC Indicator (Dodd, Donatello and Cordella 2021o)

4.17.2. COMMENTARY

A **Level 1** assessment would require the elaboration of a reporting table by the design team, stating whether or not the LCC design concepts described in Figure 0.12 (Annex B) were introduced into the design process, and if so, in what way.

Users intending to apply **Level 2** or **Level 3** calculations are obligated to choose an external LCC software or calculator that contains functionalities standardized ISO 15686-5 (guidelines for performing LCC) and a database of material costs that reflects the different elements of the project – if those costs

were not already manually provided on the Bill of Materials 2.1, then through more direct sources. Level(s) provides the instructions necessary to create a cost model in a compliant LCC software to start performing calculations. Users interested in performing this Indicator's LCC calculations on their projects are recommended to read the User Manual to better understand what information is necessary to gather from other Indicators, to be later processed by the LCC software. The final outputs of these calculations are to be reported in the table shown in Figure 4.50. To assure a better understanding of the accuracy of the results, the quality of data used as inputs must also be evaluated on Figure 4.51 in a scale of 1 (less accurate) to 4 (more accurate), described there. Level 2 and 3 assessments differ on the substitution of estimated construction and running costs by as-built and in-performance costs.

Type of cost	Normalised cost by life cycle stage (€/m ² /yr)		
	A Product and construction stages	B Use stage	C End of life stage
Initial costs	Construction	Refurbishment and adaption	Deconstruction and demolition
Annual costs	-	Energy	-
	-	Water	-
Periodic costs	-	Maintenance, repair and replacement	-
Global costs by life cycle stage	Sum of stage A costs	Sum of stage B costs	Sum of stage C costs

Figure 4.50 – Reporting Table for Indicator 6.1. Level 2 and 3 (Dodd, Donatello and Cordella 2021o)

Building elements	Types of data source used for the identified life cycle stages *			
	A Product and construction stages	Basis for future assumptions		
		B2 Maintenance	B3 Repair	B4 Replacement
Foundations				
Load bearing structural frame				
Non-load bearing elements				
Facades				
Roof				
Parking facilities				
Fixed lighting system				
Energy system				
Ventilation system				
Sanitary systems				
Miscellaneous systems				
* Data sources classification to be used: - Generic or default national or EU data - Default data provided at EU or national level - Default data provided by an existing assessment or reporting scheme - Older or less geographically specific benchmarked and averaged data - Published benchmark data, aggregated and averaged from similar projects - Estimates from published, average cost data obtained from contractors and suppliers - Recent tender and market estimates - Analysis of the bills of quantities and schedules from other similar projects - Current tender and market estimates - Direct estimates based on offers from contractors and suppliers				

Figure 4.51 – Reporting table for data quality, Indicator 6.1. Level 2 and 3 (Dodd, Donatello and Cordella 2021o)

4.18. VALUE CREATION AND RISK EXPOSURE (INDICATOR 6.2)

4.18.1. DEFINITION AND SCOPE OF THE APPLICATION

If Indicator 6.1 is targeted towards increasing consumer understanding of increased prices for sustainable building features, this Indicator focuses instead on the justifications behind those higher pricing structures. This Indicator aims to promote widespread adoption of sustainable construction practices by bridging the gap between the environmental, safety, and economic benefits of sustainable building features and the market valuation of property, making sustainability a more enticing option for stakeholders. This goal has the additional benefit of educating stakeholders and Level(s) users about considerations of sustainability that they might not have otherwise sought to learn.

Not only does this Indicator account for the more obvious factors of sustainability, such as resource efficiency, but it also includes risk assessments for the increasing frequency of extreme weather scenarios. Because it takes a comprehensive view of the building's sustainability features, its adaptability to future markets, its whole-life cost analysis, and its ability to safely withstand severe weather events, this Indicator represents a **culmination of all the previous Indicators within Level(s)**.

As of now, this Indicator has only been rolled out for **Level 1**, so that it can be integrated into the early planning stages of a project, fostering discussions among the team of Level(s) users, and shifting their attention to the main aspects that influence a value and risk appraisal of a building (Figure 4.52). If a user seeks a quantitative measurement, they are encouraged to make a comparison between a benchmark market valuation of a property (i.e., a valuation that does not account for any sustainability benefits), and an adjusted valuation which does incorporate the additional value of the building's total sustainability features. This Indicator is regulated and instructed by the Level(s) User Manual 3: Indicator 6.2 (Dodd and Donatello 2021b)

Level	Activities related to the use of indicator 6.2
1. Conceptual design (following design principles)	✓ Early stage identification of potential design influences on the appraisal of value and risk
2. Detailed design and construction	<i>Detailed design decisions</i> ✓ Support to the detailed appraisal and value engineering of design decisions ✓ The development of more informed scenarios for the performance of the property in the market <i>Financial approvals and due diligence</i> ✓ Support to demonstrate how performance aspects have been taken into account in the value engineering of the project ✓ Support to demonstrate the tangible steps taken to address possible future risks to performance and value <i>Cost control on site</i> ✓ Support to more clearly distinguish sustainability specifications that are important from a value and risk perspective
3. As-built and in-use performance	✓ Greater ongoing awareness of design features that are intended to protect the future value and minimise risks ✓ Management and monitoring of ongoing maintenance and replacement cycles, including the link to operational expenditure ✓ Management of costs and overheads that may be influenced by the improved management of risks.

Figure 4.52 – Review of the activities related to the Value Creation and Risk exposure Indicator (Dodd and Donatello 2021b)

4.18.2. COMMENTARY

Users are required to fill in the reporting table shown in Figure 4.53, stating whether the 3 potentials for future valuation (described on Figure 0.13 of Annex B) were discussed with clients in the course of making property valuations. This step is an important assessment for Users wanting to explore the full potential of Level(s). Debating each indicator potential for increasing overall value can be a great way to bring clients and property valuers up to speed with the value of sustainable features in their building, and to secure the ultimate permission to apply more costly measures that will ensure a future-proof and sustainable building. If this Indicator is performed at large scale across Europe, it will have the effect of influencing market pressures to favor, rather than disfavor, sustainable initiatives, driving up both supply and demand and resulting in a more overall sustainable Construction Industry.

However, there are certain building projects which are not subjected to market forces. The case study in question is one such building. As is common on the preliminary stages of publicly owned projects like this one, there were no mentions to measures or debates that would assess the future value growth of the Social Housing complex. The focus of this building project is rather on the good that it can provide, rather than the economic value it can generate. Even if the project team had been more focused on market factors, the format of this Indicator implies that the Level(s) application must be thoroughly completed at every level by the design teams. For this reason, it would be impossible to provide data for this indicator unless a full-scale deployment of Level(s) is conducted from the early stages of the project development.

Level(s) indicators	Has the potential influence been taken into account in discussion with the client and their property market valuers?		
	1. Increased revenues from more stable investments	2. Reduced operational overheads	3. Reduced exposure to future risk
1.1. Use stage energy consumption			
1.2. Life cycle Global Warming Potential <i>(and potentially on other environmental impacts)</i>			
2.1. Bill of quantities, materials and life spans			
2.2. Construction & demolition waste and materials			
2.3. Design for adaptability and refurbishment			
2.4. Design for deconstruction, reuse and recyclability			
3.1. Use stage water consumption			
4.1. Indoor air quality			
4.2. Time out of thermal comfort range			
4.3. Lighting and visual comfort			
4.4. Acoustics and protection against noise			
5.1. Protection of occupier health and thermal comfort			
5.2. Increased risk of extreme weather events			
5.3. Sustainable drainage			
6.1. Life cycle costs			

Figure 4.53 – Reporting table for a Level 1 assessment. Indicator 6.2 (Dodd and Donatello 2021b)

5

CONCLUSION AND FURTHER DEVELOPMENTS

5.1.CONCLUSION

In this study, the author applied the European Union's new BSAM, Level(s), to a case study in the northern region of Portugal. The proposed building project will convert an abandoned lumber yard into a social housing complex for a socially and economically marginalized segment of the Portuguese population. In performing this application, the author's main purpose was in fact not to simply assess the building in question, but rather to elaborate and contextualize the Level(s) framework as a whole, highlighting its strengths as a BSAM in the European sector and illuminating certain parts of it that will require further improvements if it is to succeed.

The Level(s) framework is intended to unite the European Construction Industry under the goal of sustainability. Prior to the publication of Level(s), the European scene was cluttered with a vast array of local and national BSAMs. Many of these certification schemes have the advantage of being specifically tailored to their local industries and cultures, but the serious drawback of not allowing for direct comparisons between buildings and sectors throughout the European continent. The approach taken by the creators of Level(s) was to build a BSAM that would not provide a conflicting certification, which would have made it seem like a threat to existing practices, but would rather provide a "common language" to allow for easier communication between different methods. In doing so, Level(s) would allow for much easier monitoring of progress towards the climate goals established by the EU in the Paris Climate Accord.

As for the other BSAM and certification schemes, there have already been developments to integrate Level(s) requirements into their structures (Kanafani et al. 2019), as its alignment with European policies comes as an enormous advantages for stakeholders: the fully integrated structure of Level(s) with sustainable and circular economy initiatives opens up the doors to fiscal incentives (taxes or fees), economic incentives (funding or aid). To obtain this much needed help provided by public bodies, building project teams will have to assess and communicate the level of sustainability and circularity of their building, and in doing so, will product and contribute crucial data to the European regulatory bodies.

As it stands, however, there are also a number of issues with the Level(s) framework that made themselves obvious in the course of this study. The Indicator User Manuals are often exceedingly technical, and sometimes written in confusing or ambiguous English. Additionally, Indicators often rely on or mention standard values and procedures that are only fully described in European Standards (EN), which must be purchased individually at a prohibitive price in order to access and employ them. This factor adds to another fragility, the lack of self-sufficiency in the Indicators, which depend to a large

extent on external sources and third-party software systems for various measurements and qualifications. This was especially the case for some of the more holistic Indicators, such as GWP, which reference regulations and obligate users to employ other softwares that comply with those regulations. Such a varied approach to a highly technical process results in major confusion and damages ease of use.

There was also a lack of information regarding the finer details of the Level(s) framework itself. Since the method is still quite new, very few examples of Level(s) applications have been performed. The lack of concise academic information about the method, as well as the nonexistence of case studies with extensive assessments performed with the most recent version of the method, presented considerable obstacles to the organization and completion of this study. As a result, many decisions in the course of this exploratory study had to be made on the basis of the author's best interpretation of the regulations.

If Level(s) is to succeed in unifying the European Construction Industries under the goal of sustainability, countries like Portugal, which have been slower to adapt to new environmentally conscious practices, must be brought up to speed with other Member States that have been actively developing these practices and customs for decades. Since this study was one of the first of its kind in the whole of Europe, and it was conducted in the Portuguese sector, it was inevitable that it would encounter obstacles in this regard, especially resulting from the relatively low priority placed on sustainability by the project team, from the lack of established information networks, and from insufficient training on behalf of the author with respect to the more meticulous measurements required by Level(s). Some of the Indicator topics are not common practice in the Portuguese Industry, and are likewise not commonly taught in school or pursued by academic research.

Moreover, there is little supervision or accountability for the minimum requirements that are established for the Portuguese Construction Industry. For instance, Portuguese regulation requires that a Waste Management Plan accompanies the construction documents of public works (*Artigo 43 do Decreto-Lei n.º 18/2008*), but there was no trace or mention of a WMP in the information provided to the author. No doubt due to bureaucratic inefficiencies, these oversights and shortcomings on behalf of Portuguese regulatory bodies have the potential to undermine the effectiveness and uptake of this very important sustainability initiative.

However, not all of the difficulties encountered in this study resulted directly from the author and the project being Portuguese, of course. In order to be a truly comprehensive BSAM, the method is as broad as possible in its scope. As such, its application creates many challenges for an individual user, since no single person is likely to be an expert in every category of sustainability covered by the method. Level(s) truly is a framework designed for large team use, and any attempt to circumvent this aspect of its design will encounter issues of both breadth and depth.

There was also the issue of perspective and extent of user involvement. Since Level(s) was designed to be applied by the project team from the inside, an application should also serve as an ongoing reference and organization resource, constantly being updated and referred to as a building moves through each phase of its life cycle. Since the present case study was performed by an outside observer, uninvolved in any of the planning, construction, or use stages of this building's life span, this application suffers some inevitable disadvantages. For example, a substantial majority of Indicators for Level 1 application focused on qualitative ideas such as shifting focus towards long-term goals and promoting discussion about sustainability features – these conversations are intended to shift the mindset of the building project team. In this way, Level(s) is not only a method that assesses sustainability, but one that actually promotes it. This intended positive affect was not a possible outcome for the present case study.

Aside from these structural limitations relating to a single author study, the biggest limitation to the application of the method to this case study was caused by insufficient information about the planned

building project. One of the most critical missing pieces of information was an altogether absent structural design for the project, which would have been accompanied by a thorough material inventory. Additionally, a material inventory was also missing from the supplied architectural design. Taken together, these inventories would have enabled an elaboration of an accurate Bill of Materials and Bill of Quantities. This missing information caused a double disadvantage as a result of the interconnectedness of the Level(s) Indicators; a missing BoM meant that circular material assessments for the building in MO2 were altogether impossible. Additionally, if price tags had also been associated with the different materials in the models, a different Life Cycle Cost analysis would have been possible in MO6. Thus, in this example, a lack of information impacted not only one but two separate macro-objectives.

The other limiting factor deserving mention was the inevitable time constraint imposed on this case study. Since Level(s) is designed to be applied throughout the life course of a building which will be in its Use Stage for at least 50 years, this case study was not able to replicate a real-life application for each phase. In particular, Level 3 was impossible to address thoroughly in this study, because the building has not yet been built or put to use, and therefore the project team was not able to provide the author with any resource metering data or other useable inputs. The author mitigated this limitation as much as possible by providing instructions on what steps would have to be completed for a Level 3 assessment in a more true-to-life application.

Despite these limitations, this study had considerable advantages, and the building project proved itself to be a fruitful testing ground for the feasibility of Level(s). The project itself is innovative and socially minded, and it is a great example of the type of building that would respond well to this kind of broad, multi-faceted assessment. Being a re-assignment of an existing building, certain particularities resulting from its former use life as a factory seem to have been well-integrated into traditionally utilized building solutions. The author was also very fortunate that the design team was willing to provide the building designs, models, and plans, which were critical for the performance of this study. Finally, the building is in an optimal phase for a snapshot analysis, with a mix of assessments at Levels 1 and 2.

The lack of sufficient information prevents the author from making any comprehensive statements about the overall level of sustainability of the building project under review. Nonetheless, the process of applying the Indicators brought to light certain strengths of the project as well as certain areas for improvement. In the former category, the adaptability of the designed apartments to increases in family size is a feature that is very likely to extend the useful life of the building. On the other end, the water consumption estimates for the building showed the project to be significantly less water efficient than the average Portuguese household. It is in this latter category – that is, identifying from early on the building features that can be improved upon – that Level(s) is likely to have the largest effect in the Construction Industry. Just as it raised the author's awareness to the many factors going into a building's water efficiency, this Indicator and others would likewise center the project team's focus on the building components with the highest impact on improving overall sustainability.

5.2. FURTHER DEVELOPMENTS

“Sustainability” was a word that was rarely used or heard until quite recently. Now, the word and the concepts it invokes have become a central part of our collective existence, and all signs seem to point to the fact that sustainability and environmental awareness will only become larger concerns for global humanity. Level(s) represents an important step in the European context in the direction of a more unified approach to climate change. However, since Level(s) is still in its early days, there is room for immense expansion and elaboration in multiple directions. After completing the general exploration of the complete method, the time has come to present what could be accomplished next to bring Level(s) into the future.

There are a few updates in the works that will dramatically improve upon the current state of Level(s). Around the end of the current year, Level(s) is set to release a group of eLearning courses that should allow a quick and comprehensive summary of the framework, without the need to dig extensively into its many User Manuals. A calculator tool will also be published around the same time (JRC 2021b), possibly facilitating an easier application of some of its more extensive Indicators. Keeping up with these and other advancements should be considered by future studies exploring the Level(s) framework.

Aside from these updates and the many changes that will inevitably come from Level(s)’ maturation as an international method, there are opportunities for further research from the side of the Level(s) user. One of these would be to accompany the conceptual design phase of a project with its complete design team, which would be available to answer the researcher’s questions. This would provide results for the many Level 1 reporting tables, and also create a pathway for the suggestions provided by the method to be incorporated in the design options, ultimately making the building more aligned with sustainable initiatives. If time is available, the researcher could also move with the building project team from those conceptual designs to a quantitative Level 2 assessment of the final design. Moreover, the field of sustainability within the Construction Industry would benefit from studies that focus specifically on the monitoring of completed residential or office buildings in line with Level(s) guidelines. Such a research approach would provide the data necessary for a Level 3 application, assuming that the user was able to gather all the precise data needed to perform quantitative use-stage and end-of-life analyses. Assuming that Level 3 would be the phase with the lowest adherence by Level(s) users across Europe, on account of the logistical inconvenience and low payoff to users, such studies could document adherence rates and/or gesture towards possible mechanisms of increasing involvement in that phase of the building’s life.

One of the most interesting further developments would be the full application of the method on a case study that provides a comprehensive BIM model, with good advancements on the Architecture, Structural, and MEP schematics (on Revit Software) and associated material prices. Additionally, Indicators like 2.1 (Bill of Quantities, Materials, and Lifespans) already provide instructions for users wanting to adjust assessments to BIM methodologies that would streamline reporting. The organization of the building information on those models seems to be exactly what is necessary for a quick understanding of the building scope and the application of Level 2 and 3 qualitative assessments. In fact, said agility in accessing and filling up the required data for the assessments, combined with the method’s contextualization and summarization provided by this research, could allow studies of a similar timeframe to quickly apply the Indicators on a Level 2 basis and follow that with as-built and in-use data measurements that would permit a Level 3 analysis. This would offer an interesting insight into the chosen building’s sustainability performance on paper and in practice, as well as a great understanding of Level(s)’ full potential.

Another promising option for future case studies in Level(s) would be to employ an LCA tool. These types of software offer an easy and interactive way of modeling the sustainability of projects. Having an LCA assessment already available for the case study could also provide agility, since the most time-consuming and tedious calculations of Level(s)' LCA (MO 1, 2 and 3) would be easily obtained by converting one method's information structure to the other's. There are currently options on the market that automatically convert the results obtained through the building data inputs into the output formats used by other international BSAMs, and some LCA tools, such as OneClick LCA, are already offering setups designed for smooth integration with Level(s). This approach could be an interesting way to complement the comparative analysis performed by this study with real data, as well as estimate more precisely the impact that Level(s) would produce on adaptations to other international BSAMs.

However, one must always be aware that the goal of Level(s) is to promote sustainability in the industry by influencing the conversation surrounding the Construction Industry. More quantitative and data-driven approaches to the method, such as LCA tools, can be very efficient in rendering accurate data, but their characteristic automation may prompt users to jump over the more qualitative steps of Level(s). These qualitative steps are the ones that aim to trigger discussions on key sustainable aspects from the early days of the design process, aspects that would later be fully incorporated into the building, boosting its performance. Skipping over these qualitative steps would therefore hinder the sustainability performance of the building as a whole, even despite increased data accuracy. Future LCA tools focusing on Level(s) should aim to include these foundational principles which very much make it unique among the range of BSAMs.

As previously mentioned in this study, the JRC team behind Level(s) states that international certification tools are making progress towards aligning their schemes with Level(s), with the objective of ensuring that EU sustainability objectives and policies are also integrated. This may take the framework to a whole new level of European adoption, and provide a much-needed unification of the sector. However, the Portuguese BSAM spectrum is still behind other European Member States. Its two most used methods, LiderA and SBTool^{PT}, have not seen new updates to their structures in more than 10 years, and the mentality in the Construction Industry is still relatively retrograde in terms of seeing the long-term picture of advantages in imposing holistic sustainability concepts. Therefore, it is unlikely that they will be reviewed and modified to include a Level(s) alignment version. For this reason, the author recommends that future studies should creatively adapt these certification schemes to the novel European framework's Indicators. Results provided in this study conclude that such adaptation can in theory be performed, if the distinct standards and regulations can be made to match the new Level(s) ones. Besides the benefits of adding a fresh new dimension of sustainability assessment to a format that is already recognized by national industry, being harmonized with European policymaking and sustainable goals may be essential for projects wanting to receive funds from the almost 15 billion Euros that the country will receive as part of the European Commission COVID-19 recovery program, NextGenerationEU (in Portugal named *Plano de Recuperação e Resiliência*). It may be exactly what the Portuguese Construction Industry needs to overcome its inertia and its difficulties acclimating to change.

As the field of sustainable construction grows, there will almost certainly be more academic undertakings which approach the topic in a similar way to the study just concluded. It is the author's hope that this case study will be useful in providing an example and the context for such research to come. The contributions made by this study, in regards both to the building assessment and to the comparison between other BSAMs, can be used as a launchpad for future researchers from which to begin their investigations.

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ANNEX A: ADDITIONAL BSAM INFORMATION

A.1: BREEAM

Table 0.1 – BREEAM INT NC Categories, Issues, Approximated Percentual Weight, and Points (BRE 2017)

Reference	Categories and Issues	Weight (%) *	Points
Tra	Transport	7,33	Max 11
	Public Transport Accessibility	-	Up to 5
	Proximity to Amenities	-	Up to 2
	Alternative Modes of Transport A	-	Up to 2
	Alternative Modes of Transport B	-	
	Maximum Car Parking Capacity	-	Up to 2
	Travel Plan	-	1
	Home Office	-	1
LE	Land Use and Ecology	3,33	Max 5
	Site Selection	-	3
	Ecological Value of site and Protection of Ecological Features	-	2
	Enhancing Site Ecology	-	3
	Long Term Impact on Biodiversity	-	2
Wat	Water	6	Max 9
	Water Consumption	-	5
	Water Monitoring	-	1
	Water Leak Detection and Prevention	-	3
	Water Efficient Equipment	-	1
Ene	Energy	22,67	Max 34
	Reduction of Energy use and Carbon Emissions	-	15
	Energy Monitoring A	-	2
	Energy Monitoring B	-	2
	External Lighting	-	1
	Low Carbon Design	-	3
	Energy Efficient Cold Storage	-	3
	Energy Efficient Transport Systems	-	3
	Energy Efficient Laboratory Systems	-	5
	Energy Efficient Equipment	-	2
	Drying Space	-	1
Mat	Materials	9,33	Max 14
	Life-Cycle Impacts	-	Up to 6
	Responsible Sourcing of Construction Product	-	4
	Design for Durability and Resilience	-	1

	Materials Efficiency	-	1
Hea	Health and Wellbeing	14	Max 21
	Visual Comfort	-	Up to 6
	Indoor Air Quality	-	5
	Safe Containment in Laboratories	-	2
	Thermal Comfort	-	3
	Acoustic Performance	-	Up to 4
	Accessibility	-	2
	Hazards	-	1
	Private Space	-	1
	Water Quality	-	1
Man	Management	13,33	Max 20
	Project Brief and Design	-	4
	Life Cycle Cost and Service Life Planning	-	4
	Responsible Construction Practices	-	6
	Commissioning and Handover	-	4
	Aftercare	-	3
Wst	Waste	8,67	Max 13
	Construction Waste Management	-	3
	Recycled Aggregates	-	1
	Operational Waste A	-	1
	Operational Waste B	-	2
	Speculative Finishes	-	1
	Adaption to Climate Change	-	1
	Functional Adaptability	-	1
Pol	Pollution	8,67	Max 13
	Impact of Refrigerants	-	4
	NOx Emissions	-	2
	Surface Water Run-off	-	5
	Reduction of Nighttime Light Pollution	-	1
	Reduction of Noise Pollution	-	1
	Innovation	6,67	Max 10
Total = 100%			
Total = 150 Points			

*The Approximated Percentual Weight was estimated by the actor by diving each Maximum Category Points per the total possible Points, 150. Since BREEAM has a cap on the maximum number of Points per Category, which deems unfeasible the calculation of the percentual weight for each Issue.

A.2: LEED

Table 0.2 – LEED BD+C Categories, Credits, and Points (USGBC 2021a)

Reference	Category and Credits	Points*
LT	Location and Transportation	14
	Sensitive Land Protection	1
	High Priority Site and Equitable Development	2
	Surrounding Density and Diverse Uses	5
	Access to Quality Transit	5
	Bicycle Facilities	1
	Reduced Parking Footprint	1
	Electric Vehicles	1
SS	Sustainable Sites	10
	Construction Activity Pollution Prevention	Required
	Site Assessment	1
	Protect or Restore Habitat	2
	Open Space	1
	Rainwater Management	3
	Heat Island Reduction	2
	Light Pollution Reduction	1
WE	Water Efficiency	11
	Outdoor Water Use Reduction	Required
	Indoor Water Use Reduction	Required
	Building-Level Water Metering	Required
	Outdoor Water Use Reduction	2
	Indoor Water Use Reduction	6
	Optimize Process Water Use	2
	Water Metering	1
EA	Energy and Atmosphere	33
	Fundamental Commissioning and Verification	Required
	Minimum Energy Performance	Required
	Building-Level Energy Metering	Required
	Fundamental Refrigerant Management	Required
	Enhanced Commissioning	6
	Optimize Energy Performance	18
	Advanced Energy Metering	1
	Grid Harmonization	2
	Renewable Energy	5
	Enhanced Refrigerant Management	1
MR	Materials and Resources	13
	Storage and Collection of Recyclables	Required
	Building Life-Cycle Impact Reduction	5
	Environmental Product Declarations	2
	Sourcing of Raw Materials	2
	Material Ingredients	2
	Construction and Demolition Waste Management	2

IQ	Indoor Environmental Quality	16
	Minimum Indoor Air Quality Performance	Required
	Environmental Tobacco Smoke Control	Required
	Enhanced Indoor Air Quality Strategies	2
	Low-Emitting Materials	3
	Construction Indoor Air Quality Management Plan	1
	Indoor Air Quality Assessment	2
	Thermal Comfort	1
	Interior Lighting	2
	Daylight	3
	Quality Views	1
	Acoustic Performance	1
		Total = 100 Points
I	Innovation	6
RP	Regional Priority	4
		Bonus Total = 110 Points

* Due to the total number of LEED points being 100 (excluding the Bonus Categories I and RP) there was no adaptation of this numeric scoring to a percentage score.

A.3: LIDERA

Table 0.3 – LiderA Threads, Criteria, and Percentual Weight (Pineiro 2011)

Reference	Threads and Criteria	Weight (%)
R	Resources	32
	Energy	17
	Water	8
	Materials	5
	Production	2
EC	Environmental Comfort	15
	Air Quality	5
	Thermal Comfort	5
	Lightning and Acoustics	5
SS	Socio-Economic Status	19
	Accessibility	5
	Economic Diversity	4
	Amenities and Social Interaction	4
	Control and Participation	4
	Life Cycle Cost	3
LI	Local Integration	14
	Soil usage	7
	Natural Ecosystems	5
	Patrimony and Landscape	2
SU	Sustainable Usage	8
	Environmental Management	6
	Innovation	2
EL	Environmental Load	12
	Effluents	3
	GHG Emissions	2
	Waste	3
	External Noise	3
	Light-thermal Pollution	1
		Total = 100 %

A.4: SBTool^{PT}

Table 0.4 – SBTool^{PT}-H Categories, Indicators and Approximated Percentual Weight (Mateus and Bragança 2011b)

Reference	Category and Indicators	Weight (%)*
A	Accessibility	9
	Accessibility To Public Transportation	5,1
	Accessibility To Urban Amenities	3,9
LUB	Land Use and Biodiversity	8
	Urban Density	3,2
	Water Permeability of The Development	0,4
	Use Of Pre-Developed Land	1,2
	Use Of Local Flora	1,6
	Heat-Island Effect	1,6
WE	Water Efficiency	2
	Fresh Water Consumption	1
	Reuse Of Grey and Rainwater	1
	Energy Efficiency	13
	Primary Energy	6,5
	In-Situ Energy Production from Renewables	6,5
MWM	Materials and Waste Management	12
	Materials And Products Reused	3,7
	Use Of Materials with Recycled Content	3,7
	Use Of Certified Organic Materials	2,9
	Use Of Cement Substitutes in Concrete	1,3
	Waste Management During Operation	0,4
OHC	Occupant's Health and Comfort	18
	Natural Ventilation Efficiency	2,1
	Toxicity Of Finishing	2,1
	Thermal Comfort	5,7
	Lighting Comfort	4,5
	Acoustic Comfort	0,6
LCC	Life-Cycle Cost	30
	Capital Cost	15
	Operation Cost	15
EAS	Education and Awareness of Sustainability	3
	Education of Occupants	3
CC	Climate Change and Outdoor Air Quality	5
	Construction Materials 'Embodied Environmental Impact	5
		Total = 100 %

* The Approximated Percentual Weight was estimated by the author by accounting the weight of each indicator on their respective category and theme.

ANNEX B: LEVEL(S) INDICATORS ADDITIONAL TABLES

B.1: USE STAGE ENERGY PERFORMANCE

Level 2 reporting item	Information to provide (select/delete as appropriate)
Type of assessment	<i>Building permit, as-built (calculated) EPC or tailored assessment</i>
Calculation method	<i>Specify the Member State and the method used</i>
Scope of energy needs assessed	<i>The energy needs included in the scope of the calculation method</i>
Unregulated energy needs assessed	<i>The unregulated energy needs assessed in addition to those included in the calculation method</i>

Energy needs	Fuel or energy carrier ¹	kWh/yr
Heating		
Cooling		
Ventilation		
Hot water		
Lighting		
Other (please specify)		

Notes:

1. Select from: electricity, natural gas, district heating, district cooling, biomass, other (to be specified)

	kWh/m ² /yr
Total primary energy	<i>Cells L2.1 + L2.2</i>
<i>L2.1 Regulated total primary energy</i>	
<i>L2.2 Unregulated total primary energy</i>	

Figure 0.1 – Reporting Tables for Level 2 and Level 3. Indicator 1,1 (Dodd, Donatello and Cordella 2021c)

Level 1 design concept	Brief description
1. Minimum energy performance requirements and Near Zero-Energy Building (NZE) design	Minimise the heating, cooling and lighting needs of the building by: • For new buildings, designing and specifying a high performance and air-tight building fabric. • Designing and specifying high performance heating, ventilation, cooling and (fixed) lighting systems. • For major renovations, detailing and specifying high performance improvements to the existing building fabric. • Designing and specifying high performance heating, ventilation, cooling and (fixed) lighting systems. Using renewable energy technologies to, as far as possible, supply the remaining energy needs of the building.
2. Site specific design	In designing a new building, or in planning a major renovation of an existing building, take into account: • The climatic conditions of the site in order to minimise heating, cooling, domestic hot water, ventilation and lighting needs and to inform the specification of noncombustion renewable energy technologies. Steps that can be taken include: – Reference to local weather data in order to understand the distinct seasonal, monthly, weekly and diurnal conditions – Reference to information about any localised microclimate conditions, such as prevailing winds, the urban heat island effect and air pollution levels. In this way, the physical design, elevations and servicing can be designed to respond to the local climate, including the potential for passive heating/cooling, intelligent structures, high yield renewables and use of daylighting. <i>This aspect has a strong interaction with indicators 4.2 and 4.3, which address thermal comfort and lighting respectively.</i>
3. Renovation specific design	In seeking to renovate a building, use information gathered in a baseline survey to adapt the improvements to the performance and conditions of the existing building, taking into account: • The construction of the original building, including the building envelope and structure. • Existing technical services, including heating, cooling, domestic hot water, ventilation and lighting. • How the orientation and floor layout influences patterns of climatic exposure, daylighting and ventilation. Information obtained from prior occupants may also yield useful information about the buildings performance.
4. High quality building fabric and services	Minimise the potential for gaps between design and actual performance by ensuring that the building fabric and technical services are designed, detailed, constructed and installed with the necessary attention to detail and quality. This could include a focus on: • The air tightness and thermal integrity of the building envelope, including the continuity of insulation and junctions with windows, doors and balconies. • The functional performance of HVAC³ systems, including the design of distribution systems and the setup of equipment.
5. Smart monitoring and control systems	Identify opportunities to install intelligent systems that can: • Provide users and building managers with timely information about the buildings energy use, whilst also allowing them to learn how to meet occupier energy needs with less energy. • Be used to maximise the potential for self-consumption of renewable energy generated by the building.

Figure 0.2 – Design concepts for improved Energy Performance on a Level 1 assessment (Dodd, Donatello and Cordella 2021c)

[\(Back to Chapter 4.3\)](#)

B.2: LIFE CYCLE GLOBAL WARMING POTENTIAL

Level 1 design concept	Brief description
1. Efficient building shape and form	✓ Minimise the surface area to volume ratio of a building and individual residential units, as well as its height, in order to improve material efficiency and minimise energy use.
2. Optimised NZEB construction	✓ Consider the potential trade-off between reducing CO ₂ emissions in the use stage to achieve NZEB performance levels and the embodied energy CO ₂ emissions associated with the manufacture of higher performance insulation, façade and wall systems, windows, structural thermal mass and renewable energy technologies.
3. Optimised material utilisation and circular value	✓ Consider the feasibility of reusing the structure of an existing building or for optimising the structural design of a new building in order to minimise material use. ✓ Consider options to minimise or even design out waste generated during product manufacturing, construction on-site in order to optimise the utilisation of materials on a construction site.
4. Extending building and component service lives	✓ Consider the options to extend the lifespan of significant building components and to minimise the number of replacement and renovation cycles.
5. Design for adaptability	✓ Consider the potential of the building design to adapt and be flexible to changing market and occupier needs in the future so as to extend the life of the building, including its structure and main elements.
6. Design for deconstruction	✓ Consider how the building design and information records about the building's material bank can facilitate future end of life deconstruction in order to recover materials for re-use and recycling.

Figure 0.3 – Design concepts for a life cycle analyses of hot stops related to GWP environmental impacts on a Level 1 assessment (Dodd, Donatello and Cordella 2021d)

[\(Back to Chapter 4.4\)](#)

B.3: BILL OF QUANTITIES, MATERIALS AND LIFESPANS

Level 1 design concept	Brief description
1. Consideration of building form on inherent material efficiency of the structure.	Always within client specifications and within project constraints, a relevant example for housing developments would be the choice between blocks of flats, terraced houses, and detached houses. Flats have inherent material savings due to a common roof and common structural elements, but structural columns will be larger and take-up a larger share of the floor space. Terraced houses have inherent material savings compared to semi-detached or detached houses due to common walls. With office buildings, taller structures generally have the inherent impacts as with taller blocks of flats, but as very tall structures are reached (e.g. >30 stories in steel structures, the extra material for lateral resistance becomes more dominant on the total structural mass.
2. For a given structural design – consider the scope for optimising material efficiency.	Within the constraints set by relevant Eurocode safety factors and the site (e.g. wind loads, seismic activity etc.), consider the potential to optimise the design loadbearing capacity of beams, columns and floor plates to match client needs.
3. Consider potential tradeoffs and benefits of material efficient design options.	Aspects such as thermal mass, noise, solar gain, daylighting, speed of construction, cost and overall CO2 footprint can all be influenced, positively or negatively, by efforts to reduce the material footprint for a given building design brief.
4. Durable and repairable building components and systems.	The service lives of all building components and systems should be considered in the context of the estimated building lifetime. More durable options should be considered where relevant. Design features that maximise the ease with which building components can be accessed, repaired, disassembled or removed (e.g. with minimum destruction of fit-out materials) should also be considered.
5. Optimum use of fit-out materials.	Where possible, obtain occupant specifications for fit-out materials before finalising the construction stage to avoid the use of speculative fit-out materials that will later be discarded. Consider the ease with which fit-out materials can be disassembled for potential re-use in other buildings.
6. Incorporation of recycled materials.	The specification of prefabricated construction products and materials with recycled content or the incorporation of recycled aggregates into ready mix concrete pours onsite.

Figure 0.4 – Design concepts for optimizing the consumption of construction materials and products on a Level 1 assessment (Dodd, Donatello and Cordella 2021e)

[\(Back to Chapter 4.5\)](#)

B.4: CONSTRUCTION AND DEMOLITION WASTE

Level 1 design concept	Brief description
1. Setting of relevant targets or Key Performance Indicators (KPIs)	When considering setting any ambition levels or targets for waste management and outcomes in the project, they should be set in the proper context of the EU waste hierarchy and the EU List of Wastes.
2. The influence of project type on CDW generation and management.	Different projects (e.g. new construction on greenfield sites, renovation projects or demolition projects) will generate different quantities of waste. Time, labour and space constraints will also vary with each project site and budget, having an influence on the CDW management.
3. Pre-demolition auditing (if demolition activities take place).	With the aim of identifying the different elements, materials and potential wastes and how they could potentially be dealt with by decontamination, stripping, selective deconstruction and sorting techniques – within the time, space and labour constraints of the project and the regionally available options for these elements, materials and wastes.
4. Good construction practice	Identify good practices that can reduce onsite waste (e.g. via the increased use of prefabricated elements) and procurement arrangements that may incentivize the reduction of over-ordered materials.
5. Outline Waste Management Plan (WMP)	Establish an outline WMP to explain (i) how environmental and health impacts from CDW can be reduced; (ii) how cost benefits can be maximised (i.e. increased revenues and avoided costs) and (iii) how the segregated collection of onsite waste can be optimised based on the different possible end market, storage, processing and disposal options.
6. "Buildings As Material Banks" (BAMB) principles.	Consider how BAMB concepts could be applied to the conceptual design of the building (e.g. design for disassembly and reuse of prefabricated elements at the End of Life).

Figure 0.5 – Design concepts to optimize management and reduce CDW on a Level 1 assessment (Dodd, Donatello and Cordella 2021f)

[\(Back to Chapter 4.6\)](#)

B.5: DESIGN FOR DECONSTRUCTION, REUSE AND RECYCLING

General deconstruction aspect	Specific design aspect to address	Description
1. Ease of recovery	1.1 Elements and their parts are independent and easily separable	The potential to separate elements that are connected to each other ¹ and to disassemble elements into their constituent components and parts. <i>The nature of the connections are addressed by design aspects 1.2 and 1.3.</i>
	1.2 Connections are mechanical and reversible	The use of mechanical, non-destructive connections as opposed to chemical bonding.
	1.3 Connections are easily accessible and sequentially reversible	Easy and sequential access in order to reverse mechanical connections and remove elements.
	1.4 The number and complexity of the disassembly steps are low.	The disassembly should not suppose the need for complex preparatory steps, the intensive use of manpower and machinery and/or off-site processes.
2. Ease of reuse	2.1 Specification of elements and parts using standardised dimensions.	Specification of elements and parts that are of a standardised specification in order to provide consistent future stock
	2.2 Specification of modular building services.	Specification of modular systems that may retain value upon de-installation or which may be more easily swapped out and upgraded.
	2.3 Design supports future adaptation to changes in functional needs.	Design of the building parts to support ongoing use in the same or a different design configuration in the same building.
3. Ease of recycling	3.1 Parts made of compatible or homogenous materials	Specification of components and constituent parts made of homogenous materials, the same materials, or materials mutually compatible with recycling processes. Finishes, coatings, adhesives, or additives should not inhibit recycling.
	3.2 Constituent materials can be easily separated	It should be possible to separate components and parts into their constituent materials.
	3.3 There are established recycling options for constituent parts or materials	The part or material is readily recyclable into products with a similar field of application and function, thereby maximising their circular value.

Figure 0.6 – Design concepts to facilitate future Deconstruction on a Level 1 assessment (Dodd, Donatello and Cordella 2021h)

[\(Back to Chapter 4.8\)](#)

B.6: WATER CONSUMPTION

Level 1 design concept	Brief description
1. Specification of water efficient sanitary devices and fittings	Consider the ranges of performance for different choices of sanitary devices and fittings (e.g. tap and showerhead flow rates in L/min, toilet flush volumes in L/flush etc.). Consult national or international labelling schemes.
2. The relevance of water scarcity as a driver for reducing water demand.	Cross-check water exploitation index (WEI+) data for the river basin in which the building will be located and compare this to other European river basins. Any average summer WEI+ value >20% should be flagged as water scarcity being a definite concern.
3. Examine the potential to use non-potable water to substitute for potable water demand.	Consider the potential of the building and site for: – rainwater harvesting (i.e. look at collection area available and rainfall patterns) – greywater reuse (i.e. consider relevant uses such as toilet flushing and irrigation together with relevant sources of greywater such as showers and bathroom wash basins).
4. Water efficient vegetated areas	When assessing whether or not to have vegetated areas at the building site, consider how the following aspects can reduce irrigation water demand: – the choice of low water demand plants – the use of efficient irrigation techniques – staging of vegetation and other factors that can create microenvironments that reduce evaporation rates.
5. Metering plan	To install multiple meters onsite to better monitor where water consumption is happening in the building, to better quantify the significance of irrigation and any contributions of harvested rainwater and reused greywater to total water consumption.

Figure 0.7 – Design concepts for efficient Water Consumption on a Level 1 assessment (Dodd, Donatello and Cordella 2021i)

[\(Back to Chapter 4.9\)](#)

B.7: INDOOR AIR QUALITY

Level 1 design concept	Brief description
1. Consider how the building will be used and the expectations level of the future occupants	The expected use patterns for the building should be considered in order to identify how much ventilation needs may vary during the day or week. According to the EN 16798-1 category system, there are four expectation levels about indoor environmental quality (I, II, III and IV, with category I being highest expectations and IV being the lowest). Higher expectations translate into better control of IAQ and lower levels of pollutants but also generally higher energy consumption.
2. A basic understanding of the main pollutants in indoor air, their sources and how they might be minimised.	Try to minimise the indoor generation of air pollutants (e.g. off-gassing of VOCs from fit out materials or insulation) by the choice of low-emission materials. Assess the outdoor air quality and the potential intake of particulate and gaseous pollutants to the ventilation system. Carefully plan the building project to address any identified existing problems relating to air quality in the case of a renovation project. During construction the ingress of damp into the building fabric should be controlled and a drying out period allowed for.
3. Preferred ventilation strategy (in the context of planned use of different building zones).	Consider if a natural, mechanical or hybrid ventilation system is necessary to meet IAQ needs, taking into account the anticipated occupation patterns and densities in different parts of the building. These choices will also affect the heating and cooling strategy associated with indicator 4.2. Consider how to control when the ventilation system is on and off and, when on, at what % of maximum capacity.
4. Localised ventilation strategies to control point sources in parts of the building.	Consider specific areas where IAQ can be most compromised (e.g. cooking areas, bathrooms, smoking areas, low-ceiling meeting rooms with occasionally high occupation densities, printing rooms etc.) and whether running a separate exhaust, for defined time periods, with a high specific ventilation rate would be desirable. The purpose of separate (and higher) ventilation rates should be defined (e.g. to limit CO₂ increases, to minimise risk of mould growth or to minimise negative occupant perception).
5. The importance of in-situ monitoring	Will the ventilation strategy be linked to real-life monitoring of IAQ and the ventilation rate? For example, with real time monitoring of duct flow, of CO₂ or relative humidity in office spaces? Will periodic monitoring of VOC and particulate emissions be undertaken? If so, consider the most representative locations to install sensors/take measurements.

Figure 0.8 – Design concepts influencing IAQ on a Level 1 assessment (Dodd, Donatello and Cordella 2021j)

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B.8: TIME OUTSIDE OF THERMAL COMFORT RANGE

Level 1 design concept	Brief description
1. Identify and assess risk factors	A number of risk factors can be identified that can contribute to the risk of thermal discomfort: - Site location: A number of factors should be taken into account: - Orientation will influence exposure to the sun in summer and prevailing winds in winter - Obstructions such as other buildings or nearby trees may limit solar gains during winter or summer - The urban microclimate may raise summer temperatures compared to data from local weather stations - Building design: A number of design factors can lead to excessive solar gain in summer or thermal losses in winter: - Glazing ratio: High glazing ratios on S/SE/SW facades can, without sufficient solar control, lead to overheating. - Insulation: Insufficient or poorly installed insulation with thermal bridging of the building envelope - Thermal mass: Insufficient thermal mass within the building envelope may result in significant temperature swings. - Aspect: Where the aspect of a residential dwelling does not allow for sufficient natural ventilation. - Shading: Where balconies, patios and shutters are not designed to provide adequate shading on S/SE/SW facades - Solar glass: Where the glazing is not specified to control infrared or ultraviolet radiation In some EU locations, an overheating assessment may be required and if carried out should be noted in the Level 1 reporting.
2. Design for comfortable thermal conditions	In designing a new building or major renovation, a range of decisions influence the thermal conditions in, on and around the building: - Building design: Design decisions in three key areas can be used to minimise seasonal swings in temperature and localised discomfort: - Envelope: A high performance, insulated building envelope with effective solar control measures will protect against outdoor conditions and minimise seasonal swings in internal temperatures. - Structure: Structural designs that provide natural ventilation and exposed thermal mass. - Servicing: Integration of heating and cooling design with the building structure and consideration of ventilation pathways. Localised indoor effects such as draughts and hot/cold spots should be avoided. - Landscape design: A number of nature-based design features can contribute to moderating the surrounding microclimate: - the presence of trees and vegetation in streets, courtyards, patios as well as on facades and roofs - The presence of water features such as ponds, drainage swales and fountains - Unsealed surfaces instead of hard, paved or dark surfaces
3. Take into account the site specific conditions	In designing the building or major renovation, take into account: - site specific conditions in order to better understand the microclimate. Steps that can be taken include: - Reference to local weather data in order to understand the distinct seasonal, monthly, weekly and daily conditions. - Reference to information about any localised microclimate conditions, such as prevailing winds, the urban heat island effect and air or noise pollution levels. In this way, the physical design, elevations and servicing can be designed to respond to the local climate, including the potential for passive heating/cooling, intelligent structures, high yield renewables and useful daylighting.
4. Take into account renovation specific conditions	In seeking to renovate a building, use information gathered in a baseline survey to adapt the improvements to the performance and conditions of the existing building location, fabric and landscaping, taking into account: - The orientation and exposure of facades and roofs - Existing floor layouts and ventilation pathways - Existing solar control features - The seasonal response of the building fabric to weather conditions, including structural thermal bridging - Existing technical services (if they are to be retained and upgraded) Information obtained from prior occupants may yield useful information about the buildings performance.

Figure 0.9 – Design concepts for improved thermal performance on a Level 1 assessment. (Dodd, Donatello and Cordella 2021k)

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B.9: LIGHTING AND VISUAL COMFORT

Quality aspect	Level 1 - Concept Design Stage	Levels 2 & 3 - Detailed Design & In-Use Stages	Units
1. Daylight: Maximising the useful contribution & minimising negative impacts on visual comfort	External view requirements	Horizontal Sight Angle	deg
		Outside Distance of the View	M
		Layers Seen	No. layers
	Daylight control and glare	Daylight Glare (Direct / Indirect / Diffuse)	
	Daylight sufficiency	Complementary Electric Light	
2. Light Levels & Distribution: For visual comfort	Light levels	Variation of Distribution	
		Task Illuminance	Lux
		Luminance	Candela
		Surface reflectance, shape and colour	% reflectance
	Light distribution	Melanopic irradiance / equivalent daylight illuminance	
		Visual hierarchy	
		Luminance Distribution	
		Brightness Contrast	
		Glare from electric lighting	
3. Control: Automated and personalised control for visual comfort	Personal control (time / activity / preference)	Illuminance Uniformity	%
		Intensity	Y/N
	Automation (time / activity / system integration)	Colour Properties (incl. CCT, Saturation, Hue, CRI)	Y/N
		Pre-Programmed Cycle over time	Y/N
		Pre-Programmed Scenes	Y/N
4. Light Source Quality: For electric light sources	Colour	Colour Rendering	
		Colour Consistency	
		Correlated Colour Temperature	K
		Spectral Power Distribution	
	Temporal light artefacts	Flicker	Pst
		Stroboscopic Effects	SVM
	Tuneable lighting	E.g. - Melanopic Irradiance, Equivalent daylight illuminance	Y/N

Figure 0.10 – Overview of Indicator 4.3 measurements (Dodd et al. 2021)

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B.10: PROTECTION OF OCCUPIER'S HEALTH AND THERMAL COMFORT

Level 1 design concept	Brief description
1. Identify and assess risk factors	A number of risk factors can be identified that can contribute to the risk of summer thermal discomfort: • Site location: A number of factors should be taken into account: - Orientation will influence exposure to the sun - Obstructions such as other buildings or nearby trees may reduce solar gains - The urban microclimate may raise summer temperatures compared to data from local weather stations • Building design: A number of design factors can lead to excessive solar gain in summer: - Glazing ratio: High glazing ratios on S/SE/SW facades can, without sufficient solar control, lead to overheating. - Insulation: Insufficient or poorly installed insulation with thermal bridging of the building envelope - Thermal mass: Insufficient thermal mass within the building envelope may result in significant temperature swings. - Aspect: Where the aspect of a residential dwelling does not allow for sufficient natural ventilation. - Shading: Where balconies, patios and shutters are not designed to provide adequate shading on S/SE/SW facades - Solar glass: Where the glazing is not specified to control infrared or ultraviolet radiation In some EU locations, an overheating assessment may be required and if carried out should be noted in the Level 1 reporting.
2. Design for comfortable thermal conditions	In designing a new building or major renovation, a range of decisions influence the thermal conditions in, on and around the building: • Building design: Design decisions in three key areas can be used to minimise seasonal swings in temperature and localised discomfort: - Envelope: A high performance, insulated building envelope with effective solar control measures will protect against outdoor conditions and minimise seasonal swings in internal temperatures. - Structure: Structural designs that provide natural ventilation and exposed thermal mass. - Servicing: Integration of heating and cooling design with the building structure and consideration of ventilation pathways. Localised indoor effects such as draughts and hot/cold spots should be avoided. • Landscape design: A number of nature-based design features can contribute to moderating the surrounding microclimate: - the presence of trees and vegetation in streets, courtyards, patios as well as on facades and roofs - The presence of water features such as ponds, drainage swales and fountains - Unsealed surfaces instead of hard, paved or dark surfaces
3. Take into account the site specific conditions	In designing the building or major renovation, take into account: • site specific conditions in order to better understand the microclimate. Steps that can be taken include: - Reference to local weather data in order to understand the distinct seasonal, monthly, weekly and daily conditions. - Reference to information about any localised microclimate conditions, such as prevailing winds, the urban heat island effect and air or noise pollution levels. In this way, the physical design, elevations and servicing can be designed to respond to the local climate, including the potential for passive heating/cooling, intelligent structures, high yield renewables and useful daylighting.
4. Take into account renovation specific conditions	In seeking to renovate a building, use information gathered in a baseline survey to adapt the improvements to the performance and conditions of the existing building location, fabric and landscaping, taking into account: • The orientation and exposure of facades and roofs • Existing floor layouts and ventilation pathways • Existing solar control features • The seasonal response of the building fabric to weather conditions, including structural thermal bridging • Existing technical services (if they are to be retained and upgraded)

Figure 0.11 – Design concepts for to future-proof the building's thermal performance on a Level 1 assessment(Dodd, Donatello and Cordella 2021I)

[\(Back to Chapter 4.14\)](#)

B.11: LIFE CYCLE COSTS

Level 1 design concept	Description
1. Take a longer-term perspective on costs and decisions	Life cycle cost models create the potential to look at the whole life cycle cost of an investment. This means that a link should be made between initial investment (capital) costs and ongoing operational and maintenance costs. By investing in order to lower long-term operational and maintenance costs the value obtained from a building can be increased.
2. Quality and representativeness of cost data	The cost data on which decisions may be made should be as geographically, temporally and technically representative as possible of the building design and construction, as well as the long-term predictions made for maintenance and replacement schedules. In this way the margins for error in the life cycle cost model can be minimised.
3. Schedule and estimate future costs, risks and liabilities	Experience gained from the long-term management of building stock, such as social housing, provides a useful starting point for scheduling and estimating the future costs associated with the maintenance, repair and replacement of building elements and components. In this way a plan can also be used to manage potential future risks and liabilities.
4. Make the link between life cycle cost and environmental performance	By making assessments of life cycle costs in parallel with assessments of environmental performance, such energy use and life cycle GWP, investment to improve environmental performance can be optimised. The potential synergies can also be more easily identified, with the long-term benefit of improved environmental performance being better captured by LCC.
5. Empowering building owners and occupiers	By estimating life cycle costs, important information can be provided to investors, asset managers and occupiers. The latter includes homeowners, who may wish to understand the costs associated with maintaining and running a home for the duration of a full mortgage term, and residents' organisations responsible for the communal costs of maintaining apartment blocks.

Figure 0.12 – Design concepts for reducing LCCs on a Level 1 assessment (Dodd, Donatello and Cordella 2021o)

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B.12: VALUE CREATION AND RISK EXPOSURE

Level 1 design concept	Brief description
Increased revenues from more stable investments	Here the influence of the property being recognised as a high-quality, sustainable building with a healthy internal environment on the potential for a property investment to maintain a high occupancy and therefore associated rental revenue over time, is a primarily considered. The ability of the building to adapt to changing needs and even mixes of uses in the future is also a potential consideration. <i>Indicators with a strong potential influence: 1.1, 2.3, 4.1, 4.2, 4.3, 4.4, 5.1</i>
Reduced operational overheads	<i>Here the potential for a property investment to be designed and specified in a way that operational overheads and expenditure are minimised over the long-term. This can include the cost of utility supplies, such as energy and water, but it can also encompass the cost of maintaining, repairing and replacing elements of the building as they are worn out.</i> <i>Indicators with a strong potential influence: 1.1 and 3.1 for utilities and for repair and durability/maintenance/replacement of materials, 2.1 (with links to 1.2 and 6.1).</i>
Reduced exposure to future risk	Here the potential for a property investment to be conceived and designed in order to minimise exposure to future risks of stranded assets, as well as unplanned costs and claims, are considered. This can include consideration of: - the tolerance of the building to projected future climate change and how this may affect both the need for repair or replacement of building elements that exceed their tolerance to, for example, wind, rain and temperature variations. - how changes in climatic conditions may influence the internal comfort conditions and health of the building occupiers. <i>Indicators with a strong potential influence: For repair and durability/maintenance/replacement of materials, 2.1 (with links to 1.2 and 6.1); for indoor comfort, 4.2 and 5.1 and for resilience of building design to extreme weather events, 5.2 and 5.3.</i>

Figure 0.13 – Design concepts for allowing property valuation on a Level 1 assessment (Dodd and Donatello 2021b)

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