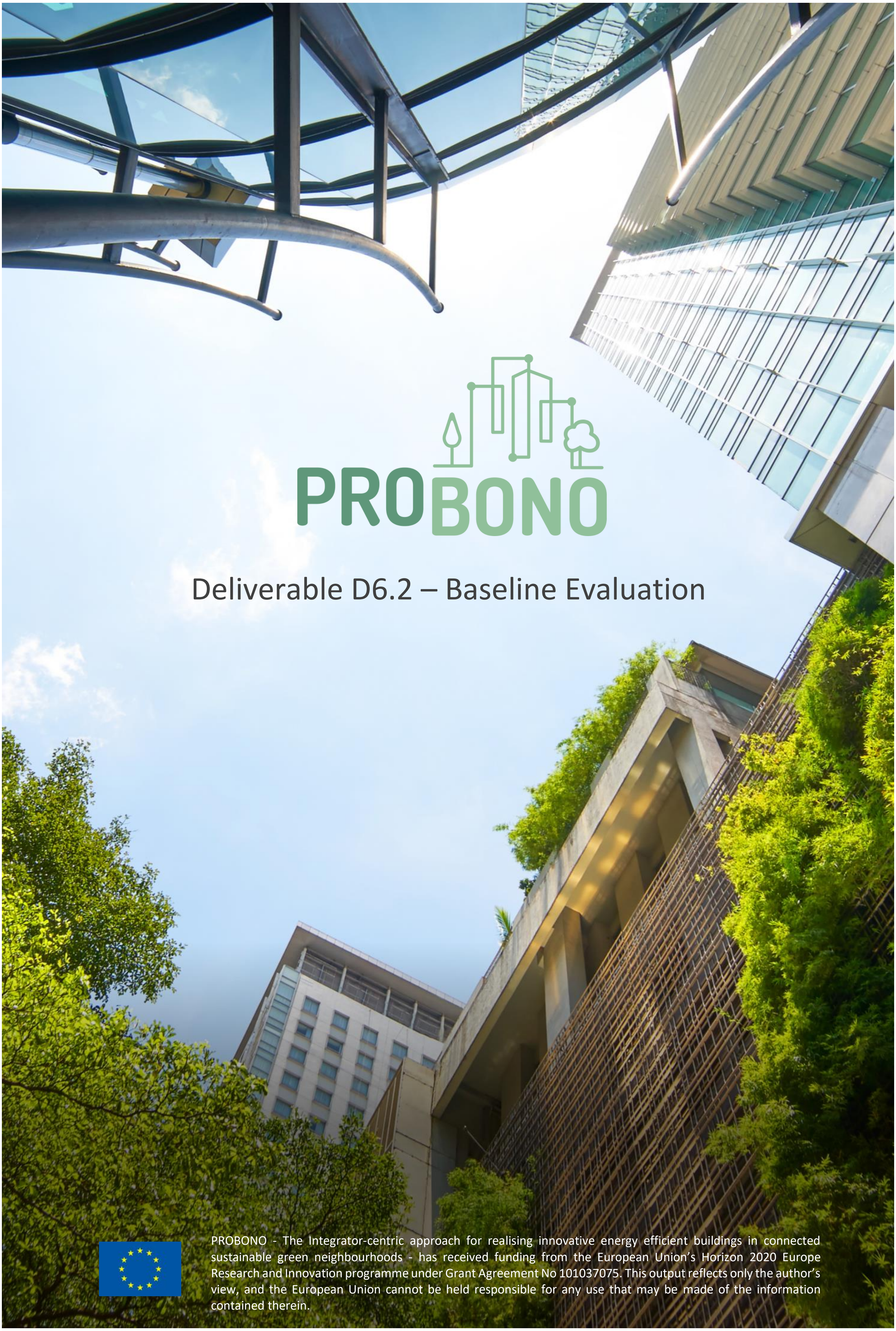

PROBONO

Deliverable D6.2 – Baseline Evaluation

PROBONO - The Integrator-centric approach for realising innovative energy efficient buildings in connected sustainable green neighbourhoods - has received funding from the European Union's Horizon 2020 Europe Research and Innovation programme under Grant Agreement No 101037075. This output reflects only the author's view, and the European Union cannot be held responsible for any use that may be made of the information contained therein.

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Authors:	**Javier Antolín (CARTIF)** **Álvaro Corredera (CARTIF)** **Julia Vicente (CARTIF)** **Rafael Sánchez (ACC)** **Carla Tortelli (ACC R&D)** **Leire Domínguez (ACC R&D)** **Marina Laskari (INLECOM)** **Gustaf Lohm (AU)** **Sidsel Bruun (SIN)** **Stephen Curran (UCD)** **Kostas Zavitsas (VLTN)** **Javier Dorao (DCN)** **Catarina Nunes (SONAE)** **Jirí Tencar (CTU)** **Pedro Neves (CAPW)** **Laurence Marzell (SERCO)**

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Contributors:

Partner	Contribution
CAR	WP6, T6.2 and D6.2 leader. Definition of the baseline templates.
ACC/ACC-R&D	Contributor to the definition of the baseline templates as part of the LCA and LCC. Baseline data collection for the Madrid LL as Madrid LL leader.
INLE	WP7 leader (Demonstration actions). Support in all related with the interactions with the Living Labs for the baseline data collection.
AU	Baseline data collection for the Aarhus LL as Aarhus LL leader.
SIN	Contributor to the definition of the baseline templates as part of the s-LCA.
UCD	Baseline data collection for the Dublin LL as Dublin LL leader.

Partner	Contribution
VLTN	Contributor by defining the conventional construction processes.
DCN	Baseline data collection for the Madrid LL.
SONAE	Baseline data collection for the Porto LL as Porto LL leader.
CTU	Baseline data collection for the Prague LL as Prague LL leader.
CAPW	Baseline data collection for the Porto LL.
SERCO	Baseline data collection for the Brussels LL as Brussels LL leader.

Peer reviewed by:

Partner	Reviewer
ACC R&D	Carla Tortelli, Leire Domínguez
MC SONAE	Marlos Silva

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DEFINITIONS[1]

A Green Building (GB) (new or retrofit) is a building that, in its design, construction and operation, reduces or eliminates negative impacts, and can create positive impacts, on the climate, social, and natural environment. GBs preserve precious natural resources and improve quality of life[2]. Specifically, this means that GBs should be very energy efficient, use extensively the potential of locally available renewable energy, use sustainable materials, and aim for a low environmental impact over the entire life cycle. GBs offer their users and residents a healthy climate and a high quality of stay, they are resilient e.g., to environmental change and contribute to social inclusion.

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[1] Please refer to the last submitted reports for the latest status of the definitions

[2] https://www.worldgbc.org/what-green-building

Green Neighborhoods aligned with the European Green Deal[3], is a set of buildings over a delimited area, at a scale that is smaller than a district, with potential synergies, in particular in the area of energy. A green neighborhood is a neighborhood that allows for environmentally friendly, sustainable patterns and behaviors to flourish e.g., bioclimatic architecture, renewable energy, soft and zero-emission mobility etc. Green neighborhoods are the building blocks of Positive Energy Districts (PEDs)[4] by implementing key elements of PED energy systems. For example, the exchange of energy between buildings increases the share of local self-supply with climate-neutral energy and system efficiency. They also provide the technical conditions to enable Citizen Energy Communities[5] and Renewable Energy Communities[6] to be implemented.

Green Buildings and Neighborhoods (GBN) in PROBONO are GBs integrated at delimited area or district level with green energy and green mobility management and appropriate infrastructure supported by policies, investments and stakeholders' engagement and behaviors that ensures just transition that maximize the economic and social cobenefits considering a district profile (population size, socio-economic structure, and geographical and climate characteristics). Delivered in the right way, GBN infrastructure is a key enabler of inclusive growth, can improve the accessibility of housing and amenities, reduce poverty and inequality, widen access to jobs and education, make communities more resilient to climate change, and promote public health and wellbeing.

DGNB certification serves as a quality stamp ensuring the state of the building for buyers. The Green Building Council Denmark (2010) established the German certification DGNB meaning 'German Society for Sustainable Buildings'. The Danish version of DGNB was created to obtain a common definition of what sustainability is towards and making it measurable. A consortium of experts was established from all parts of the construction sector. DGNB had to be reshaped for the Danish standards, practice, traditions, and laws but is now available to certify any construction project. They chose DGNB as an innovation-forward and sustainable future guarantee. DGNB diversifies itself by focusing on sustainability and not just the environment. DGNB creates a standardized framework for the construction operations conditions and creates a common language which facilitates communication between professions and helps organize and prioritize the efforts in long and complicated development phases.

Life cycle assessment (LCA)[7] is a tool used for the systematic quantitative assessment of each material used, energy flows and environmental impacts of products or processes. LCA assesses various aspects associated with development of a product and its potential impact throughout a product's life (i.e., cradle to grave) from raw material acquisition, processing, manufacturing, use and finally its disposal. In PROBONO, LCA represents the statement of a building's total energy, resource consumption and environmental impact in the manufacture, transport, and replacement of materials and for its operation over its expected life. Social life cycle assessment (S-LCA)[8] is a method to assess the social and sociological aspects of products, their actual and potential positive as well as negative impacts along the life cycle. Life-cycle costing (LCC)[9] considers all the costs incurred during the lifetime of the product, work, or service.

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[3] European_Green_Deal_EN_200710_fin

[4] SET-Plan Action 3.2: https://setis.ec.europa.eu/system/files/setplan_smartcities_implementationplan.pdf

[5] Internal Electricity Market Directive (EU) 2019/944 5 Renewable Energy Directive (EU)

[6] Renewable Energy Directive (EU) 2018/20012018/2001

[7] https://op.europa.eu/en/publication-detail/-/publication/16cd2d1d-2216-11e8-ac73-01aa75ed71a1/language-en

[8] https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/social-lca/

[9] https://ec.europa.eu/environment/gpp/lcc.htm

Table of contents

List of Figures

List of Tables

Abbreviations and Acronyms

Acronym	Description
BER	Building Energy Rating
BIPV	Building Integrated Photovoltaic
COP	Coefficient of Performance
DHW	Domestic Hot Water
EF	Emission Factor
EPD	Energy Product Declaration
GA	Grant Agreement
GB	Green Building
GBN	Green Building Neighbourhood
GHG	Green House Gas emissions
GWP	Global Warming Potential
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IPMVP	International Performance Measurement and Verification Protocol
KPI	Key Performance Indicator
LC	Life Cycle
LCA	Life Cycle Assessment
LCC	Life Cycle Cost assessment
LL	Living Lab
M&V	Measurement and Verification
MNN	Madrid Nuevo Norte
NZEB	Nearly Zero Energy Building
PEF	Primary Energy Factor
PV	Photovoltaic
RA	Reclaimed Asphalt
REC	Renewable Energy Community
RES	Renewable Energy System
SCMs	Supplementary Cementitious Materials
s-LCA	Social Life Cycle Assessment
V2G	Vehicle to Grid
WP	Work Package

Executive summary

PROBONO aims to turn six European district and site level areas into Green Building Neighbourhoods (GBN). Acting as the PROBONO Living Labs (LLs), two large-scale demonstrators are located in Madrid and Dublin and four business-focused demonstrators are located in Porto, Brussels, Aarhus and Prague. The PROBONO LLs will provide both an experimentation and innovation environment and testbed for GBN innovative solutions. Although having a distinct scope, each LL will follow a common process, starting with the GBN transition and strategic plan definition in WP1, the social innovations and stakeholders engagement activities in WP2 and the specification and selection of the maturing innovation technologies from WP3 and WP4, considering all the digitalization aspects in WP5 through the definition and deployment of the specific Digital Twins of each LL, going through the monitoring and evaluation in WP6, the implementation of all the actions in WP7 and ending with the dissemination, communication and replicability actions in WP8 and WP9.

WP6 "Monitoring and evaluation of the project's Living Labs" aims to define the evaluation framework and monitoring approach to be applied in each of the PROBONO LLs in order to collect all the necessary data to deploy the assessment activities and therefore to know the effectiveness of impacts achieved in each of the LLs once the innovations have been implemented.

The specific objectives of WP6 are the following and each of the objectives is aligned with each one of the WP6 tasks.

- Definition of the LLs evaluation framework based on Key Performance Indicators (KPIs), Measurement and Verification (M&V) plans and Life Cycle (LC) methodologies. T6.1.
- Baseline calculation for the Living Labs prior the implementation of the actions. T6.2.
- Monitoring program definition and associated execution plan for each Living Lab. T6.3.
- LLs impact assessment under operational and life cycle perspectives. T6.4.

D6.2 "Baseline Evaluation" formulates the findings of Task 6.2 containing the baseline calculation for all LLs. LLs baselines will allow assessing the effectiveness of the project actions and impacts assessment of GBNs comparing the status before and after.

T6.2 "Baseline calculation for the Living Labs" is composed by two sub-tasks:

- Subtask 6.2.1. Baseline data collection. Collection of baseline data through specific templates covering all the requirements of the Evaluation Framework defined in T6.1. The templates are shared with LLs teams to perform the data collection about the baseline conditions of each LL that is the status before the implementation of the innovative solutions.
- Subtask 6.1.2. Baseline data integration. Identifying the baseline data sets for each of the LLs that will be then integrated in the Digital platform through WP5 activities.

1 Introduction

1.1 Mapping PROBONO Outputs

The purpose of this section is to map PROBONO's GA commitments, both within the formal deliverable as well as the task description, against the project's respective outputs and work performed.

GA Component Title	GA Component Outline	Respective Document Chapter(s)	Justification
TASK			
Task 6.2 Baseline calculation for the Living Labs	Baselines will allow assessing the effectiveness of the project actions and impacts assessment of GBNs comparting the status before and after the implementations.	Sections 2, 3 and 4	This report collects the baseline data information needed to define the status of the six Living Labs before the implementation of the PROBONO innovations. Baseline status of the Living Labs will be compared with the after situation of the Living Labs once the innovations have been implemented.
	Create templates covering all the requirements for data collection of the Evaluation Framework and share it with LLs teams.	Section 2.3	To have a complete definition of the reference situation of each of the Living Labs, baseline templates have been defined and shared with the LLs to coordinate and facilitate the data collection process.
	Perform data collection about the baseline conditions of each LLs that is the conditions of before the implementation of the actions.	Section 3	Based on the defined baseline templates, each of the PROBONO Living Labs has been in charge on the data collection of their specific site.
	Perform the integration of data sources to enable baseline measurements and deploy a complete evaluation procedure, further established through the DT platforms.	Section 3	Specific information about the already existing data sources, monitoring systems, etc. is included in the baseline definition of the Living Labs. This information will allow to start defining the best mechanisms to integrate the baseline data sources into the Digital Platform developed in WP5.
DELIVERABLE			
D6.2: Baseline Evaluation This report formulates the findings of T6.2 containing the baseline calculation for all LLs			

Table 1: Adherence to PROBONO's GA Deliverable & Task description

1.2 Purpose and scope of the document

This document defines the baseline evaluation of the LLs setting the reference conditions before the implementation of the innovations.

Figure 1 shows the WP6 working flow. T6.2 establish the baseline calculation based on the Evaluation Framework defined in T6.1. Baseline calculation will be then compared with the status of the LLs after the implementation of the innovative solutions in order to assess the impacts achieved at the end of the project in T6.4.

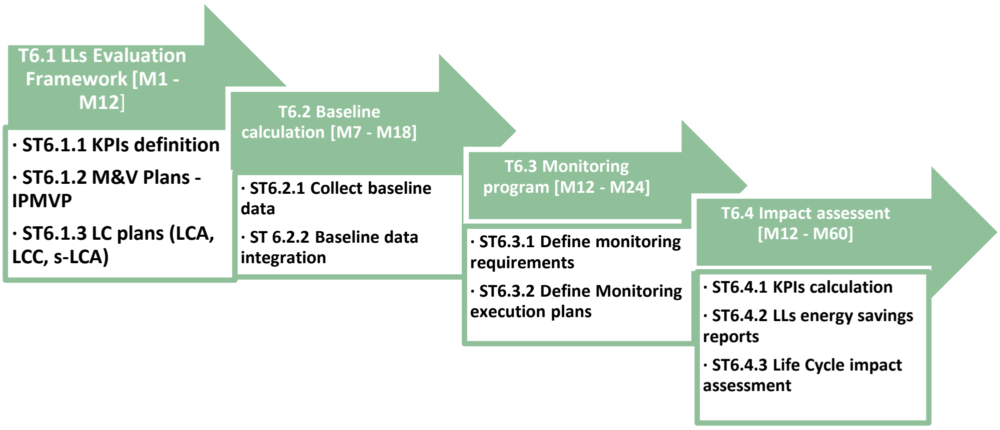


Figure 1: WP6 working flow

Baseline Evaluation receives inputs mainly from the LLs from WP7 in order to define well the reference conditions from each site.

The main outputs from D6.2 will be to WP5 for the consideration of the variables needed from each of the LLs that need to be integrated in the Digital Platform as baseline conditions, also to WP7 setting the reference conditions for each of the LLs.

1.3 Structure of the document

Deliverable D6.2 is structured in six different main sections. Section 1 is dedicated to the introduction. Section 2 presents the baseline calculation process, including information about the baseline definition, scope and templates used for the data collection. Section 3 is the one related with the baseline data collection process for each of the LLs, this information is collected by each of the LLs representatives based on their LL specific scope and data availability. Section 4 is dedicated to present references for the conventional construction processes to be compared with the innovative PROBONO ones. Section 5, presents some additional details for the applicability of the Life Cycle methods in relation with the baseline definition. Section 6 summarizes the conclusions.

1.4 Contribution to creating GBN

D6.2 collects all the information relative to the reference scenario for each of the LLs of the PROBONO project. LLs are part of the GBN global concept. By defining the reference scenario, it will be possible to validate the innovations applied as part of the project in each of the LLs and therefore to validate part of the GBN concept.

2 Baseline calculation process

2.1 Baseline definition

Baseline refers to the procedure to assess the situation before the interventions take place and which will be used to compare the effect of the interventions.

The baseline is usually the performance of the facility or system prior to any modification. In existing constructions, this baseline physically exists and can be measured before changes are implemented. Baseline period should be stablished to represent a full operating cycle. In new construction, there are no existing data to compare with, in this case the baseline is usually hypothetical and defined in terms of code, regulation, standard practice or similar facilities.

In the case of the PROBONO project LLs, the baseline is the status of each the LLs before the implementation of the technical innovations. There are three different approaches for the different LLs considering their current status.

- **Renovation of an already existing Living Labs (keeping the same final use):**
    - In the case of Dublin, Brussels and Prague as they are currently existing buildings and infrastructure, the baseline definition is based on their current status before the implementation of any action. The baseline data collection is done considering the current status of the Labs before the implementation of the actions.
    - In the case of Porto LL, although it is also existing, the approach is slightly different because of the perspective on how to address the PROBONO innovations, considering here a complete campus approach such as an energy community (involving several buildings and energy systems all together and not in a separate way). In this regard, some adaptations of the baseline data collection process have been implemented.
    - It is very relevant to have at least one complete reference year in order to cover the complete operational cycle. In all these four LLs, baseline data will be collected (if available) from the previous three years (2020-2022). The idea is to define a consistent reference for each site (e.g.: avoiding for example the specific impact the COVID could have on the buildings).
- **Complete renovation (changing the final end use):** Aarhus LL is composed by a complete renovation of an old hospital campus, meaning that the baseline definition needs to be address as if new buildings were constructed (this is because the final use of the buildings are completely different changing from a hospital to a university campus). This means that the baseline will be based on code, normative or information from similar facilities/buildings in the existing university campus.

- **Completely new construction:** For Madrid LL the approach followed is based on code, regulations, etc. as it is a completely new construction and no baseline data is available before the implementation of the actions.

2.2 Baseline scope

The baseline scope is completely aligned with the PROBONO Evaluation Framework defined in D6.1. The baseline will cover all the requirements needed to define the reference scenario for the calculation of the baseline KPIs, the definition of the energy models for the M&V plans based on the IMPVP and the applicability of the Life Cycle assessments.

All the information needed to cover with these requirements indicated above, is the one included in the baseline templates and shared with the LLs representatives for the data collection process.

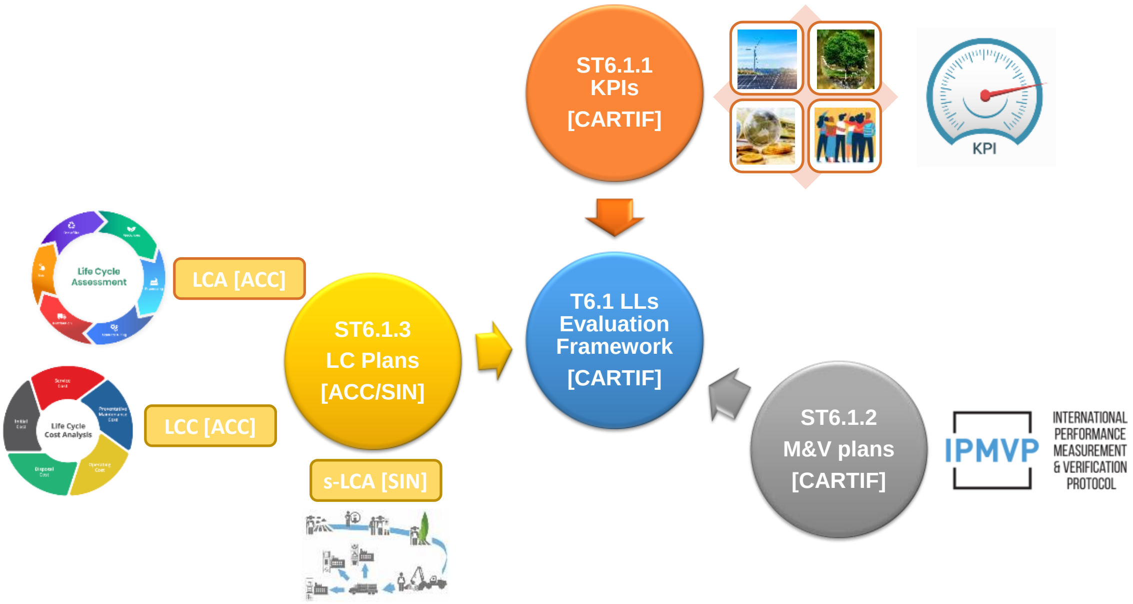


Figure 2: General view of the PROBONO Evaluation Framework

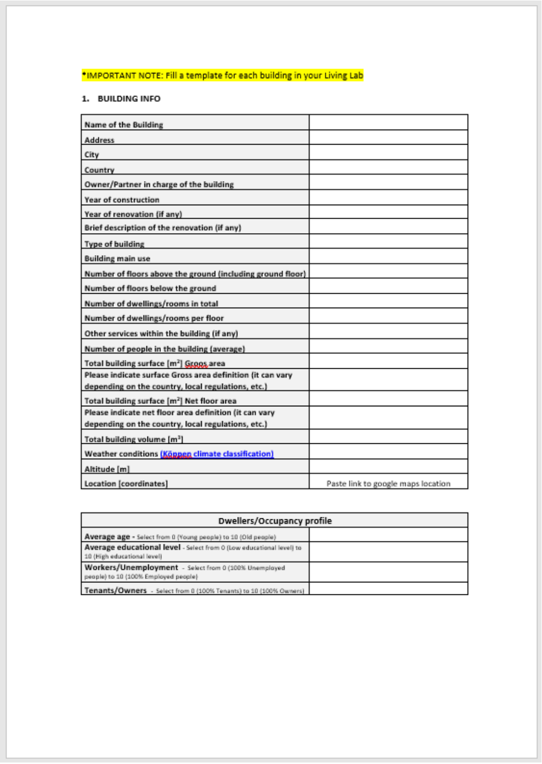
2.3 Baseline templates

This specific subsection presents the baseline template defined for the LLs data collection. These templates have been shared with the LLs representatives in order to collect the necessary data to define the reference scenario for each site. This request has covered all the baseline requirements in terms of KPIs, M&V plans and LC methods (LCA, LCC and s-LCA) from the Evaluation Framework defined in D6.1.

The baseline template is composed mainly by 4 different sections:

- Section 1 “Building info”. To collect the general information from each of the buildings that compose the Living Lab.
    - Building info: Name of the building, address, city, owner, year of construction, etc.
    - Occupancy profile.

  - Indoor Environmental Quality perception from the end-uses of the building.
  - Occupancy schedules.
  - Representative pictures of the building and their surroundings.
- Section 2 “Envelope/ Passive elements”. To collect information which allows to define the passive elements of the specific building (walls, roof, floor, windows, etc.).
- Section 3 “Active elements”. To collect information from the energy active elements of the specific building (heating systems, cooling systems, ventilation systems, etc.). In addition, within this section is also collected information about the energy fluxes (energy consumption from the different fuels, energy production from Renewable Energy Systems (RES), etc.), monitoring systems available, information about the maintenance, Building Energy Rating (BER) and if apply, information about the e-mobility aspects.
- Section 4 “Life cycle assessment”. This section is defined to collect the data needed to define the reference conditions before applying the life cycle assessment methods.

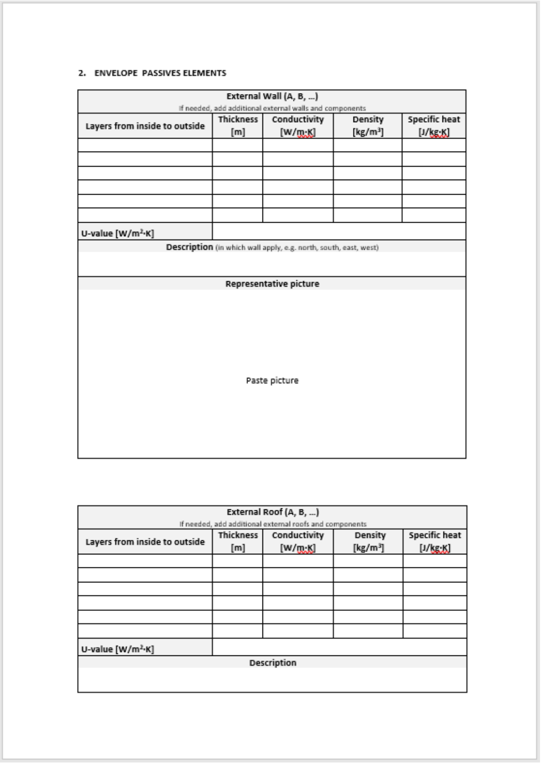


*IMPORTANT NOTE: Fill a template for each building in your Living Lab

1. BUILDING INFO

Name of the Building	
Address	
City	
Country	
Owner/Partner in charge of the building	
Year of construction	
Year of renovation (if any)	
Brief description of the renovation (if any)	
Type of building	
Building main use	
Number of floors above the ground (including ground floor)	
Number of floors below the ground	
Number of dwellings/rooms in total	
Number of dwellings/rooms per floor	
Other services within the building (if any)	
Number of people in the building (average)	
Total building surface [m²] Groos area	
Please indicate surface Gross area definition (it can vary depending on the country, local regulations, etc.)	
Total building surface [m²] Net floor area	
Please indicate net floor area definition (it can vary depending on the country, local regulations, etc.)	
Total building volume [m³]	
Weather conditions (Köppen climate classification)	
Altitude [m]	
Location [coordinates]	Paste link to google maps location

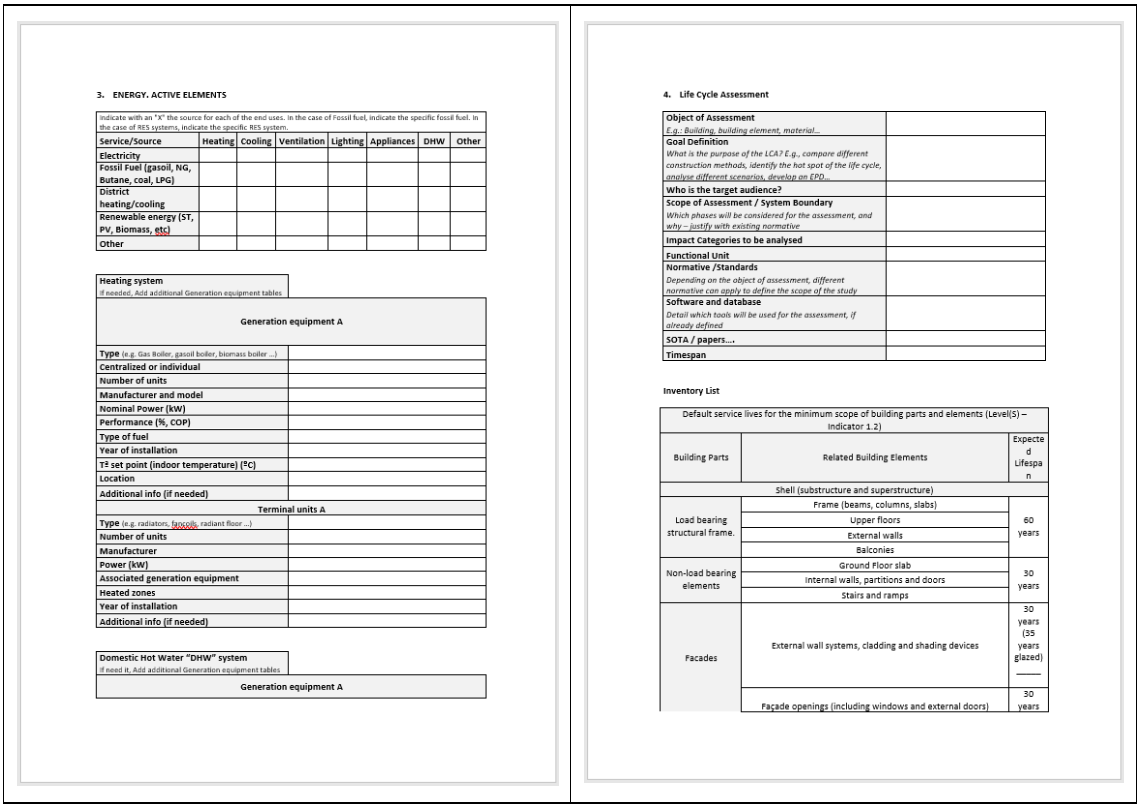
Dwellers/Occupancy profile	
Average age - Select from 0 (Young people) to 10 (Old people)	
Average educational level - Select from 0 (Low educational level) to 10 (High educational level)	
Workers/Unemployment - Select from 0 (100% Unemployed people) to 10 (100% Employed people)	
Tenants/Owners - Select from 0 (100% Tenants) to 10 (100% Owners)	



2. ENVELOPE PASSIVES ELEMENTS

External Wall (A, B, …) If needed, add additional external walls and components				
Layers from inside to outside	Thickness [m]	Conductivity [W/m·K]	Density [kg/m³]	Specific heat [J/kg·K]
U-value [W/m²·K]				
Description (in which wall apply, e.g. north, south, east, west)				
Representative picture				
Paste picture				

External Roof (A, B, …) If needed, add additional external roofs and components				
Layers from inside to outside	Thickness [m]	Conductivity [W/m·K]	Density [kg/m³]	Specific heat [J/kg·K]
U-value [W/m²·K]				
Description				



3. ENERGY. ACTIVE ELEMENTS

Indicate with an "X" the source for each of the end uses. In the case of Fossil fuel, indicate the specific fossil fuel. In the case of RES systems, indicate the specific RES system.							
Service/Source	**Heating**	**Cooling**	**Ventilation**	**Lighting**	**Appliances**	**DHW**	**Other**
Electricity							
Fossil Fuel (gasoil, NG, Butane, coal, LPG)							
District heating/cooling							
Renewable energy (ST, PV, Biomass, etc)							
Other							

Heating system If needed, Add additional Generation equipment tables	
Generation equipment A	
Type (e.g. Gas Boiler, gasoil boiler, biomass boiler ...)	
Centralized or individual	
Number of units	
Manufacturer and model	
Nominal Power (kW)	
Performance (%, COP)	
Type of fuel	
Year of installation	
Tª set point (indoor temperature) (ºC)	
Location	
Additional info (if needed)	
Terminal units A	
Type (e.g. radiators, fancoils, radiant floor ...)	
Number of units	
Manufacturer	
Power (kW)	
Associated generation equipment	
Heated zones	
Year of installation	
Additional info (if needed)	

Domestic Hot Water "DHW" system If need it, Add additional Generation equipment tables	
Generation equipment A	

4. Life Cycle Assessment

Object of Assessment *E.g.: Building, building element, material…*	
Goal Definition *What is the purpose of the LCA? E.g., compare different construction methods, identify the hot spot of the life cycle, analyse different scenarios, develop an EPD…*	
Who is the target audience?	
Scope of Assessment / System Boundary *Which phases will be considered for the assessment, and why – justify with existing normative*	
Impact Categories to be analysed	
Functional Unit	
Normative /Standards *Depending on the object of assessment, different normative can apply to define the scope of the study*	
Software and database *Detail which tools will be used for the assessment, if already defined*	
SOTA / papers….	
Timespan	

Inventory List

Default service lives for the minimum scope of building parts and elements (Level(S) – Indicator 1.2)		
Building Parts	Related Building Elements	Expected Lifespan
Shell (substructure and superstructure)		
Load bearing structural frame.	Frame (beams, columns, slabs)	60 years
	Upper floors	
	External walls	
	Balconies	
Non-load bearing elements	Ground Floor slab	30 years
	Internal walls, partitions and doors	
	Stairs and ramps	
Facades	External wall systems, cladding and shading devices	30 years (35 years glazed) ———
	Façade openings (including windows and external doors)	30 years

Figure 3: Baseline template screenshots

As mentioned before, depending on the specific Living Lab context, each Living Lab will collect the information from a different perspective (currently existing data, normative/code data, similar facilities data, etc.). In addition to this, the specific data collection about passive and active elements and about the Life Cycle requirements will depend on the specific impacts, scopes and data availability of each of the Living Labs within the PROBONO project.

3 Living Labs baseline data collection

This section presents the baseline data collection from each of the LLs for the PROBONO project based on the baseline templates shared with them. The baseline template is defined considering a general approach to cover the complete Evaluation Framework needs but the final data collection depends on the final context and needs of each Living Lab. This means that not all the Living Labs have collected the complete baseline template requirements if this is not needed for the specific assessment process of the Lab. In each of the subsections is explained in detail the scope covered for each Living Lab.

3.1 Madrid LL baseline data collection

Madrid LL will be a completely new construction. This means that baseline data does not exist at this moment and the baseline evaluation need to be based on normative/legislation at country/local level. In the case of Madrid LL, the baseline reference will be based on the Building

Technical Code for Spain ("Código Técnico de la Edificación (CTE)")[10] as it is the one that establish the minimum requirements to comply for construction activities.

The specific Living Lab as part of PROBONO will be composed by two different types of buildings, one residential building and one tertiary office building. In the following sections information from the technical code has been collected for both types of buildings to define the reference scenario for the next stages of the project in which the impacts will be evaluated. The reference model will be defined and created in the next stages of the project based on this normative data collection.

Below there are some representative pictures of the Madrid LL area. The red circles indicate the specific location for the two types of buildings as part of the PROBONO project.

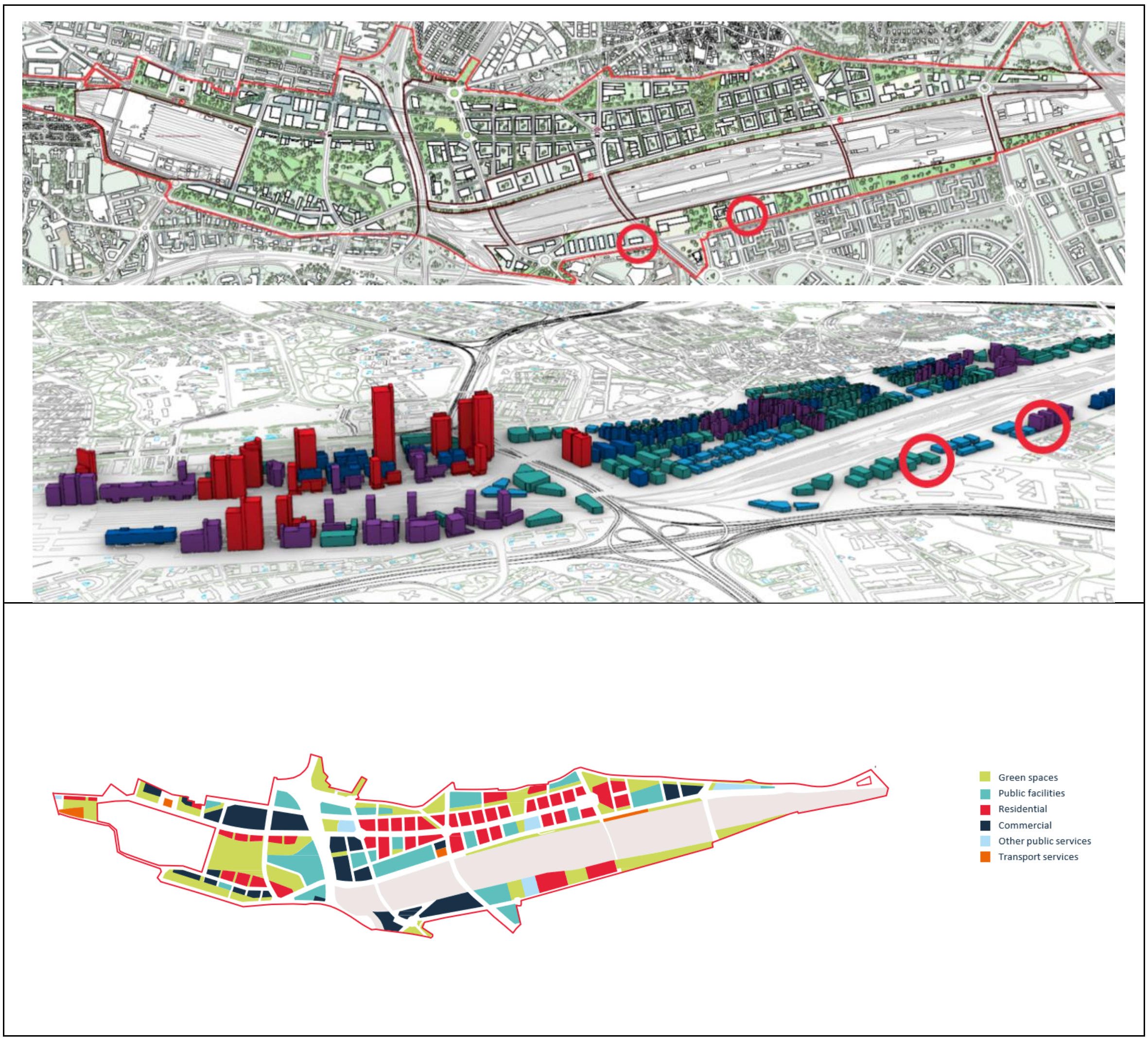


Figure 4: Madrid LL representative pictures

In terms of LCA, the approach is different, as in the Madrid LL the LCA will be done over specific individual components part of the project such as a low carbon concrete, a sustainable road pavement and the geothermal plant and distribution network, therefore the baseline data collection for the LCA is defined considering the component level of these specific innovations.

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[10] https://www.codigotecnico.org/

3.1.1 General info for the buildings baseline

3.1.1.1 Residential building info

Name of the Building	PROBONO Residential building
Address	Calle Castillo de Candachú
City	Madrid
Country	Spain
Owner/Partner in charge of the building	DCN
Year of construction	2025
Year of renovation (if any)	N.A.
Brief description of the renovation (if any)	N.A
Type of building	Residential
Building main use	Residential
Number of floors above the ground (including ground floor)	14 (at maximum)
Number of dwellings/rooms in total	125
Number of people in the building (average)	482.5
Please indicate surface Gross area definition (it can vary depending on the country, local regulations, etc.)	Buildability 42,960 m² residential and 8,100 m² commercial, in which PROBONO will satisfy the thermal energy demand of 12,620m² residential y 2,380 m² commercial
Weather conditions (Köppen climate classification)	Mediterranean climate
Altitude [m]	649m
Location [coordinates]	40°29'43.6"N 3°40'33.1"W (F8WF+5MJ Madrid)

Table 2: Madrid LL Residential building general information

3.1.1.2 Tertiary offices building info

Name of the Building	PROBONO Office building
Address	Calle Castillo de Candachú
City	Madrid
Country	Spain
Owner/Partner in charge of the building	DCN
Year of construction	2025
Year of renovation (if any)	N.A.
Brief description of the renovation (if any)	N.A
Type of building	Offices
Number of floors above the ground (including ground floor)	12 (at maximum)
Number of people in the building (average)	346

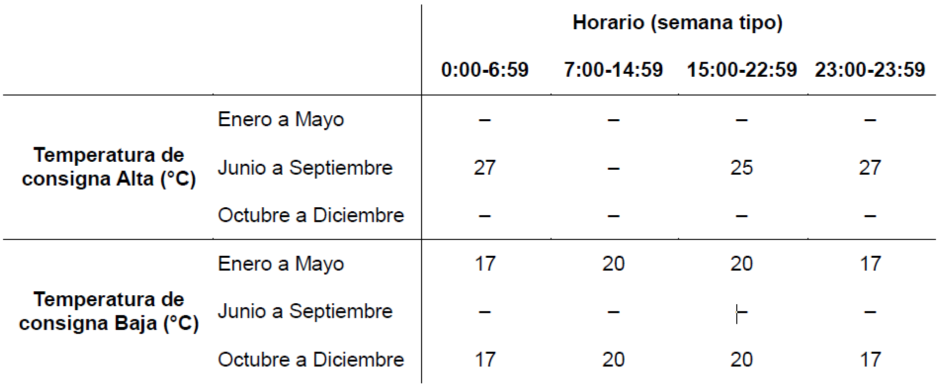
Please indicate surface Gross area definition (it can vary depending on the country, local regulations, etc.)	Buildability 92,006m² tertiary, in which PROBONO will satisfy the thermal energy demand of 15,000 m² tertiary
Weather conditions (Köppen climate classification)	Mediterranean Climate
Altitude [m]	649m
Location [coordinates]	40°29'43.6"N 3°40'33.1"W (F8WF+5MJ Madrid)

Table 3: Madrid LL Office building general information

Operational conditions and use profiles[11]

The spaces of the thermal model will have associated operational conditions and use profiles that correspond to the specific use of each space.

The set of setpoint temperatures of the operational conditions and the use profile for spaces for private residential use, for the purposes of calculating the energy demand, will be those specified in Table 4, Table 5 and Table 6:



		Horario (semana tipo)			
		0:00-6:59	**7:00-14:59**	**15:00-22:59**	**23:00-23:59**
Temperatura de consigna Alta (°C)	Enero a Mayo	–	–	–	–
	Junio a Septiembre	27	–	25	27
	Octubre a Diciembre	–	–	–	–
Temperatura de consigna Baja (°C)	Enero a Mayo	17	20	20	17
	Junio a Septiembre	–	–	–	–
	Octubre a Diciembre	17	20	20	17

Table 4: Operational conditions for conditioned spaces in private residential buildings (Documento Básico HE, 2022)

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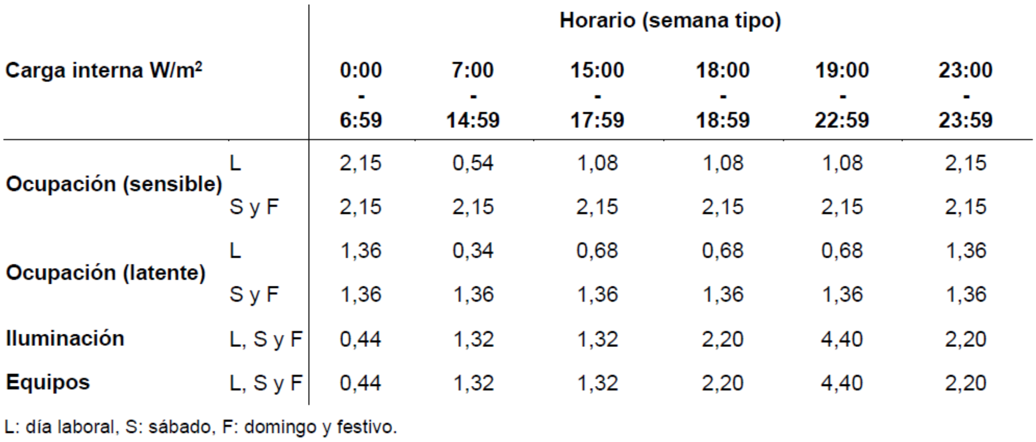
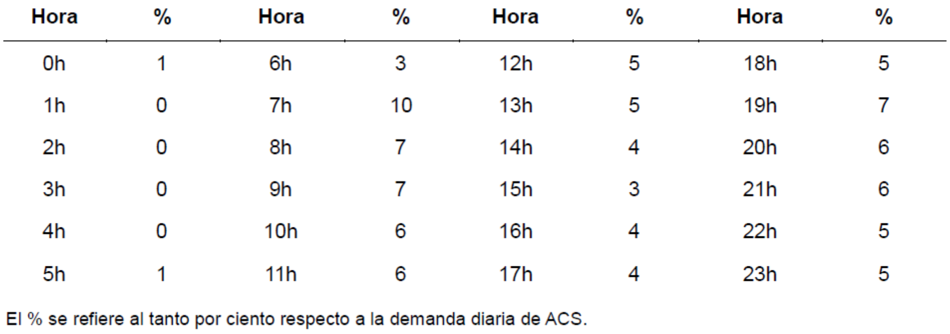
[11] (Documento Básico HE, 2022) – Table a-Appendix D; Table b-Appendix D; Table c-Appendix D.



Carga interna W/m^2		Horario (semana tipo)					
		0:00 - 6:59	7:00 - 14:59	15:00 - 17:59	18:00 - 18:59	19:00 - 22:59	23:00 - 23:59
Ocupación (sensible)	L	2,15	0,54	1,08	1,08	1,08	2,15
	S y F	2,15	2,15	2,15	2,15	2,15	2,15
Ocupación (latente)	L	1,36	0,34	0,68	0,68	0,68	1,36
	S y F	1,36	1,36	1,36	1,36	1,36	1,36
Iluminación	L, S y F	0,44	1,32	1,32	2,20	4,40	2,20
Equipos	L, S y F	0,44	1,32	1,32	2,20	4,40	2,20

L: día laboral, S: sábado, F: domingo y festivo.

Table 5: Use profile of spaces in private residential buildings (Documento Básico HE, 2022)



Hora	%	Hora	%	Hora	%	Hora	%
0h	1	6h	3	12h	5	18h	5
1h	0	7h	10	13h	5	19h	7
2h	0	8h	7	14h	4	20h	6
3h	0	9h	7	15h	3	21h	6
4h	0	10h	6	16h	4	22h	5
5h	1	11h	6	17h	4	23h	5

El % se refiere al tanto por ciento respecto a la demanda diaria de ACS.

Table 6: Use profile of DWH in spaces for private residential buildings (Documento Básico HE, 2022)

3.1.2 Envelope passive elements

Thermal envelope transmittance[12]

The thermal transmittance (U) of each element belonging to the thermal envelope shall not exceed the limit value (Ulim) of Table 7:

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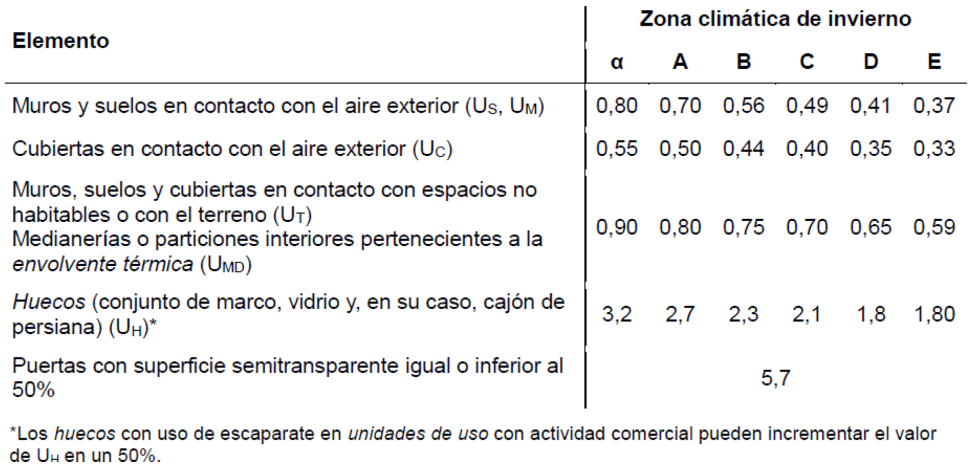
[12] (Documento Básico HE, 2022) - Table 3.1.1.a –HE1; Table 3.1.1.b –HE1 Table 3.1.1.c –HE1



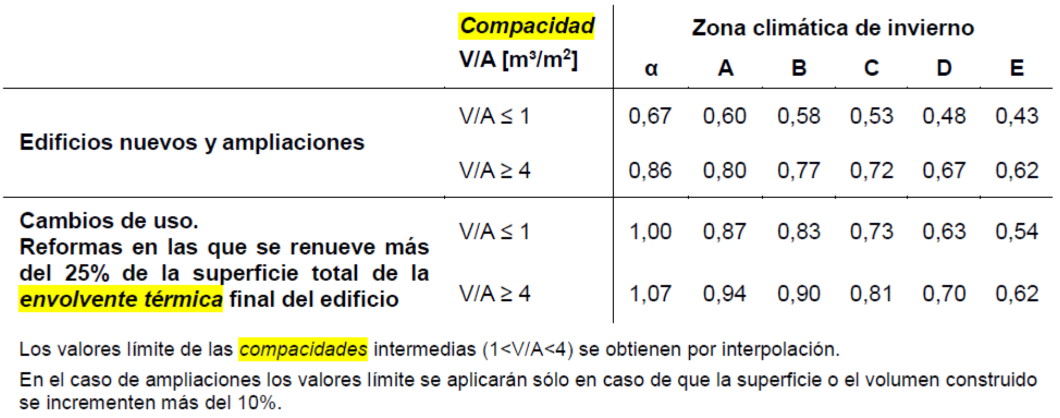
Elemento	Zona climática de invierno					
	α	A	B	C	D	E
Muros y suelos en contacto con el aire exterior (U_S, U_M)	0,80	0,70	0,56	0,49	0,41	0,37
Cubiertas en contacto con el aire exterior (U_C)	0,55	0,50	0,44	0,40	0,35	0,33
Muros, suelos y cubiertas en contacto con espacios no habitables o con el terreno (U_T) Medianerías o particiones interiores pertenecientes a la *envolvente térmica* (U_{MD})	0,90	0,80	0,75	0,70	0,65	0,59
Huecos (conjunto de marco, vidrio y, en su caso, cajón de persiana) (U_H)*	3,2	2,7	2,3	2,1	1,8	1,80
Puertas con superficie semitransparente igual o inferior al 50%	5,7					

*Los *huecos* con uso de escaparate en *unidades de uso* con actividad comercial pueden incrementar el valor de U_H en un 50%.

*Madrid climatic zone corresponds to letter D

Table 7: Limit values of thermal transmittance, U_{lim} [W/m^2·K] (Documento Básico HE, 2022)

The overall coefficient of heat transmission through the thermal envelope (K) of the building, or part of it, for private residential use, shall not exceed the limit value (Klim) obtained from Table 8:



	Compacidad V/A [m³/m²]	Zona climática de invierno					
		α	A	B	C	D	E
Edificios nuevos y ampliaciones	V/A ≤ 1	0,67	0,60	0,58	0,53	0,48	0,43
	V/A ≥ 4	0,86	0,80	0,77	0,72	0,67	0,62
Cambios de uso. Reformas en las que se renueve más del 25% de la superficie total de la *envolvente térmica* final del edificio	V/A ≤ 1	1,00	0,87	0,83	0,73	0,63	0,54
	V/A ≥ 4	1,07	0,94	0,90	0,81	0,70	0,62

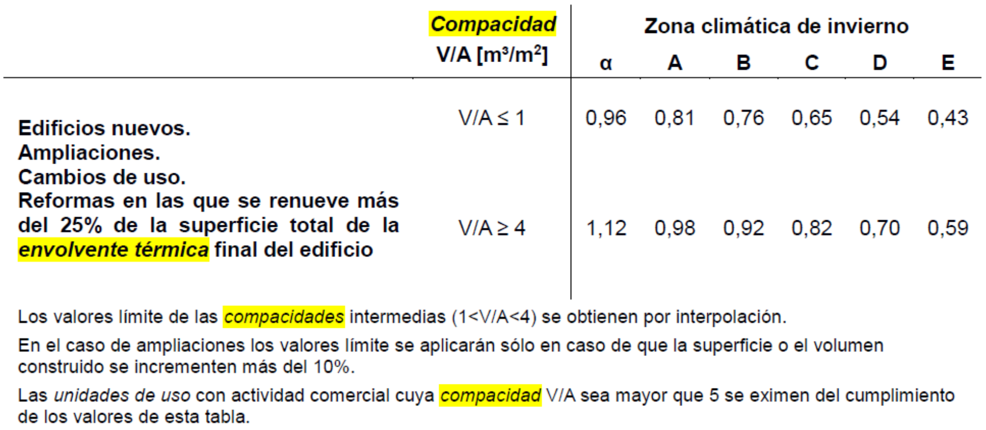
Los valores límite de las *compacidades* intermedias (1<V/A<4) se obtienen por interpolación.

En el caso de ampliaciones los valores límite se aplicarán sólo en caso de que la superficie o el volumen construido se incrementen más del 10%.

*Madrid climatic zone corresponds to letter D

Table 8: Limit values for private residential buildings, K_{lim} [W/m^2·K] (Documento Básico HE, 2022)

The global coefficient of heat transmission through the thermal envelope (K) of the building, or part of it, with different use from private residential will not exceed the limit value (Klim) obtained from Table 9:



	Compacidad V/A [m³/m²]	Zona climática de invierno					
		α	A	B	C	D	E
Edificios nuevos. Ampliaciones. Cambios de uso. Reformas en las que se renueve más del 25% de la superficie total de la *envolvente térmica* final del edificio	V/A ≤ 1	0,96	0,81	0,76	0,65	0,54	0,43
	V/A ≥ 4	1,12	0,98	0,92	0,82	0,70	0,59

Los valores límite de las *compacidades* intermedias (1<V/A<4) se obtienen por interpolación.

En el caso de ampliaciones los valores límite se aplicarán sólo en caso de que la superficie o el volumen construido se incrementen más del 10%.

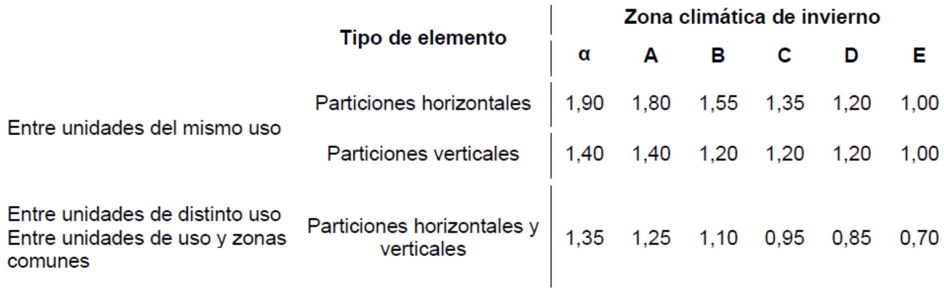
Las *unidades de uso* con actividad comercial cuya *compacidad* V/A sea mayor que 5 se eximen del cumplimiento de los valores de esta tabla.

*Madrid climatic zone corresponds to letter D

Table 9: Limit values for different use to private residential buildings, K_{lim} [$W/m^2 \cdot K$] (Documento Básico HE, 2022)

Thermal transmittance of the interior partitions[13]

The thermal transmittance of the interior partitions will not exceed the value of Table 10, depending on the use assigned to the different units of use that delimit:



	Tipo de elemento	Zona climática de invierno					
		α	A	B	C	D	E
Entre unidades del mismo uso	Particiones horizontales	1,90	1,80	1,55	1,35	1,20	1,00
	Particiones verticales	1,40	1,40	1,20	1,20	1,20	1,00
Entre unidades de distinto uso Entre unidades de uso y zonas comunes	Particiones horizontales y verticales	1,35	1,25	1,10	0,95	0,85	0,70

*Madrid climatic zone corresponds to letter D

Table 10: Limit values of thermal transmittance for interior partitions, U_{lim} [$W/m^2 \cdot K$] (Documento Básico HE, 2022)

Indicative transmittance values[14]

Table 11 provides indicative values of the characteristic parameters of the thermal envelope that may be useful for the pre-dimensioning of constructive solutions for buildings for private residential use, for compliance with the conditions established for the global coefficient of heat transmission through the envelope:

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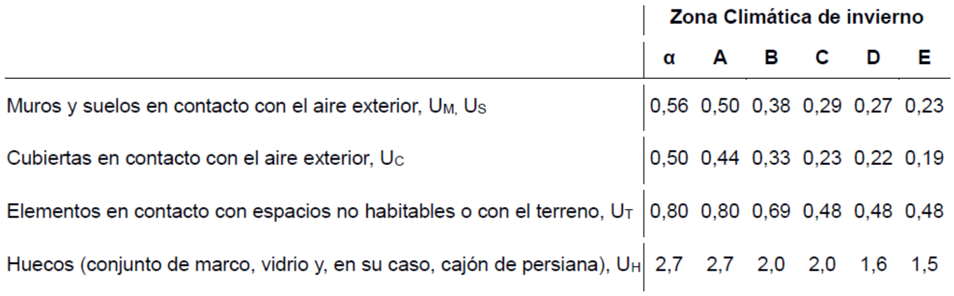
[13] (Documento Básico HE, 2022) - Table 3.2 – HE1

[14] (Documento Básico HE, 2022) - Table a-Appendix E.

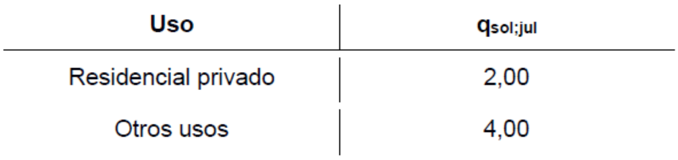


	Zona Climática de invierno					
	α	A	B	C	D	E
Muros y suelos en contacto con el aire exterior, U_M, U_S	0,56	0,50	0,38	0,29	0,27	0,23
Cubiertas en contacto con el aire exterior, U_C	0,50	0,44	0,33	0,23	0,22	0,19
Elementos en contacto con espacios no habitables o con el terreno, U_T	0,80	0,80	0,69	0,48	0,48	0,48
Huecos (conjunto de marco, vidrio y, en su caso, cajón de persiana), U_H	2,7	2,7	2,0	2,0	1,6	1,5

Table 11: Thermal transmittance for different elements, U_{lim} [W/m^2·K] (Documento Básico HE, 2022)

Solar control of the thermal envelope[15]

In the case of new buildings and extensions, changes of use or rehabilitation in which more than 25% of the total area of the final thermal envelope of the building is renewed, the solar control parameter will not exceed the limit value from Table 12:



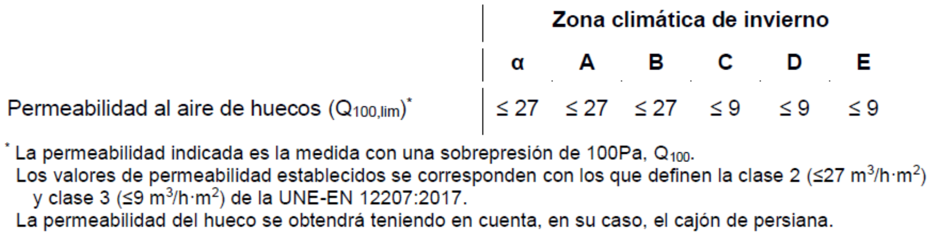
Uso	$q_{sol;jul}$
Residencial privado	2,00
Otros usos	4,00

Table 12: Limit value for the Solar control parameter, q_{sol} [kWh/m^2·month] (Documento Básico HE, 2022)

Air permeability of the thermal envelope[16]

The constructive solutions and execution conditions of the elements of the thermal envelope will ensure adequate air tightness. Particular care will be taken in the encounters between openings and opaque, points of passage through the thermal envelope and access doors to unconditioned spaces.

The air permeability (Q100) of the openings that belong to the thermal envelope will not exceed the limit value of Table 13:



	Zona climática de invierno					
	α	A	B	C	D	E
Permeabilidad al aire de huecos ($Q_{100,lim}$)*	≤ 27	≤ 27	≤ 27	≤ 9	≤ 9	≤ 9

* La permeabilidad indicada es la medida con una sobrepresión de 100Pa, Q_{100}.
Los valores de permeabilidad establecidos se corresponden con los que definen la clase 2 (≤27 m^3/h·m^2) y clase 3 (≤9 m^3/h·m^2) de la UNE-EN 12207:2017.
La permeabilidad del hueco se obtendrá teniendo en cuenta, en su caso, el cajón de persiana.

Table 13: Limit value for the permeability to the air in the thermal envelope voids, $Q_{100,lim}$ [m^3/h·m^2] (Documento Básico HE, 2022)

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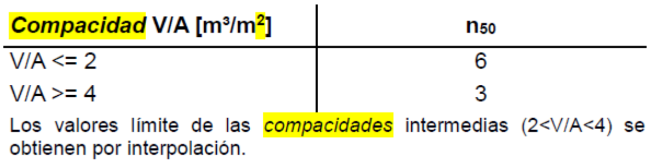
[15] (Documento Básico HE, 2022) – Table 3.1.2-HE1.

[16] (Documento Básico HE, 2022) – Table 3.1.3.a-HE1; Table 3.1.3.b-HE1.

In private residential new buildings with a total usable area greater than 120 m^2, the air exchange ratio with a differential pressure of 50 Pa (n50) shall not exceed the limit value of *Table 14*.



Compacidad V/A [m³/m²]	n₅₀
V/A <= 2	6
V/A >= 4	3

Los valores límite de las compacidades intermedias (2<V/A<4) se obtienen por interpolación.

Table 14: Limit value of the ratio of the change of air with a pressure of 50 Pa, n_{50} [h^{-1}] (Documento Básico HE, 2022)

Determination of the air permeability of the building[17]

The determination of the air permeability of the building must be carried out with one of the following methods:

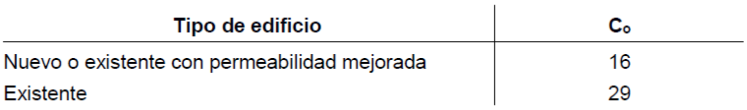
1. Determination by test: The value of the air change ratio at 50 Pa, n50 obtained by test according to method 1 or 2 of the UNE-EN ISO 9972:2019. Determination of the air permeability of buildings. Pressurization method by fan.

2. Determination by reference values: The value of the ratio of the air exchange at 50 Pa, n50 though reference values will be obtained from the following expression.

$$n_{50} = 0{,}629 \cdot (C_o \cdot | A_o + C_h \cdot A_h) / V_{int}$$

Where:

- n_{50}: air change ratio value at 50 Pa.
- V_{int}: internal volume of the thermal envelope [m^3]
- C_o: coefficient of the airflow of the opaque part of the thermal envelope at 100 Pa [m^3/h·m^2]
- A_o: Surface of the opaque thermal envelope in contact with external air [m^2]
- C_h: permeability of the voids of the thermal envelope at 100 Pa [m^3/hm^2]
- A_h: Surface of the voids in the thermal envelope [m^2]



Tipo de edificio	Cₒ
Nuevo o existente con permeabilidad mejorada	16
Existente	29

Table 15: Reference values of the coefficient for the airflow for the opaque part of the thermal envelope, C_o [m^3/h·m^2] (100 Pa) (Documento Básico HE, 2022)

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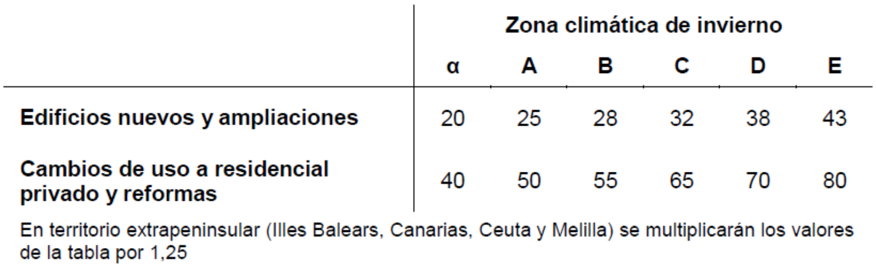
[17] (Documento Básico HE, 2022) – Table a-Appendix H.

3.1.3 Energy. Active elements

Non-renewable Energy Consumption[18]

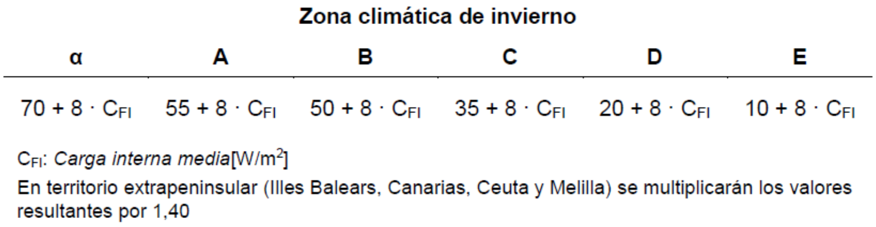
The non-renewable primary energy consumption (Cep,nren) of the spaces contained within the thermal envelope of the building or, where applicable, of the part of the building considered, shall not exceed the limit value (Cep,nren,lim) obtained from Table 16 or Table 17:



	Zona climática de invierno					
	α	A	B	C	D	E
Edificios nuevos y ampliaciones	20	25	28	32	38	43
Cambios de uso a residencial privado y reformas	40	50	55	65	70	80

En territorio extrapeninsular (Illes Balears, Canarias, Ceuta y Melilla) se multiplicarán los valores de la tabla por 1,25

Table 16: Limit value $C_{ep,nren,lim}$ *for private residential use [kWh/m*^{2}*·year] (Documento Básico HE, 2022)*



Zona climática de invierno					
α	A	B	C	D	E
$70 + 8 \cdot C_{FI}$	$55 + 8 \cdot C_{FI}$	$50 + 8 \cdot C_{FI}$	$35 + 8 \cdot C_{FI}$	$20 + 8 \cdot C_{FI}$	$10 + 8 \cdot C_{FI}$

C_{FI}: *Carga interna media*[W/m^2]

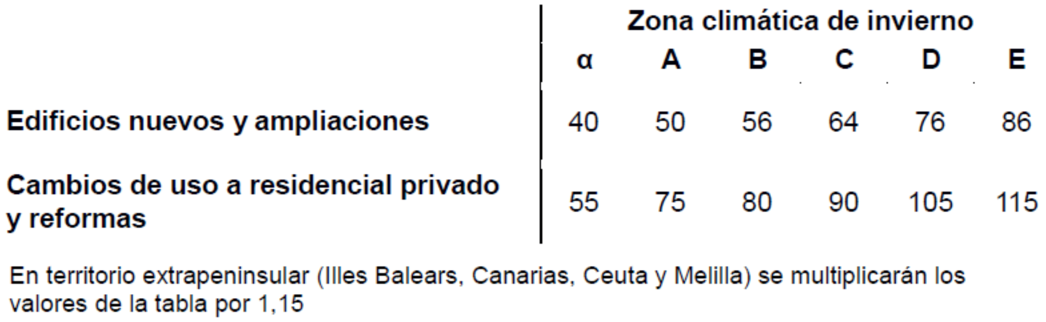
En territorio extrapeninsular (Illes Balears, Canarias, Ceuta y Melilla) se multiplicarán los valores resultantes por 1,40

*Madrid climatic zone corresponds to letter D

Table 17: Limit value $C_{ep,nren,lim}$ *for different use to private residential [kWh/m*^{2}*·year] (Documento Básico HE, 2022)*

Energy Primary Consumption[19]

The primary energy consumption of the spaces contained within the thermal envelope of the building or, where applicable, of the part of the building considered, shall not exceed the limit value (Cep,tot,lim) obtained from Table 18 or Table 19:



	Zona climática de invierno					
	α	A	B	C	D	E
Edificios nuevos y ampliaciones	40	50	56	64	76	86
Cambios de uso a residencial privado y reformas	55	75	80	90	105	115

En territorio extrapeninsular (Illes Balears, Canarias, Ceuta y Melilla) se multiplicarán los valores de la tabla por 1,15

Table 18: Limit value $C_{ep,tot,lim}$ *for private residential use [kWh/m*^{2}*·year] (Documento Básico HE, 2022)*

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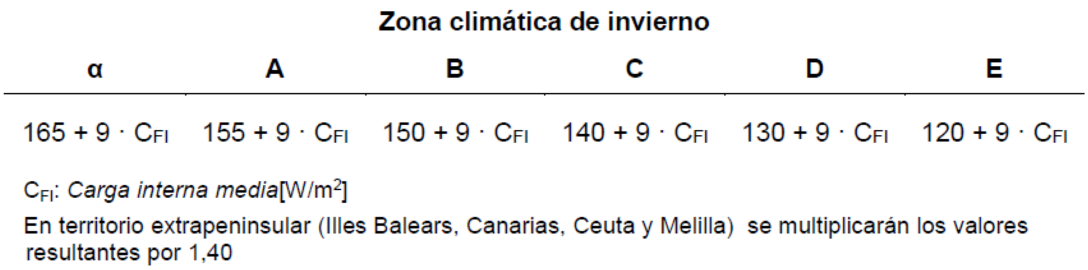
[18] (Documento Básico HE, 2022) – Table 3.1.a – HE0; Table 3.1.b – HE0.

[19] (Documento Básico HE, 2022) – Table 3.2.a –HE0; Table 3.2.b – HE0.



Zona climática de invierno					
α	A	B	C	D	E
165 + 9 · C_{FI}	155 + 9 · C_{FI}	150 + 9 · C_{FI}	140 + 9 · C_{FI}	130 + 9 · C_{FI}	120 + 9 · C_{FI}

C_{FI}: *Carga interna media*[W/m^2]

En territorio extrapeninsular (Illes Balears, Canarias, Ceuta y Melilla) se multiplicarán los valores resultantes por 1,40

*Madrid climatic zone corresponds to letter D

Table 19: Limit value $C_{ep,tot,lim}$ for different use to private residential [kWh/m^2·year] (Documento Básico HE, 2022)

Minimum generation of electricity from renewable sources

The buildings will have electricity generation systems from renewable sources for their own use or supply to the grid.

The minimum power to be installed Pmin will be the smaller of those resulting from these two:

P1 =Fpr;el · S

P2= 0.1 ·(0.5·Sc - Soc)

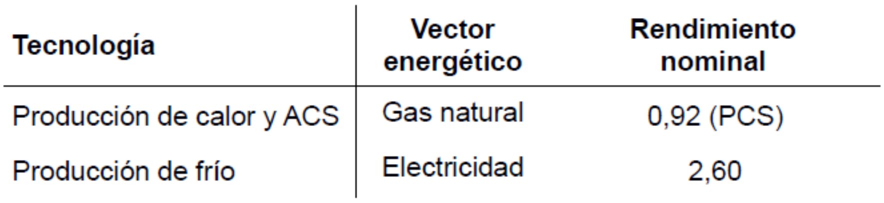
- *Pmin;, Power to install [kW];*
- *Fpr;el: electric production factor, 0.005 for residential use and 0.01 for the rest of uses [kW/m^2];*
- *S: Building constructed surface [m^2]*
- *Sc: Roof Surface not passable [m^2]*
- *Soc: non-passable roof surface or accessible only for conservation occupied by solar thermal collectors [m^2].*

Minimum contribution of renewable energy to cover the demand for domestic hot water

The minimum contribution of energy from renewable sources will cover at least 70% of the annual energy demand for Domestic Hot Water (DHW) and for pool heating obtained from the monthly values, and including thermal losses by distribution, accumulation and recirculation. This minimum contribution may be reduced to 60% when the DHW demand is less than 5,000 l/d. Only the renewable contribution of energy originating in situ or in the vicinity of the building, or from solid biomass, will be considered.

Reference systems in private residential use[20]

In the case of buildings for private residential use, when no systems are defined in the project for the heating, cooling or water heating service, the presence of a system with the characteristics indicated in table 4.5 will be considered for calculation purposes. -HE0:

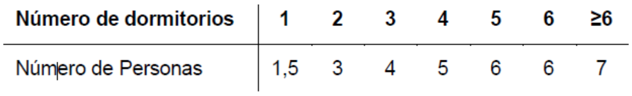


Tecnología	Vector energético	Rendimiento nominal
Producción de calor y ACS	Gas natural	0,92 (PCS)
Producción de frío	Electricidad	2,60

Table 20: Reference systems (Documento Básico HE, 2022)

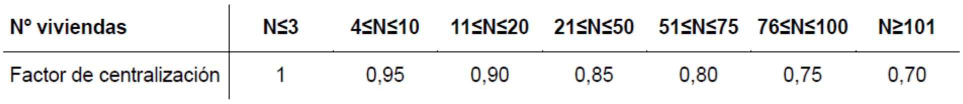
DHW reference demand[21]

The DHW reference demand for buildings for private residential use will be obtained considering a need of 28 litres/person day (at 60ºC), an occupancy at least equal to the minimum established in Table 21 and, in the case of multi-family dwellings, a centralization factor according to Table 22, increased according to the thermal losses by distribution, accumulation and recirculation.



Número de dormitorios	1	2	3	4	5	6	≥6
Número de Personas	1,5	3	4	5	6	6	7

Table 21: Minimum values for occupation in private residential use (source: CTE)



Nº viviendas	N≤3	4≤N≤10	11≤N≤20	21≤N≤50	51≤N≤75	76≤N≤100	N≥101
Factor de centralización	1	0,95	0,90	0,85	0,80	0,75	0,70

Table 22: value of the centralization factor in multifamily dwellings (source: CTE)

For the calculation of the reference demand for DHW for buildings for uses other than private residential, the values of Table 23, which includes indicative values of DHW demand for uses other than private residential, at the temperature of reference of 60ºC, which will be increased according to the thermal losses by distribution, accumulation and recirculation. The DHW reference demand for cases not included in Table 23 will be obtained from DHW needs proven by experience or collected by sources of recognized solvency.

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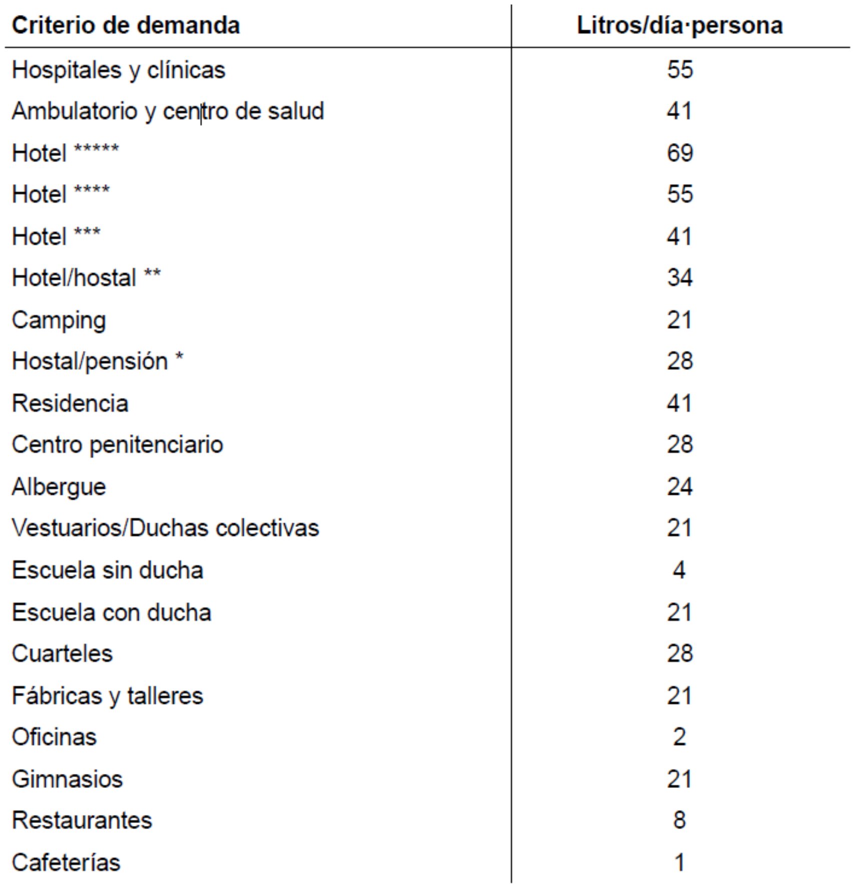
[20] (Documento Básico HE, 2022) – Table 4.5-HE0.

[21] (Documento Básico HE, 2022) – Table a-Appendix F. Table b-Appendix F. Table c-Appendix F.



Criterio de demanda	Litros/día·persona
Hospitales y clínicas	55
Ambulatorio y centro de salud	41
Hotel *****	69
Hotel ****	55
Hotel ***	41
Hotel/hostal **	34
Camping	21
Hostal/pensión *	28
Residencia	41
Centro penitenciario	28
Albergue	24
Vestuarios/Duchas colectivas	21
Escuela sin ducha	4
Escuela con ducha	21
Cuarteles	28
Fábricas y talleres	21
Oficinas	2
Gimnasios	21
Restaurantes	8
Cafeterías	1

Table 23: Indicative demand of DHW for uses different to the private residential (Documento Básico HE, 2022)

The consumption of DHW at a temperature (T), of preparation, distribution or use, other than that of reference (60ºC), can be obtained from the consumption of DHW at the reference temperature using the following expressions:

$$D(T) = \sum_{i=1}^{12} D_i(T)$$

$$D_i(T) = D_i(60^oC) \ \frac{60-T_i}{T-T_i}$$

- D(T): Annual DHW demand at selected T.
- Di(T): Annual DHW demand for the month i at selected T.
- Di(60ºC): Annual DHW demand for the month i at 60ºC.

- T: Temperature of the final storage.
- Ti: Average temperature of the cold water at the month i.

Regulation of thermal installations in buildings "RITE"[22]

In terms of heating systems calculation, a calculation temperature of the interior conditions will be 21 ºC. For cooling systems, the calculation temperature will be 25 ºC (Real Decreto 1027/2007 [RITE]).

Minimum performance required (65%) for solid fuel local heating system.

Boilers that use woody biomass (pellets, chips, firewood...) of up to 500 kW are affected, since the 1st of January of 2020, by EU Regulation 2015/1189, which establishes minimum values for seasonal energy efficiency of 77%. (Boilers from 20 to 500 kW) and 75% (boilers of less than 20 kW).

If olive pits or nut shells are used, the minimum (nominal) performance required will be 80% at full load, except for closed local heating appliances and cookers, which will be 65%.[23]

Monitoring System[24]

The new standard introduces digitization in non-residential buildings with high consumption, with a useful nominal climate control power of more than 290 kW.

Maintenance Energy System[25]

E-Mobility[26]

MOBILITY SYSTEM	Y/N	Location	**Additional info.** Model and Number charging Point, Power (kW)
E-Vehicles for residential building	Y	-	The infrastructure installed will let the future charging point for 100% parking spots
E-Vehicles for office building	Y	-	The infrastructure installed will let the future charging points for 20% parking spots. Additionally, 1 charging point installed per 40 parking spots

Table 24: E-mobility aspects for Madrid LL

3.1.4 Life Cycle Assessment approach

3.1.4.1 Low Carbon Concrete

Within WP3, ACCIONA will develop innovative concrete mixes formulation with reduced CO_2 footprint using recycled aggregates to replace natural aggregates. Alternative supplementary

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[22] Real Decreto 1027/2007 [RITE]

[23] IT 1.2.4.1.2.1 Requisitos mínimos de rendimientos energéticos de los generadores de calor

[24] T 1.2.4.4 Contabilización de consumos.

[25] IT 3.3 Programa de mantenimiento preventivo. «IT 3.4.2 Evaluación periódica del rendimiento de los equipos generadores de frío. «IT 3.4.3 Instalaciones de energía renovable.

[26] Sección HE 6 Dotaciones mínimas para la infraestructura de recarga de vehículos eléctricos (Documento Básico HE, 2022).

cementitious materials (SCMs) like fly ash and slags may be also investigated to partially replace the Portland cement. In addition, CELSA investigates the use of black and white slag generated during steel production as additive to cement, concrete and asphalt production, respectively.

Name of the MATERIAL	Low Carbon Concrete
City	Madrid
Country	Spain
Owner/Partner in charge of the building	ACCIONA R&D
Type of material	Structural concrete
Material main use	Building structural elements in the Geothermal plant and distribution network, part of Madrid LL project in PROBONO.

Table 25: Madrid LL Low Carbon Concrete general info

Life Cycle Assessment

Object of Assessment	Low Carbon Concrete
Goal Definition	Perform a LCA of the Low Carbon Concrete, developed by ACCIONA and CELSA in WP3, to assess its reduced CO_2 footprint in comparison to an existing and standard market product. Furthermore, the objective is to develop an Energy Product Declaration (EPD) of this material, following the existing Product Category Rules for concrete.
Who is the target audience?	PROBONO partners.
Scope of Assessment / System Boundary	A1-A3 (product stage) - cradle to gate processes for the materials and services used in the construction, including raw material extraction, transportation, production, and acquisition. The LCA of the cradle to gate processes will be performed according to: ESC16/12 - Product Category Rules & Environmental Product Declarations (EPDs) for Concrete. EN 16757 – Sustainability of Construction Works - Environmental Product Declarations – Product Category Rules for Concrete and Concrete Elements.
Impact Categories to be analysed	Minimum: Global Warming Potential. Other impact categories to be defined.
Functional Unit	Depending on the type of concrete element, the functional unit is defined in relation to the application of the product in the construction work.

	The object of study is the Low Carbon Concrete that will be used for structural elements in the Geothermal Plant of the Madrid LL, including foundations, columns, beams, slabs and walls. Thus, the declared unit for this study is the mass of the material, expressed in tonnes (1,000 kg).
Normative /Standards	EN 15804:2012+A1:2013, Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products. EN 15978, Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method. EN 16757 – Sustainability of Construction Works - Environmental Product Declarations - Product Category Rules for Concrete and Concrete Elements. ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework.
Software and database	LCA software SimaPRO or Sphera (GaBi)
SOTA / papers	Scientific paper used to estimate the energy demand to produce 1 m^3 of Low Carbon Concrete for PROBONO. Mel, J., del Caño, A., & de la Cruz, M. P. (2014, July). Sustainability in the Preparation, Transport and Casting of Concrete in Spain: Analysis of Energy Consumption and CO2 Emissions. In *Proceedings of the AEIPRO-IPMA 18th International Congress on Project Management and Engineering* (pp. 02-004).
Timespan / Reference Service Life (RSL)	According to the concrete PCR, when the use of the concrete or concrete element in the building or civil engineering work is known, the RSL of the product shall be consistent with its Estimated Service Life (at least equal to). In this case, since the concrete elements will be used for the Geothermal plant, the timespan of the RSL will be considered as 50 years for the LCA.

Table 26: Madrid LL Low Carbon Concrete Life Cycle Assessment

Inventory List

The definite inventory list is yet to be specified, and it will follow the recommended data which meet EPD objectives, at the appropriate level (e.g. national, European level) especially for the following:

— cement;

— additions;

— transport;

— energy use;

— water use.

The GOAL and SCOPE of the assessment will follow the Product Category Rules of Concrete materials in construction and will be limited to a cradle to gate approach, which means only phases A1-A3 (Production Stage) will be analysed.

- **The cradle-to-gate (A1-A3)** - includes the initial phases of a product, known as the construction product manufacturing. It assesses a partial product life cycle from resource extraction to the factory gate (i.e., before it is transported to the consumer), and they are often used as the basis for environmental product declarations (EPD).

A - Before the use stage (modules A0 – A5)	
A1-3 – Production Stage *The boundary for modules A1 to A3 covers the 'cradle to gate' processes for the materials and services used in the construction; the rules for determining their impacts and aspects are defined in EN 15804.*	
A1 – Raw Material Supply	Production of raw materials or constituent products for ready-mixed and site-mixed concrete, materials to be considered are the constituents of concrete: - Recycled material from the demolition of DCN existing buildings and infrastructure - Aggregates - Cement - Water - Admixtures - Additions - Fibres
A2 – Transport Transport of raw material to the mixing or precast plant:	Transportation information from demolition waste treatment plant located in Distrito Castellana Norte (DCN) to production facility (to be defined).
A3 – Manufacturing	Manufacturing of ready-mixed or site-mixed concrete may include the following: - Transportation activities on the production site. - Land filling, disposal and processing (up to the end-of-waste stage) of any output from this stage of the product system at this unit process (A3) which reaches the end-of-waste state. - Use of materials and equipment for wastewater treatment. - Energy used during manufacture.

Table 27: Madrid LL Low Carbon Concrete LCA scope

3.1.4.2 Sustainable Road Pavement

Road construction and pavements is a sector where measures need to be taken to reduce the energy demand, environmental impact, and the use of raw materials cost-effectively. To that end, ACCIONA aims to provide technologies that facilitate asphalt recycling and the use of recycled concrete aggregates. These will be integrated appropriately into an optimal design of asphalt pavements and thereby increase their commercial viability.

Thus, medium and high rates of reclaimed asphalt (RA) will be incorporated for the preparation of new asphalt mixtures in the structural layers (surface, binder and base). Also, recycled aggregates from concrete waste will be used as secondary aggregates to replace natural graded aggregates for the subbase.

Such solution improves both sustainability and cost-efficiency of the asphalt pavement industry reducing the CO_2 footprint of pavements, the environmental impact and associated costs related to the waste generation and disposal.

Name of the MATERIAL	Sustainable Pavement
City	Madrid
Country	Spain
Owner/Partner in charge of the building	ACCIONA R&D
Type of material	Asphalt mixes
Material main use	Asphalt mixes with recycled aggregates to integrate the structural layers of the asphalt pavement.

Table 28: Madrid LL Sustainable road pavement general info

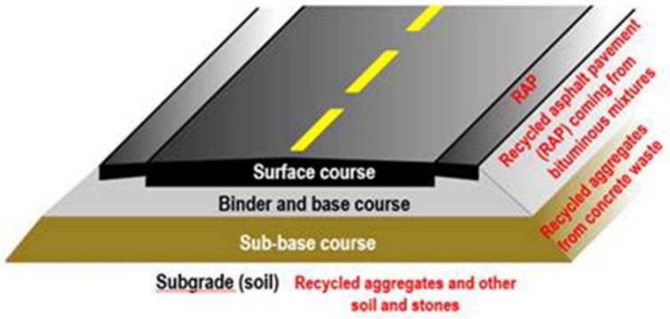


Figure 5: Madrid LL Sustainable road pavement representative picture

Life Cycle Assessment

Object of Assessment	Asphalt mixes with recycled aggregates - Sustainable Road Pavement
Goal Definition	Perform a LCA of the Asphalt mixes with recycled aggregates, developed by ACCIONA and CELSA in WP3, to assess its reduced CO_2 footprint in comparison to an existing and standard market product.
Who is the target audience?	PROBONO partners
Scope of Assessment / System Boundary	According to the Material PCR: Asphalt Mixtures. Product Category Classification: UN CPC 1533 & 3794, the minimum scope of the LCA shall be "cradle to gate", which will also be referred to in this study as Upstream Processes, or A1-A3: - Producing input to the core processes (i.e. raw material acquisition and refinement, and production of intermediate components).
Impact Categories to be analysed	Minimum: Global Warming Potential.

	Other impact categories to be defined.
Functional Unit	The specific use of the asphalt mixture is still unknown; therefore, the declared unit is **1 metric tonne of manufactured asphalt mixture**.
Normative/Standards	Material PCR: Asphalt Mixtures. Product Category Classification: UN CPC 1533 & 3794. ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework EN 15978, Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.
Software and database	LCA software SimaPRO or Sphera (GaBi)
SOTA / papers	No bibliographic references used yet (to be declared if applicable in the next steps of the LCA processes).
Reference Service Life (RSL)	RSL is dependent on the properties of the product and reference in use conditions. The “service life” of an asphalt mixture after the first installation, is the expected lifetime until it no longer fits its purpose. The asphalt producers can define this themselves, but the claim must be documented.

Table 29: Madrid LL Sustainable road pavement Life Cycle Assessment

Inventory List

The definite inventory list is yet to be specified, and it will follow the recommended data in the Product Category Rules for Asphalt Mixtures, limited to the minimum mandatory approach of cradle to gate processes, which means only phases A1-A3 (Production Stage) will be analysed.

- **The cradle-to-gate (A1-A3)** - includes the initial phases of a product, known as the construction product manufacturing. It assesses a partial product life cycle from resource extraction to the factory gate (i.e., before it is transported to the consumer), and they are often used as the basis for environmental product declarations (EPD).

Other LCA phases are considered optional, and might be added to the study if considered relevant.

A - Before the use stage (modules A0 – A5)
A1-3 – Production Stage *The boundary for modules A1 to A3 covers the 'cradle to gate' processes for the materials and services used in the construction; the rules for determining their impacts and aspects are defined in EN 15804.*

A1 – Raw Material Supply	- Extraction and processing of raw materials (e.g., mining processes of aggregates) and recycling processes of secondary materials from a previous product system (e.g. reclaimed asphalt pavement RAP, out of use tyres, recycled asphalt shingles RAS), but not including those processes that are part of the waste processing in the previous product system, referring to the polluter pays principle. - Impacts of all co-products of crude oil refining including extraction, transport, refining, and storage. The co-products of interest to this PCR guidance include gasoline, diesel, bituminous binder, bitumen additives and polymers. - Generation of electricity, steam and heat from primary energy resources, also including their extraction, refining and transport. This also includes energy needed for raw material supply and energy for manufacturing in core process. - Energy recovery and other recovery processes from secondary fuels, but not including those processes that are part of waste processing in the previous product system. - Extraction of raw material and processing of asphalt additives. - Processing up to the end-of-waste state or disposal of final residues including any packaging not leaving the factory gate with the product.
A2 – Transport	- External transportation (e.g., bituminous binders, aggregates, fuels, additives) to the asphalt production plant.
A3 – Manufacturing	- Manufacturing of the asphalt mixture and co-products (e.g., heating, mixing) - Water use - Emissions of the plant (e.g., fuel burning, stack) - Packing materials used (if relevant). - Material used for maintenance (e.g., lubricants, filters) - Treatment of waste generated from the manufacturing processes. Processing up to the end-of-waste state or disposal of final residues including any packaging not leaving the factory gate with the product.

Table 30: Madrid LL Sustainable road pavement LCA scope

3.1.4.3 Geothermal Plant and Distribution Network

Within PROBONO, the Madrid Living Lab proposes the construction of the geothermal plant for District Heating and Cooling located in Las Tablas. The design process shall maximise the use of existing materials from the buildings and infrastructure to be deconstructed.

As a base, the design team shall use a tool already developed for Madrid Nuevo Norte (MNN) that classifies existing materials and provides a guide for deconstruction, treatment, and reuse whenever possible. Moreover, the project must consider the use of Level(S) and DGNB as part of the certification/standardization analysis and benchmarking, focusing on resource-efficiency with the whole life cycle of the building.

MNN is already registered to achieve LEED Cities and Communities and BREEAM ES sustainable certifications aiming the highest qualification in both rating systems.

Name of the Building	Geothermal Plant and Distribution Network

Address	Madrid LL
City	Madrid
Country	Spain
Owner/Partner in charge of the building	DCN
Year of construction	According to the current timelines, the construction of Las Tablas urbanization shall be done between 2023 and 2025, including the energy grid and the district heating and cooling system.
Year of renovation (if any)	n/a
Brief description of the renovation (if any)	n/a
Type of building	Energy production and distribution

Table 31: Madrid LL Geothermal plant and distribution network general info

Life Cycle Assessment

Object of Assessment	Geothermal plant and distribution network. The objective of study is limited to the building itself and the distribution network system – without considering the energy production of the geothermal plant.
Goal Definition	Perform a complete LCA of the Geothermal plant and distribution network to comply with the rigorous sustainability goals defined by DCN, which exceeds the minimum requirements of the local normative. Two scenarios will be analysed and compared: the construction of the geothermal plant and distribution network using standard concrete, and a second one with an alternative low carbon concrete (result from WP3, developed by ACCIONA and CELSA). Sustainability goals are based on the indicators of Level(S) framework and existing certification schemes, such as DGNB, BREEAM ES and LEED.
Who is the target audience?	PROBONO partners (especially DCN).
Scope of Assessment / System Boundary	Cradle to grave approach - A1-A3, A4-A5, B1-B7, C1-C4 The scope of the analysis is all elements that represent more than 1% of the weight of the development project.
Impact Categories to be analysed	Embodied Carbon Global Warming Potential Acidification potential Eutrophication potential Ozone depletion potential Photochemical ozone formation Abiotic Depletion Potential – Elements Abiotic Depletion Potential - fossil fuels
Functional Unit	A non-residential building with a lifespan of 50 years from design to demolition.

Normative /Standards	Product Category Rules (PCR) – UN CPC 531 - Buildings EN 15978, Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method. ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework Level(s) – Indicator 1.2 – Global Warming Potential LCA related indicators from certification schemes DGNB, BREEAM ES and LEED
Software and database	LCA software SimaPRO or Sphera (GaBi)
SOTA / papers	No bibliographic references used yet (to be declared if applicable in the next steps of the LCA processes).
Timespan	50 years, according to average timespan considered for building LCA studies.

Table 32: Madrid LL Geothermal plant and distribution network Life Cycle Assessment

Inventory List

Inventory list to be retrieved from executive project provided by DCN and IDOM. For identifying the included and excluded items, the Building PCR will be used as reference.

Cradle-to-grave (A1-A3, A4-A5, B1-B7, C1-C4) - is the full life cycle assessment from resource extraction to the use phase and disposal phase, involving all phases in a linear approach from start to end.

A - Before the use stage (modules A0 – A5)	
A1-3 – Production Stage *The boundary for modules A1 to A3 covers the 'cradle to gate' processes for the materials and services used in the construction; the rules for determining their impacts and aspects are defined in EN 15804.*	
A1 – Raw Material Supply	- Extraction and processing of raw materials/e.g. mining processes) and biomass production and processing (e.g. agricultural or forestry operations); - Reuse of products or materials from a previous product system; - Processing of secondary materials used as input for manufacturing the product, but not including those processes that are part of the waste processing in the previous product system; - Generation of electricity, steam and heat from primary energy resources, also including their extraction, refining and transport; - Energy recovery and other recovery processes from secondary fuels, but not including those processes that are part of waste processing in the previous product systems.
A2 – Transport	- Transportation up to the factory gate and internal transports.
A3 – Manufacturing	- Production of ancillary materials or pre-products; - Manufacturing of products and co-products; - Manufacturing of packaging; The technical system shall not include:

	- Manufacturing of production equipment, buildings and other capital goods. - Upstream processes not listed may also be included. All elementary flows at resource extraction shall be included, except for the flows that fall under the general 1 % cut-off rule.
A4-5 – Construction Stage	
A4 – Transport	- Transport of materials and products from the factory gate to the building site, including any transport, intermediate storage and distribution; - Transport of construction equipment (cranes, scaffolding, etc.) to and from the site; - All impacts and aspects related to losses due to the transportation (i.e. production, transport and waste management of the products and materials that are damaged or otherwise lost during transportation). Transport of persons to and from the site shall not be included.
A5 - Construction – Installation process	- Ground works and landscaping; - Storage of products, including the provision of heating, cooling, humidity, etc.; - Transport of materials, products, waste and equipment within the site; - Temporary works, including temporary works located off-site as necessary for the construction installation process; - On-site production and transformation of a product; - Provision of heating, cooling, ventilation, humidity control etc. during the construction process; - Installation of the products into the building including ancillary materials not counted in the EPD of the products e.g. releasing agents in formworks for concrete, formworks discarded at the end of the project; - Water use for cooling of the construction machinery or on-site cleaning; - Waste management processes of other wastes generated on the construction site. This includes all processes (including transportation from the building site) until final disposal or until end of waste state is reached; - Production, transportation and waste management of products and materials lost during the construction and installation process

Table 33: Madrid LL Geothermal plant and distribution network LCA stage A

B – USE STAGE	
B1 – Use, installed products	Module B1 reports of activities, materials and emissions related to the building's normal uses that are not covered by the Modules B2-B7. Continuous emissions from materials in the house are included, for example, substances from the facade, roof, floor covering, and other surfaces (interior or exterior) emitted to air, soil or water.

B2 – Maintenance	Module B2 includes scheduled maintenance that is required in the daily work of building operations, including on-going maintenance of the property, preventive and regular maintenance such as cleaning or replacement/maintenance of worn parts. Water and energy required for cleaning shall be included in this module (not in Module B6-B7). In addition, this module includes: - The production and transportation of the components and ancillary products used for maintenance; - All cleaning processes of the interior and exterior of the building; - All processes for maintaining the functional and technical performance of the building fabric and building integrated technical systems, as well as aesthetic qualities of the building's interior and exterior components, including water and energy use - Transportation of any waste from maintenance processes or from maintenance related transportation - The end-of-life processes of any waste from transportation and the maintenance process, including any part of the component and ancillary materials removed
B3 – Repair	Module B3 refers to measures that are not typically scheduled during the lifetime of the building. This includes corrective and preventive handling of a product or installation when it is broken or out of order, so that the required function and performance is achieved. Replacement of a faulty component or part due to injury should be reported in this module, while the replacement of an entire product design or significant part of the building to be reported in replacement (Module B4). This shall be included for existing buildings where the repair history is available. If no data is available for new buildings, module B3 may be omitted. This omission must be thoroughly explained and justified. Module B3 includes: - The production of the repaired part of a component and of ancillary products used for repair; - The transportation of the repaired part of component and of ancillary products, including production impacts and aspects of any losses of material during transportation; - The repair process of the repaired part of component and ancillary products including related water and energy use; - Transportation of any waste from repair processes or from repair related transportation; - The end-of-life processes of any waste from transportation and the repair process, including any part of the component and ancillary materials removed.
B4 – Replacement	Module B4 refers to when a material, part of the building or installation is exchanged for a new product. This may be e.g. replacement of windows, facade replacement or replacement of heat exchangers. If a building component is changed as part of a refurbishment program, this shall be reported during the refurbishment module (Module B5), otherwise it shall be reported in this module. If a building is changed because it has been destroyed, it should be reported in the repair module (Module B3). Module B4 includes:

	- The production of the replaced component and of ancillary products used for replacement; - The transportation of the replaced component and ancillary products, including production impacts and aspects of any losses of materials during transportation; - The replacement process of the replaced components and ancillary products including related water and energy use; - Transportation of any waste from replacement processes or from replacement related transportation; - The end-of-life processes of any waste from transportation and the replacement process, including any part of the component and ancillary materials removed.
B5 – Refurbishment	Module B5 data typically originates from a coordinated and planned maintenance program for refurbishment. The refurbishment of a building includes a significant part or whole section of the building. Module B5 includes: - Production of the new building components and of ancillary materials used for refurbishment; - Transportation of the new building components including production of any materials lost during transportation; - Construction as a part of the refurbishment process including production of any material lost during refurbishment and related water and energy use; - Transportation of any waste from refurbishment processes or from refurbishment related transportation; - The end-of-life processes of any waste from transportation and the refurbishment process, including any part of the component and ancillary materials removed.
B6 – Operational Energy Use	The system boundaries for Module B6 shall include the energy used in the operating phase of the technical systems that are integrated into the building. The integrated building technical systems are installed technical equipment supporting operation of a building including: - Heating, cooling, humidification/de-humidification, ventilation; - Lighting; - Domestic hot water for sanitation and other systems for sanitation; - Auxiliary energy used for pumps, lifts, escalators, control and automation; - Safety and security installation and communication systems. If the energy use of appliances that are not building-related (plug in appliances, e.g. computers, washing machines, refrigerators, audio, TV and production or process-related energy in the use of the building) is included within the energy calculation, then this shall be documented and reported separately, including the environmental information associated with such energy consumption. The energy use in the building refers to the activity and processes as presented in EN 15603. The calculation method used for heating and cooling energy shall however be specified. Moreover, if semi-steady methods have been used, supplementary information on energy needs calculated by dynamic method should be reported.

	Energy aspects related to the production, transportation and installation of equipment required to supply energy to the building shall be assigned to modules A1-A5. Energy use during maintenance, repair, replacement or refurbishment activities for the equipment shall be assigned to modules B2-B5. Aspects related to the waste processing and final disposal of equipment shall be assigned to modules C1-C4.
B7 – Operational Water Use	The module covers the period from the handover of the building to when the building is deconstructed or demolished. The boundary of this module shall include the consumption of net fresh water (potable water) during the operation of the integrated building technical systems, together with its associated environmental aspects and impacts considering the life cycle of water including production, transportation and wastewater treatment. Examples of integrated building technical systems included in this module are systems for: - Heating, cooling, ventilation and humidification; - Domestic hot water for sanitation and other systems for sanitation; - Security, fire safety and internal transport; - Irrigation of associated landscape areas, green roofs, green walls; - Other specific water use of building-integrated systems e.g. fountains, swimming pools, saunas. If water use of appliances that are not building-related (e.g. dishwashers, washing machines) is included within the assessment, this shall be reported and communicated separately. Water consumed by users of the building shall not be included, e.g. drinking water etc.
B8 – User's Activities	Does not apply.

Table 34: Madrid LL Geothermal plant and distribution network LCA stage B

C – END OF LIFE STAGE	
A0 – Pre-Construction Stage	
C1 – Deconstruction	Deconstruction, dismantling and/or demolition of the building, including initial on-site sorting of the materials
C2 – Transport	Transports for disposal of the discarded materials and products, i.e. to final disposal and/or all transports until the end-of-waste stage is reached.
C3 – Waste processing for reuse, recycling, and energy recovery	Collection of waste fraction from the deconstruction site and waste processing of the materials intended for reuse, recycling and energy recovery, i.e., waste processing until the end-of-waste stage is reached. Materials from which energy is recovered are considered materials for energy recovery if the efficiency rate of the energy recovery process is 60 % or higher, without prejudice to existing legislation. Materials from which energy is recovered with an efficiency rate below 60 % are considered materials for incineration (from which the environmental loads are declared in module C4). *NOTE 1. Processing after the end-of-waste stage is reached, in order to replace primary materials or fuels (as secondary materials or fuels) in*

	another product system, are considered beyond the building's system boundaries and are assigned to module D. *NOTE 2. Materials can only be considered as materials for energy recovery if they have reached the end-of-waste state.*
C4 – Disposal	Physical pre-treatment of waste for final disposal and management of the disposal site. Module C4 quantifies all environmental loads resulting from final disposal of materials, e.g. neutralisation, incineration (with or without utilization of energy) and landfilling (with or without utilization of landfill gases). Environmental loads from waste disposal are considered part of the building's product system, according to the "polluter pays principle". If the waste disposal process generates energy such as heat and power, the potential benefits from utilization of such energy in the next product system are assigned to Module D.

Table 35: Madrid LL Geothermal plant and distribution network LCA stage C

3.2 Dublin LL baseline data collection

The case of Dublin LL, is an existing constructed area composed by several buildings (Country Hall, Ferry Terminal, Lexicon Library, Harbour Building, and Social housing). For the specific activities related with baseline data collection only those buildings applying some PROBONO innovations will be considered and these are the County Hall (Flagship building) and Harbour Lodge.

The other buildings in the LL play different roles and they are not addressing any change as part of PROBONO project, and therefore they are out of the baseline process.

As they are real existing buildings, all the data collected in the next sub-sections is based on the real data from the current status of the building, before the implementation of the innovations.

3.2.1 Country Hall Baseline data collection

3.2.1.1 Country Hall building info

Name of the Building	County Hall
Address	2 Marine Rd, Dún Laoghaire, Dublin, A96 K6C9
City	Dún Laoghaire
Country	Ireland
Owner/Partner in charge of the building	Dún Laoghaire-Rathdown County Council
Year of construction	1879
Year of renovation (if any)	1999
Brief description of the renovation (if any)	Modern extension attached to old building
Type of building	Administrative
Building main use	Office and Council Chamber

Number of floors above the ground (including ground floor)	4
Number of floors below the ground	1
Number of dwellings/rooms in total	144
Number of dwellings/rooms per floor	Floor 1 – 23 Floor 2 – 37 Floor 3 – 46 Floor 4 - 38
Other services within the building (if any)	Civic Hub
Number of people in the building (average)	600
Total building surface [m²] Groos area	16,100m²
Please indicate surface Gross area definition (it can vary depending on the country, local regulations, etc.)	15,000m²
Weather conditions (Köppen climate classification)	Cwa
Altitude [m]	4m
Location [coordinates]	53.2948395361778, -6.134237769311834 Link

Table 36: Dublin LL Country hall general info

Dwellers/Occupancy profile	
Average age - Select from 0 (Young people) to 10 (Old people)	7
Average educational level - Select from 0 (Low educational level) to 10 (High educational level)	9
Workers/Unemployment - Select from 0 (100% Unemployed people) to 10 (100% Employed people)	9
Tenants/Owners - Select from 0 (100% Tenants) to 10 (100% Owners)	10

Table 37: Dublin LL Country hall Occupancy social info

Indoor Environmental Quality (IEQ) perception (Select from 1 (Low quality) to 5 (High quality))					
	USER 1	**USER 2**	**USER 3**	**USER 4**	**USER 5**
Thermal environment quality perception					
Temperature	4	4	2	3	4
Humidity	4	5	4	5	4
Air Speed	5	4	2	2	3
Lighting environment quality perception					
Luminosity level	3	5	4	4	3
Natural lighting availability	3	5	5	5	1
Indoor air quality perception					
Ventilation rates	4	4	4	4	4
Odour	4	5	5	5	5

Acoustic environment quality perception					
Indoor noises	2	5	4	4	3
Outdoor noises	5	5	4	5	5

Table 38: Dublin LL Country hall IEQ perception by end-users

Occupancy												
Indicate the typical % of monthly building occupation (being 0% not occupied; 50% partially occupied; 100% fully occupied)												
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Week days	100	100	100	100	100	100	100	100	100	100	100	100
Weekends	10	10	10	10	10	10	10	10	10	10	10	10

Indicate the typical % of daily occupation for the building (being 0% not occupied; 50% partially occupied; 100% fully occupied)		
Hourly	**Week day**	**Weekends/Holidays**
0 - 6	0	0
6 - 7	5	0
7 - 8	10	0
8 - 9	50	0
9 - 10	80	5
10 - 11	100	5
11 - 12	100	10
12 - 13	100	10
13 - 14	100	10
14 - 15	100	10
15 - 16	100	5
16 - 17	70	0
17 - 18	30	0
18 - 19	10	0
19 - 20	5	0
20 - 21	0	0
21 - 22	0	0
22 - 23	0	0
23 - 24	0	0

Table 39: Dublin LL Country hall occupancy profile

Figure 6: Dublin LL Country hall representative picture

Figure 7 Dublin LL Country hall surroundings areas

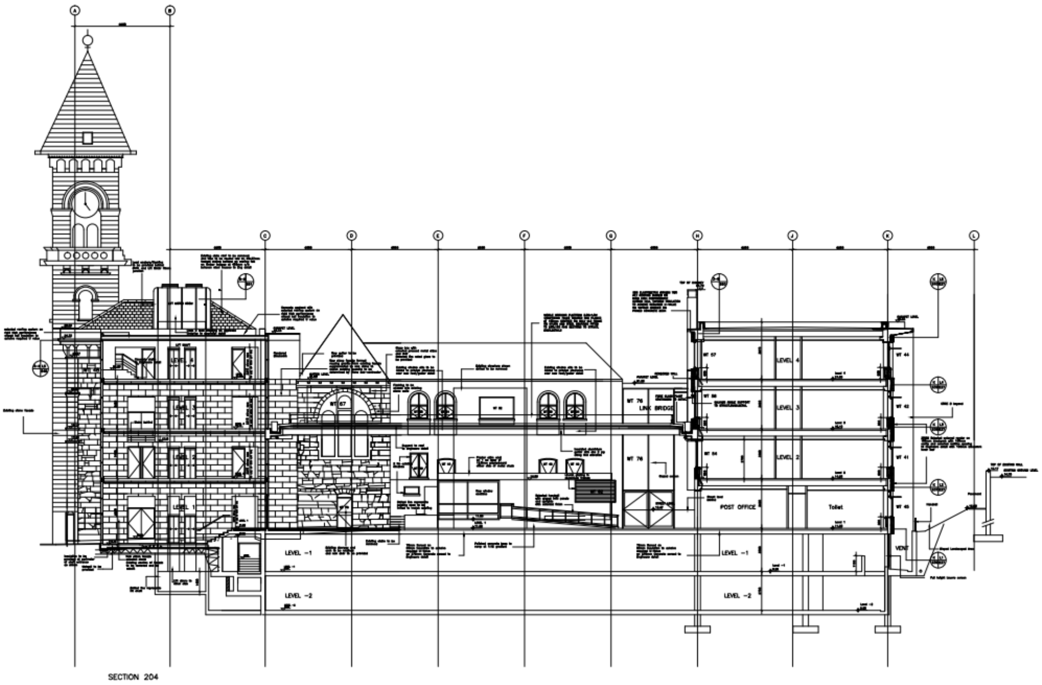
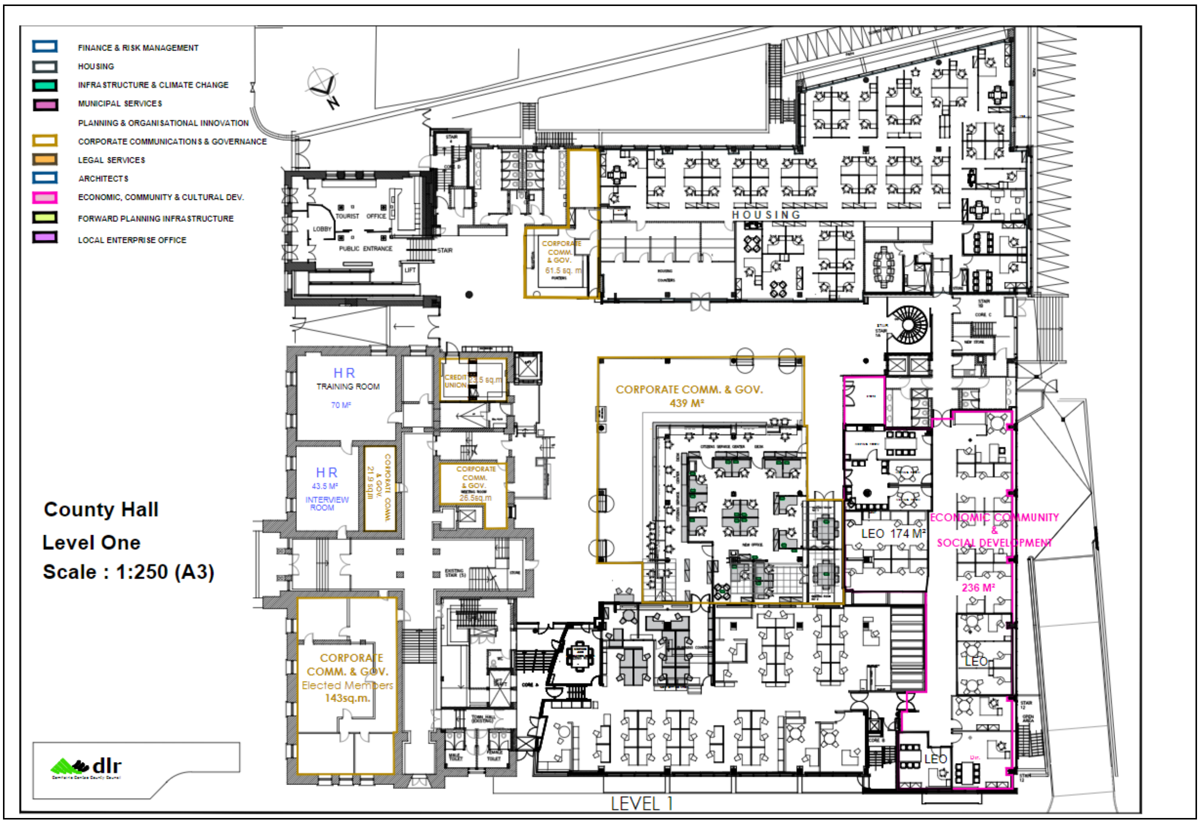
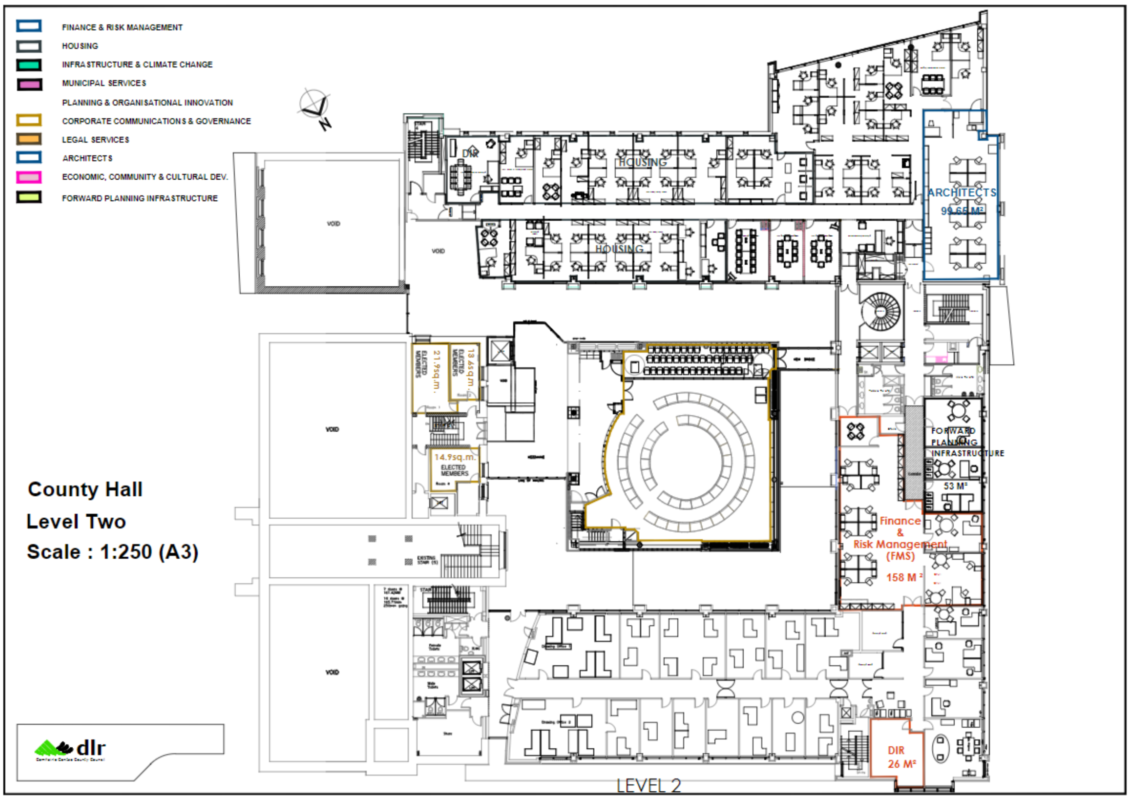
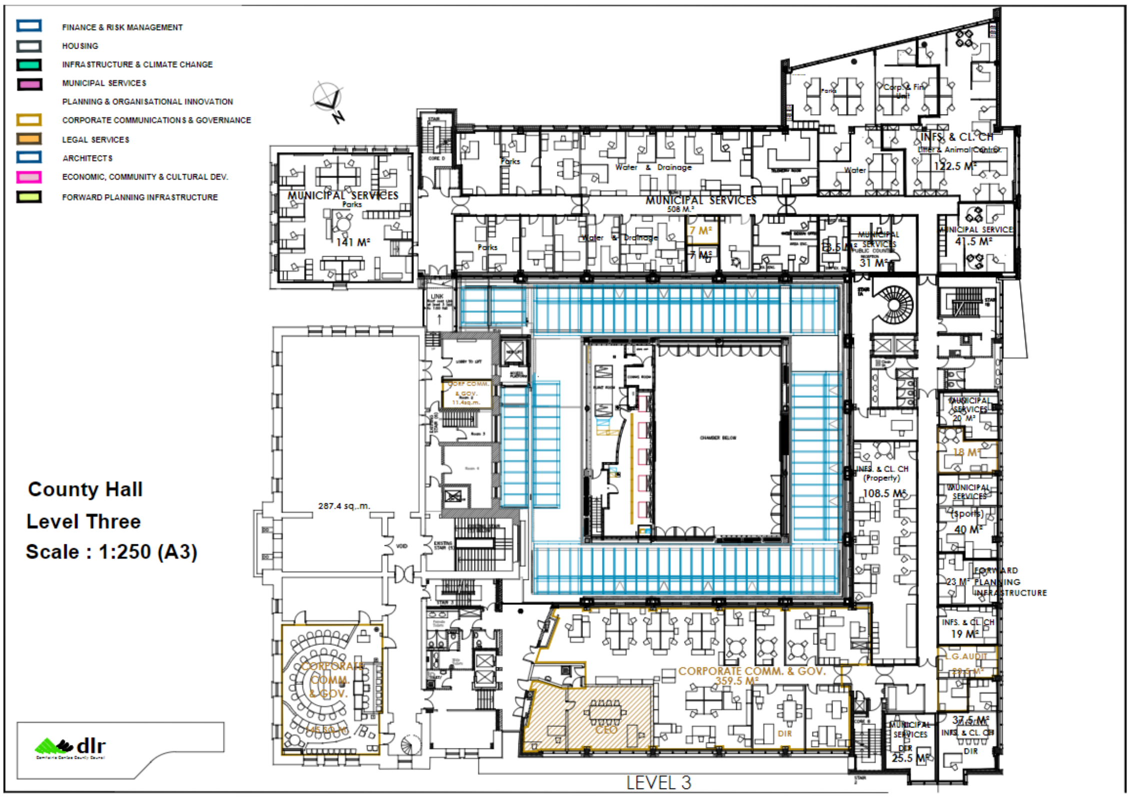


Figure 8: Dublin LL Country hall cross section




FINANCE & RISK MANAGEMENT
HOUSING
INFRASTRUCTURE & CLIMATE CHANGE
MUNICIPAL SERVICES
PLANNING & ORGANISATIONAL INNOVATION
CORPORATE COMMUNICATIONS & GOVERNANCE
LEGAL SERVICES
ARCHITECTS
ECONOMIC, COMMUNITY & CULTURAL DEV.
FORWARD PLANNING INFRASTRUCTURE
N
County Hall
Level Two
Scale : 1:250 (A3)
dlr
HOUSING
HOUSING
ARCHITECTS
99.65 M²
VOID
VOID
VOID
VOID
18.6sq.m.
21.9sq.m.
ELECTED MEMBERS
14.9sq.m.
ELECTED MEMBERS
FORWARD PLANNING INFRASTRUCTURE
53 M²
Finance & Risk Management (FMS)
158 M²
DIR
26 M²
LEVEL 2


FINANCE & RISK MANAGEMENT
HOUSING
INFRASTRUCTURE & CLIMATE CHANGE
MUNICIPAL SERVICES
PLANNING & ORGANISATIONAL INNOVATION
CORPORATE COMMUNICATIONS & GOVERNANCE
LEGAL SERVICES
ARCHITECTS
ECONOMIC, COMMUNITY & CULTURAL DEV.
FORWARD PLANNING INFRASTRUCTURE
N
County Hall
Level Three
Scale : 1:250 (A3)
dlr
MUNICIPAL SERVICES
Parks
141 M²
Parks
Water & Drainage
MUNICIPAL SERVICES
508 M²
Water
INFS. & CL.CH
122.5 M²
Parks
Water
Drainage
7 M²
7 M²
MUNICIPAL SERVICES
31 M²
MUNICIPAL SERVICE
41.5 M²
CORP COMM. & GOV.
CHAMBER BELOW
287.4 sq..m.
MUNICIPAL SERVICES
20 M²
18 M²
INFS & CL CH (Property)
108.5 M²
MUNICIPAL SERVICES (sports)
40 M²
23 M²
FORWARD PLANNING INFRASTRUCTURE
INFS. & CL CH
19 M²
I.G.AUDIT
CORPORATE COMM. & GOV.
CORPORATE COMM. & GOV.
359.5 M²
CEO
DIR
MUNICIPAL SERVICES
DIR
25.5 M²
37.5 M²
INFS & CL CH
DIR
LEVEL 3

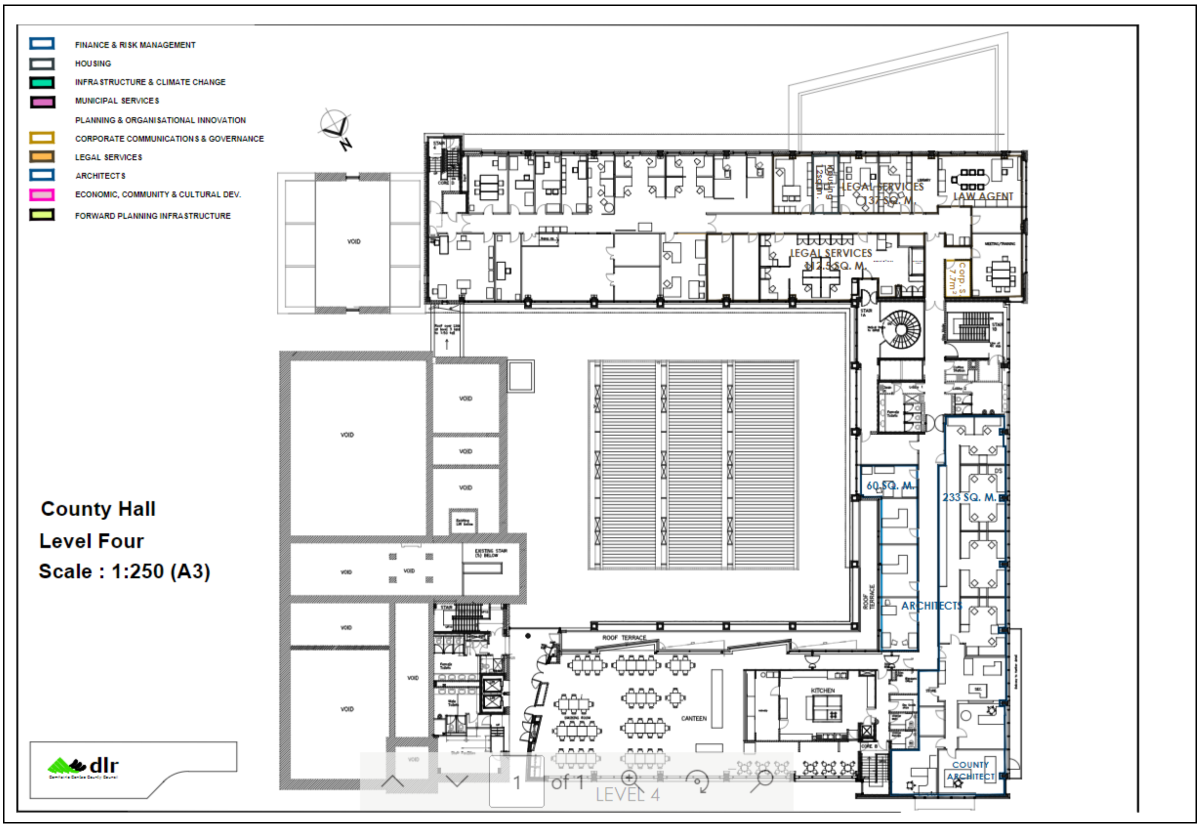


Figure 9: Dublin LL Country hall floors plans

3.2.1.2 Envelope passive elements

External Wall (A)				
Layers from inside to outside	**Thickness [m]**	**Conductivity [W/m·K]**	**Density [kg/m^3]**	**Specific heat [J/kg·K]**
Render	0.02	0.57	1,830	950
Granite block	0.8	3.2	2,750	790
U-value [W/m^2·K]	2.208			
Description (in which wall apply, e.g. north, south, east, west)				
Historic County Hall walls. Granite construction.				
Representative picture				

Table 40: Dublin LL Country hall External Wall A

External Wall (B)				
Layers from inside to outside	**Thickness [m]**	**Conductivity [W/m·K]**	**Density [kg/m^3]**	**Specific heat [J/kg·K]**
Render	0.02	0.57	1,830	950
Block (dense)	0.1	0.96	1,700	800
Insulation	0.05	0.035	25	1,400
Cavity	0.05	0.18	1.2	1
Block (dense)	0.1	0.96	1,700	800
U-value [W/m2·K]	0.505			
Description (in which wall apply, e.g. north, south, east, west)				
Block walls of 1994 extension.				
Representative picture				

Table 41: Dublin LL Country hall External Wall B

External Wall (C)				
Layers from inside to outside	**Thickness [m]**	**Conductivity [W/m·K]**	**Density [kg/m^3]**	**Specific heat [J/kg·K]**
Render	0.02	0.57	1,830	950
Reinforced concrete	0.1	0.96	1,700	800
Insulation	0.05	0.035	25	1,400
Cavity	0.05	0.18	1.2	1
Block (dense)	0.1	0.96	1,700	800
U-value [W/m2·K]	0.505			
Description (in which wall apply, e.g. north, south, east, west)				
Reinforced concrete walls with block in extension.				
Representative picture				

Table 42: Dublin LL Country hall External Wall C

<table>
<tr><th colspan="5">External Wall (D)</th></tr>
<tr><th>Layers from inside to outside</th><th>Thickness [m]</th><th>Conductivity [W/m·K]</th><th>Density [kg/m³]</th><th>Specific heat [J/kg·K]</th></tr>
<tr><td>Render</td><td>0.02</td><td>0.57</td><td>1,830</td><td>950</td></tr>
<tr><td>Reinforced concrete</td><td>0.3</td><td>1.9</td><td>2,300</td><td>840</td></tr>
<tr><td>Insulation</td><td>0.05</td><td>0.035</td><td>25</td><td>1,400</td></tr>
<tr><td>Cavity</td><td>0.05</td><td>0.18</td><td></td><td></td></tr>
<tr><td>Granite</td><td>0.02</td><td>3.2</td><td>2,750</td><td>790</td></tr>
<tr><td>U-value [W/m²·K]</td><td colspan="4">0.525</td></tr>
<tr><td colspan="5">Description (in which wall apply, e.g. north, south, east, west)</td></tr>
<tr><td colspan="5">Reinforced concrete walls with block in extension.</td></tr>
<tr><td colspan="5">Representative picture</td></tr>
<tr><td colspan="5"></td></tr>
</table>

Table 43: Dublin LL Country hall External Wall D

3.2.1.3 Energy Active elements

Service/Source	Heating	Cooling	Ventilation	Lighting	Appliances	DHW	Other
Electricity		N/A	x	x	x		
Fossil Fuel (gasoil, NG, Butane, coal, LPG)	x					x	

Table 44: Dublin LL Country hall Energy active elements summary

Heating system	
Generation equipment A	
Type (e.g. Gas Boiler, gasoil boiler, biomass boiler …)	Gas Boiler
Centralized or individual	Centralised
Number of units	4
Manufacturer and model	Bisley 10/211 Gas Boilers
Nominal Power (kW)	200
Performance (%, COP)	78%

Type of fuel	Gas
Year of installation	1995
Tª set point (indoor temperature) (ºC)	19ºC
Location	Basement
Terminal units A	
Type (e.g. radiators, fancoils, radiant floor …)	Radiators
Number of units	4 Circuits
Manufacturer	Varies
Power (kW)	Varies
Associated generation equipment	Gas Boiler
Heated zones	7
Year of installation	Varies

Table 45: Dublin LL Country hall heating system technical details

Domestic Hot Water "DHW" system	
Generation equipment A	
Type (e.g. Boiler, heat pump, …)	Gas Boiler
Same generator as heating? (Y/N)	Y
Centralized or individual	Centralised
Number of units	1
Manufacturer and model	Joule1500-litre
Type of fuel	Gas
Year of installation	2021
Location	Basement
Volume of storage (if any) (l)	1,500l

Table 46: Dublin LL Country hall DHW system technical details

2020					
Natural GAS			**ELECTRICITY**		
Timestamp	**Consumption (kWh/Day)**	**Price (€/Day)**	**Timestamp**	**Consumption (kWh/Day)**	**Price (€/Day)**
January	**5,394.9**	**190.39**	**January**	**2,357.3**	**304.43**
February	**5,202.8**	**210.17**	**February**	**2,431.5**	**314.45**
March	**4,895.5**	**195.7**	**March**	**2,270.1**	**297.93**
April	**3,224.1**	**146.91**	**April**	**1,953.4**	**237.98**
May	**2,167.0**	**116.68**	**May**	**1,899.9**	**241.53**
June	**1,858.7**	**107.86**	**June**	**1,983.1**	**255.25**
July	**801.5**	**80.42**	**July**	**2,004.1**	**258.71**
August	**740.5**	**79.15**	**August**	**1,925.7**	**247.58**

September	1,179.8	92.69	September	2,004.0	252.86
October	3,045.9	145.44	October	2,005.9	277.39
November	4,190.7	184.09	November	2,040.9	291.91
December	5,035.2	214.01	December	2,088.5	291.26

Table 47: Dublin LL Country hall energy consumptions year 2020

2021					
Natural GAS			**ELECTRICITY**		
Timestamp	**Consumption (kWh/Day)**	**Price (€/Day)**	**Timestamp**	**Consumption (kWh)**	**Price (€/Day)**
January	5,455.3	212.31	January	1,343.6	267.21
February	6,141.4	223.24	February	1,331.6	266.42
March	5,867.8	242.7	March	1,270.5	259.5
April	5,282.3	200.63	April	1,264.3	242.85
May	1,821.5	161.18	May	1,177.2	233.17
June	752.3	132.27	June	1,155.8	229.08
July	710.4	94.42	July	1,212.0	235.62
August	702.4	85.28	August	1,180.6	230.2
September	2,539.1	97.95	September	1,337.9	249.21
October	2,670.3	156.09	October	1,345.1	254.78
November	2,670.3	183.79	November	1,476.5	284.66
December	5,619.6	280.54	December	1,371.9	267.57

Table 48: Dublin LL Country hall energy consumptions year 2021

2022					
Natural GAS			**ELECTRICITY**		
Timestamp	**Consumption (kWh/Day)**	**Price (€/Day)**	**Timestamp**	**Consumption (kWh)**	**Price (€/Day)**
January	5,455.3	240.09	January	1,445.1	276.12
February	6,141.4	259.44	February	1,559.7	297.65
March	5,867.8	242.7	March	1,522.2	296.78
April	5,282.3	203.34	April	1,419.4	249.27
May	1,821.5	110.98	May	1,387.7	246.2
June	752.3	81.76	June	1,423.2	254.9
July	710.4	80.81	July	1,421.9	877.23
August	702.4	80.63	August	1,450.1	1150.92
September	2,539.1	141.35	September	1,428.6	1145.87
October	2,670.3	145.68	October	1,482.6	555.01
November	2,670.3	145.68	November	1,576.8	708.22
December	5,619.6	178.45	December	1,448.9	924.67

Table 49: Dublin LL Country hall energy consumptions year 2022

Building Energy Rating BER
D3

Table 50: Dublin LL Country hall Building Energy Rating

E-Mobility			
MOBILITY SYSTEM	**Y/N**	**Location**	**Additional info.** Model and Number charging Point, Power (kW)
E-Vehicles	Y	Basement	-
Infrastructure/Charger	Y	Basement	32 amp

Table 51: Dublin LL Country hall E-mobility aspects

3.2.2 Harbour Master's Lodge Baseline data collection

3.2.2.1 Harbour Master's Lodge building info

Name of the Building	Harbour Master's Lodge
City	Dún Laoghaire
Country	Ireland
Owner/Partner in charge of the building	Dún Laoghaire-Rathdown County Council
Year of construction	1820
Year of renovation (if any)	2009
Brief description of the renovation (if any)	Extension to existing structure
Type of building	Administrative
Building main use	Offices
Number of floors above the ground (including ground floor)	2
Number of floors below the ground	0
Number of people in the building (average)	10
Total building surface [m²] Net floor area	468 m^2 approx.
Total building volume [m³]	1310 m^3 approx.
Weather conditions (Köppen climate classification)	Cwa
Altitude [m]	4m
Location [coordinates]	53.2948395361778, -6.134237769311834 Link

Table 52: Dublin LL Harbour Master's Lodge general info

Dwellers/Occupancy profile	
Average age - Select from 0 (Young people) to 10 (Old people)	7
Average educational level - Select from 0 (Low educational level) to 10 (High educational level)	9

Workers/Unemployment - Select from 0 (100% Unemployed people) to 10 (100% Employed people)	10
Tenants/Owners - Select from 0 (100% Tenants) to 10 (100% Owners)	Dún Laoghaire Rathdown County Council

Table 53: Dublin LL Harbour Master's Lodge Occupancy social info

IEQ (Indoor Environmental Quality) perception (Select from 1 (Low quality) to 5 (High quality))					
	USER 1	**USER 2**	**USER 3**	**USER 4**	**USER 5**
Thermal environment quality perception					
Temperature	2	1	2	3	2
Humidity	4	4	3	5	4
Air Speed	5	4	4	3	4
Lighting environment quality perception					
Luminosity level	2	3	3	2	4
Natural lighting availability	1	2	3	2	3
Indoor air quality perception					
Ventilation rates	3	3	2	4	2
Odour	4	5	4	3	3
Acoustic environment quality perception					
Indoor noises	4	4	5	3	4
Outdoor noises	4	4	5	3	3

Table 54: Dublin LL Harbour Master's Lodge IEQ perception by end-users

Occupancy												
Indicate the typical % of monthly building occupation (being 0% not occupied; 50% partially occupied; 100% fully occupied)												
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Week days	100	100	100	100	100	100	100	100	100	100	100	100
Weekends	10	10	10	10	10	10	10	10	10	10	10	10

Indicate the typical % of daily occupation for the building (being 0% not occupied; 50% partially occupied; 100% fully occupied)		
Hourly	**Week day**	**Weekends/Holidays**
0 - 6	0	0
6 - 7	0	0
7 - 8	0	0
8 - 9	50	0
9 - 10	50	0
10 - 11	50	0
11 - 12	50	0
12 - 13	50	0
13 - 14	50	0

14 - 15	50	0
15 - 16	50	0
16 - 17	50	0
17 - 18	50	0
18 - 19	0	0
19 - 20	0	0
20 - 21	0	0
21 - 22	0	0
22 - 23	0	0
23 - 24	0	0

Table 55: Dublin LL Harbour Master's Lodge occupancy profile

Figure 10: Dublin LL Harbour Master's Lodge *representative picture*

Figure 11 Dublin LL Harbour Master's Lodge *surroundings areas*

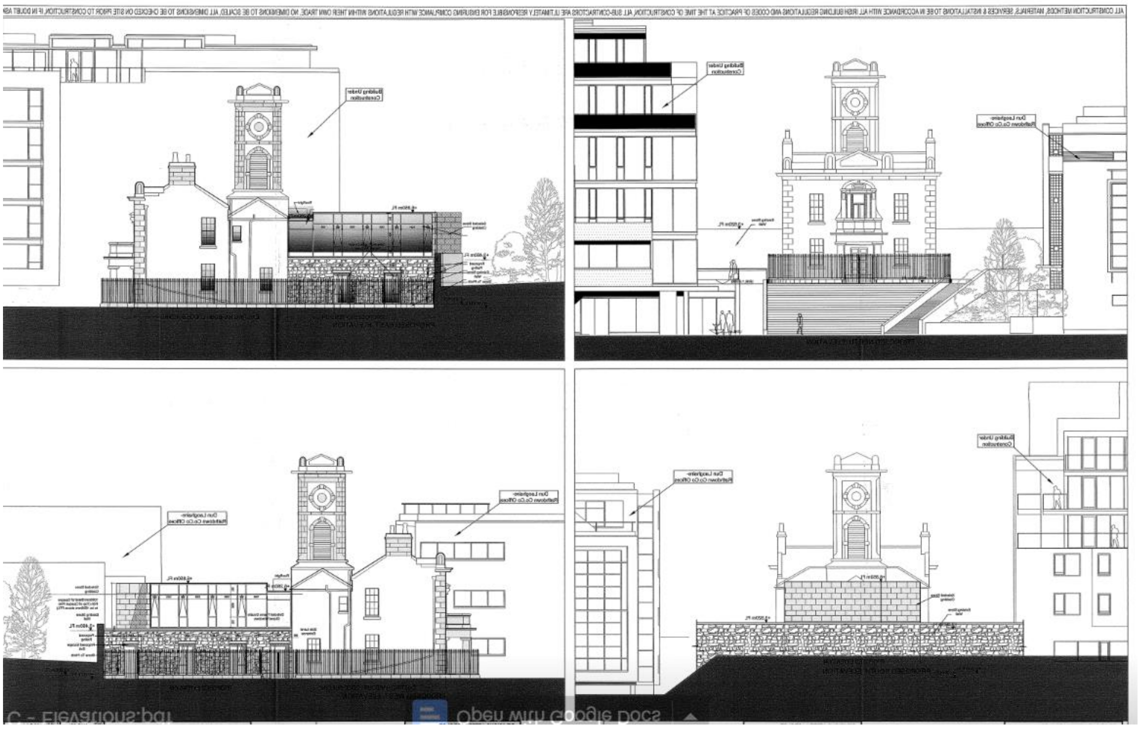


Figure 12: Dublin LL Harbour Master's Lodge *cross section*

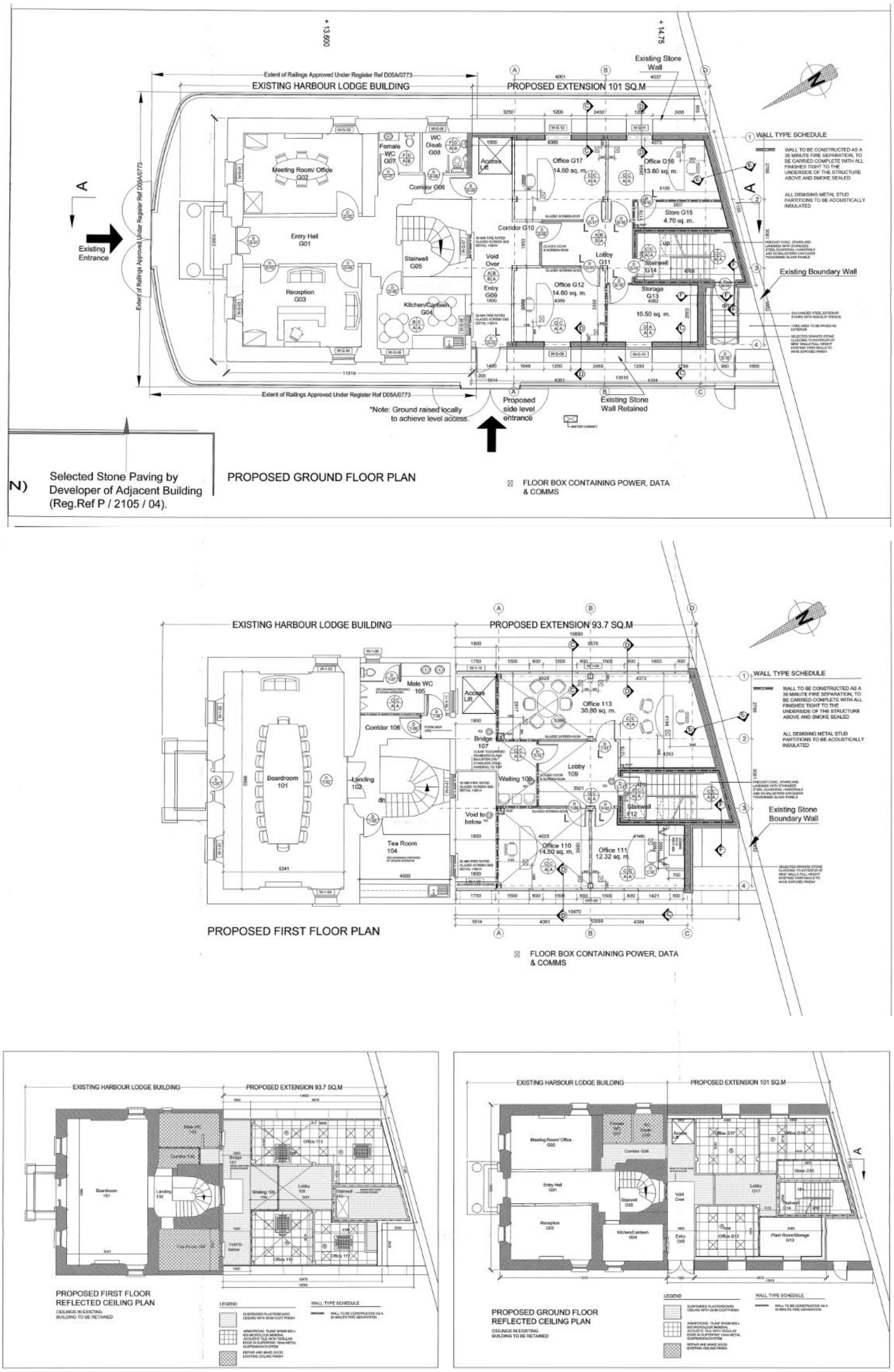


Figure 13: Dublin LL Harbour Master's Lodge *floors plans*

3.2.2.2 Envelope passive elements

Window type (A, B …)	
Type	Single glazed sash and case windows
U-value [W/m²·K]	5.44 W/m²·K
Shading elements	Description of the installed devices per façade and per opening
Frame (material, U-value)	Wooden frames
Representative picture	

Table 56: Dublin LL Harbour Master's Lodge Window type A

3.2.2.3 Energy Active elements

Service/Source	**Heating**	**Cooling**	**Ventilation**	**Lighting**	**Appliances**	**DHW**	**Other**
Electricity		x	x	x	x	x	
Fossil Fuel (gasoil, NG, Butane, coal, LPG)	NG						

Table 57 Dublin LL Harbour Master's Lodge Energy active elements summary

Heating system	
Generation equipment A	
Type (e.g. Gas Boiler, gasoil boiler, biomass boiler …)	Gas boiler
Centralized or individual	Individual
Number of units	1
Manufacturer and model	Riello
Nominal Power (kW)	40
Performance (%, COP)	80
Type of fuel	NG
Year of installation	2018
Tª set point (indoor temperature) (ºC)	19
Location	Plantroom

Table 58: Dublin LL Harbour Master's Lodge heating system technical details

Domestic Hot Water "DHW" system	
Generation equipment A	
Same generator as heating? (Y/N)	N
Centralized or individual	Individual
Number of units	5
Nominal Power (kW)	3
Type of fuel	Electric
Location	Local
Storage (Y/N)	Y
Volume of storage (if any) (l)	6

Table 59: Dublin LL Harbour Master's Lodge DHW system technical details

3.3 Porto LL baseline data collection

SONAE Campus is seeing as a Renewable Energy Community (REC) and the whole Campus is the Living Lab not assessing individual buildings. The main target is the optimization of the energy consumption of the whole campus.

3.3.1 General info for SONAE Campus baseline

3.3.1.1 SONAE campus info

Sonae Campus	
Address	Lugar do Espido, Via Norte, 4470-177 Maia
City	Porto
Country	Portugal
Owner/Partner in charge of the building	Sonae / Capwatt
Building main use	60% Logistics; 30% Offices; 10% Industry and storage
Number of people in the building (average)	3,000
Total building surface [m^2] Gross area	300,000 sqm
Weather conditions (Köppen climate classification)	Csb: Warm-summer Mediterranean climate
Location [coordinates]	41.23635108746936, -8.641010944177694

Table 60: Porto LL general info

Figure 14: Porto LL – Sonae Campus Top view

Figure 15: Porto LL – Sonae Campus Overview

3.3.1.2 Energy Active elements

SONAE Campus is a mix of different companies (services, industry and retail) that have different needs in respect of energy consumption; the whole Campus has three connections points to the electricity grid ("CPE") that correspond to different areas and consumptions within the campus. These areas can be just one building or they can be several ones combined. The three CPE’s represent different consumption profiles, different production profiles, different renewables %'s , among others. Nevertheless, based on the internal group directives, all of them want to achieve the best "green" performance.

Approaching this way, the measurements will take advantage of the current organization and infrastructure, facilitate data grabbing and will be more in line to the Living Labs ambition, as the users already now this distribution and will be easier to identify and communicate improvements.

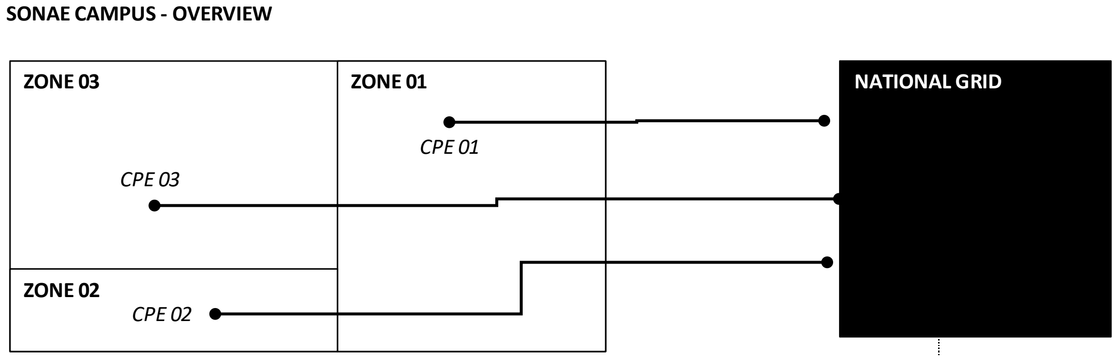


Figure 16: Porto LL campus electrical connection scheme

Location | Project Code	Service	Internal Designation
CPE 01	Buildings and Retail	Lote 2
CPE 02	Buildings	Lote 4A
CPE 03	Industry	Lote 1

CPE - "*Código Ponto de Entrega*", means Delivery Point Code, it is the place where it is made the connection between the consumption/supply and the National Grid

Table 61: Porto LL CPEs (Electricity supply points).

CPE 01		2019											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Installed Power - Renewable	*MW*	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Consumed Electricity	*MWh/month*	762.76	702.24	796.97	778.35	823.40	806.82	926.70	928.67	869.24	862.59	837.64	850.40
Produced Electricity - Renewable	*MWh/month*	61.83	80.80	117.40	107.87	147.54	135.08	130.45	133.91	106.99	76.07	41.81	46.80
Exported Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Auto-consumption Electricity - Renewable	*MWh/month*	61.83	80.80	117.40	107.87	147.54	135.08	130.45	133.91	106.99	76.07	41.81	46.80
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	-	-	-	-	-	-	-	-	-	-	2	6
Total Power Installed of EV Charging Points	*MW*	-	-	-	-	-	-	-	-	-	-	0.044	0.132

Table 62: Porto LL CEP 01 2019

CPE 01		2020											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Installed Power - Renewable	*MW*	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Consumed Electricity	*MWh/month*	808.98	767.31	803.83	808.72	845.59	854.44	937.51	888.02	886.02	871.92	798.44	820.91
Produced Electricity - Renewable	*MWh/month*	49.69	70.34	99.87	95.67	136.99	133.16	144.97	115.41	109.24	83.66	53.62	41.68
Exported Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Auto-consumption Electricity - Renewable	*MWh/month*	49.69	70.34	99.87	95.67	136.99	133.16	144.97	115.41	109.24	83.66	53.62	41.68
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	6	6	6	6	6	6	6	6	6	6	6	6
Total Power Installed of EV Charging Points	*MW*	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132

Table 63: Porto LL CEP 01 2020

CPE 01		2021											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Installed Power - Renewable	*MW*	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Consumed Electricity	*MWh/month*	768.60	709.97	769.28	790.70	798.80	814.17	885.28	872.94	848.25	844.58	784.22	768.64
Produced Electricity - Renewable	*MWh/month*	54.91	54.52	112.08	114.87	141.79	138.82	133.74	132.70	100.78	88.52	76.15	46.23
Exported Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Auto-consumption Electricity - Renewable	*MWh/month*	54.91	54.52	112.08	114.87	141.79	138.82	133.74	132.70	100.78	88.52	76.15	46.23
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	6	6	6	6	6	6	6	6	6	15	15	15
Total Power Installed of EV Charging Points	*MW*	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.211	0.211	0.211

Table 64: Porto LL CEP 01 2021

CPE 02		2019											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	-	-	-	-	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Installed Power - Renewable	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Consumed Electricity	*MWh/month*	-	-	-	-	9.90	28.31	38.02	36.96	37.78	40.63	40.10	39.30
Produced Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Exported Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Auto-consumption Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	-	-	-	-	-	4	4	4	4	4	4	4
Total Power Installed of EV Charging Points	*MW*	-	-	-	-	-	0.088	0.088	0.088	0.088	0.088	0.088	0.088

Table 65: Porto LL CEP 02 2019

CPE 02		2020											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Installed Power - Renewable	*MW*	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Consumed Electricity	*MWh/month*	39.08	31.27	23.82	14.45	13.03	12.51	12.92	14.51	23.46	28.79	23.09	24.00
Produced Electricity - Renewable	*MWh/month*	6.56	8.99	12.68	12.22	17.22	16.66	19.13	15.71	14.12	10.76	6.49	5.08
Exported Electricity - Renewable	*MWh/month*	0.44	0.49	2.79	4.57	7.68	6.85	7.97	6.06	1.37	0.85	0.81	0.32
Auto-consumption Electricity - Renewable	*MWh/month*	6.12	8.50	9.89	7.65	9.54	9.81	11.16	9.65	12.75	9.91	5.68	4.75
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	4	4	4	4	4	4	4	4	4	4	4	4
Total Power Installed of EV Charging Points	*MW*	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088

Table 66: Porto LL CEP 02 2020

CPE 02		2021											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Installed Power - Renewable	*MW*	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Consumed Electricity	*MWh/month*	22.03	17.79	15.79	15.07	14.32	18.72	19.78	20.37	27.18	30.51	33.77	32.11
Produced Electricity - Renewable	*MWh/month*	6.92	6.68	14.04	13.76	17.47	16.71	16.05	16.72	12.90	11.31	9.78	5.84
Exported Electricity - Renewable	*MWh/month*	1.27	1.85	5.42	5.30	6.78	3.90	2.61	2.83	1.89	1.08	0.93	0.52
Auto-consumption Electricity - Renewable	*MWh/month*	5.66	4.83	8.62	8.46	10.69	12.80	13.45	13.89	11.01	10.23	8.85	5.32
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	4	4	4	4	4	4	4	4	24	24	24	24
Total Power Installed of EV Charging Points	*MW*	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.236	0.236	0.236	0.236

Table 67: Porto LL CEP 02 2021

CPE 03		**2019**											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Installed Power - Renewable	*MW*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Consumed Electricity	*MWh/month*	421.40	390.98	425.24	402.03	464.09	413.65	502.22	388.85	494.25	456.79	406.98	394.79
Produced Electricity - Renewable	*MWh/month*	0.01	25.65	38.11	34.42	46.88	41.40	40.91	42.26	33.40	23.83	11.73	10.28
Exported Electricity - Renewable	*MWh/month*	0.01	25.65	38.11	34.42	46.88	41.40	40.91	42.26	33.40	23.83	11.73	10.28
Auto-consumption Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	4	4	4	4	4	5	5	7	7	7	9	11
Total Power Installed of EV Charging Points	*MW*	0.088	0.088	0.088	0.088	0.088	0.132	0.132	0.1468	0.1468	0.1468	0.3068	0.3508

Table 68: Porto LL CEP 03 2019

CPE 03		**2020**											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Installed Power - Renewable	*MW*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Consumed Electricity	*MWh/month*	435.49	401.19	385.15	357.50	322.75	345.71	424.32	321.23	404.26	380.81	305.30	274.48
Produced Electricity - Renewable	*MWh/month*	11.94	20.65	30.94	29.61	41.40	40.40	45.76	38.76	34.92	27.39	14.51	10.03
Exported Electricity - Renewable	*MWh/month*	11.94	20.65	30.94	29.61	41.40	40.40	45.76	38.76	34.92	27.39	14.51	10.03
Auto-consumption Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Power	*MW*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Capacity	*MWh*	-	-	-	-	-	-	-	-	-	-	-	-
Quantity of EV Charging Points	*(number)*	11	12	12	12	16	16	16	16	16	16	16	16
Total Power Installed of EV Charging Points	*MW*	0.3508	0.3508	0.3508	0.3508	0.4388	0.4388	0.4388	0.4388	0.4388	0.4388	0.4388	0.4388

Table 69: Porto LL CEP 03 2020

CPE 03		**2021**											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Installed Power	*MW*	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Installed Power - Renewable	*MW*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Consumed Electricity	*MWh/month*	267.84	345.84	380.28	377.33	385.89	429.75	426.51	317.00	434.48	432.44	406.73	429.46
Produced Electricity - Renewable	*MWh/month*	13.08	17.16	35.55	36.96	44.95	42.65	40.31	41.54	31.41	27.68	21.07	10.49
Exported Electricity - Renewable	*MWh/month*	13.08	17.16	35.55	36.96	44.95	42.65	40.31	41.54	31.41	27.68	21.07	10.49
Auto-consumption Electricity - Renewable	*MWh/month*	-	-	-	-	-	-	-	-	-	-	-	-
Storage Systems - Installed Power	*MW*	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Storage Systems - Installed Capacity	*MWh*	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798
Quantity of EV Charging Points	*(number)*	18	18	18	18	18	18	18	18	24	24	24	24
Total Power Installed of EV Charging Points	*MW*	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	0.498	0.498	0.498	0.498

Table 70: Porto LL CEP 03 2021

The main characteristics of the production and storage systems, installed throughout the Campus, are as follows:

PV plants:

- Mini-generation with 225 kWp (mini-generation with feed-in tariff – will not be part of the energy community).
- UPAC2 with 0.83 MWp (auto-consumption, behind-the-meter).
- UPAC1 with 0.25 MWp (auto-consumption, behind-the-meter).

Cogeneration Plant:

7.4 MW electrical and 11.1 MW thermal; this plant will not be made part of the Renewable Energy Community, because of regulation.

EV charging stations:

- AC Charging Stations 7.4 kW and 22kW – several units

3.3.2 Life Cycle Assessment approach

The Porto LL will develop conditions, through the PROBONO project, for a more energy efficient campus with the creation of a renewable energy community and the creation of an energy tech hub to test and develop new emerging technologies.

In the renewable energy community, the main implementation in the scope of PROBONO, is only concerning development registration and software tools. The technologies of the tech hub will be small scale pilots, to test for applicability in the future. In that regard, a life cycle assessment being a systematic analysis of the environmental impacts over the course of the life of a product, does not apply to the Porto LL in the scope of the PROBONO project.

3.4 Brussels LL baseline data collection

Brussels LL composed by an already existing school and therefore the baseline data collection included in the next subsections, is based on the real existing school before implementing the PROBONO innovations.

3.4.1 General info for the buildings baseline

Name of the Building	De l'autre côté de l'école
Address	1789, Chaussée de Wavre
City	1160 Brussels
Country	Belgium
Owner/Partner in charge of the building	De l'autre côté de l'école
Year of construction	1984
Year of renovation (if any)	2014
Brief description of the renovation (if any)	Transformation of office premises into a school
Type of building	Offices
Building main use	School

Number of floors above the ground (including ground floor)	5
Number of floors below the ground	1
Number of dwellings/rooms in total	No dwelling/ 45 rooms
Number of dwellings/rooms per floor	-1 : 21 Ground floor:20 +1, +2, +3 : 13 per floor +4: 12
Other services within the building (if any)	/
Number of people in the building (average)	630
Total building surface [m^2] Groos area	8,267.49 + around 500m^2 exteriors
Total building surface [m^2] Net floor area	7,523.46
Please indicate net floor area definition (it can vary depending on the country, local regulations, etc.)	https://environnement.brussels/sites/default/files/user_files/annexe2_codedemesurage_vcoord_nov2018.pdf
Weather conditions (Köppen climate classification)	CFB
Altitude [m]	0
Location [coordinates]	https://goo.gl/maps/91f8i5zFryGPFUBh8 50.815900, 4.429468 ACE, Waversesteenweg 1789, 1160 Oudergem

Table 71: Brussels LL general info

Dwellers/Occupancy profile	
Average age - Select from 0 (Young people) to 10 (Old people)	5 to 7
Average educational level - Select from 0 (Low educational level) to 10 (High educational level)	4 to 10
Workers/Unemployment - Select from 0 (100% Unemployed people) to 10 (100% Employed people)	10
Tenants/Owners - Select from 0 (100% Tenants) to 10 (100% Owners)	10

Table 72: Brussels LL Occupancy social info

IEQ (Indoor Environmental Quality) perception (Select from 1 (Low quality) to 5 (High quality))					
	USER 1	**USER 2**	**USER 3**	**USER 4**	**USER 5**
Thermal environment quality perception					
Temperature	2	2	3	3	5
Humidity	2	2	2	2	3
Lighting environment quality perception					

Luminosity level	4	4	4	4	4
Natural lighting availability	2	2	1	2	1
Indoor air quality perception					
Ventilation rates	3	3	3	3	3
Odour	2	3	3	1	3
Acoustic environment quality perception					
Indoor noises	1	1	1	1	1
Outdoor noises	1	1	1	1	1

Table 73: Brussels LL IEQ perception by end-users

<table>
<tr><th colspan="13">Occupancy</th></tr>
<tr><td colspan="13">Indicate the typical % of monthly building occupation (being 0% not occupied; 50% partially occupied; 100% fully occupied)</td></tr>
<tr><th>Month</th><th>January</th><th>February</th><th>March</th><th>April</th><th>May</th><th>June</th><th>July</th><th>August</th><th>September</th><th>October</th><th>November</th><th>December</th></tr>
<tr><th>Week days</th><td>50</td><td>100</td><td>100</td><td>100</td><td>50</td><td>100</td><td>50</td><td>50</td><td>100</td><td>100</td><td>50</td><td>50</td></tr>
<tr><th>Weekends</th><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="13">Indicate the typical % of daily occupation for the building (being 0% not occupied; 50% partially occupied; 100% fully occupied)</td></tr>
<tr><th colspan="2">Hourly</th><th colspan="3">Week day</th><th colspan="8">Weekends/Holidays</th></tr>
<tr><th colspan="2">0 - 8</th><td colspan="3">---</td><td colspan="8">---</td></tr>
<tr><th colspan="2">8 - 9</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">9 - 10</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">10 - 11</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">11 - 12</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">12 - 13</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">13 - 14</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">14 - 15</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">15 - 16</th><td colspan="3">100</td><td colspan="8">0</td></tr>
<tr><th colspan="2">16 - 24</th><td colspan="3">---</td><td colspan="8">---</td></tr>
</table>

Table 74: Brussels LL occupancy profile

Figure 17: Brussels LL representative pictures

Figure 18: Brussels LL surroundings areas

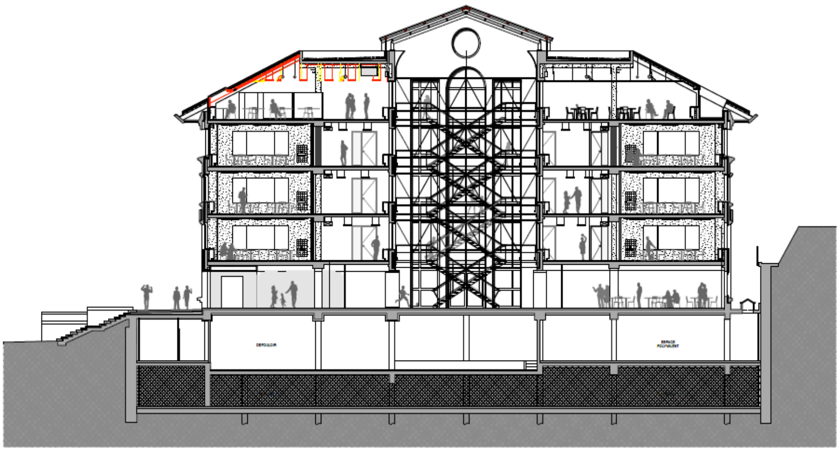
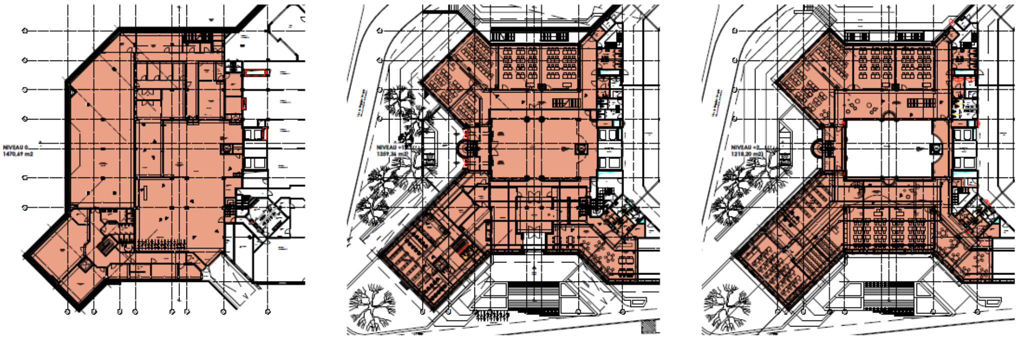
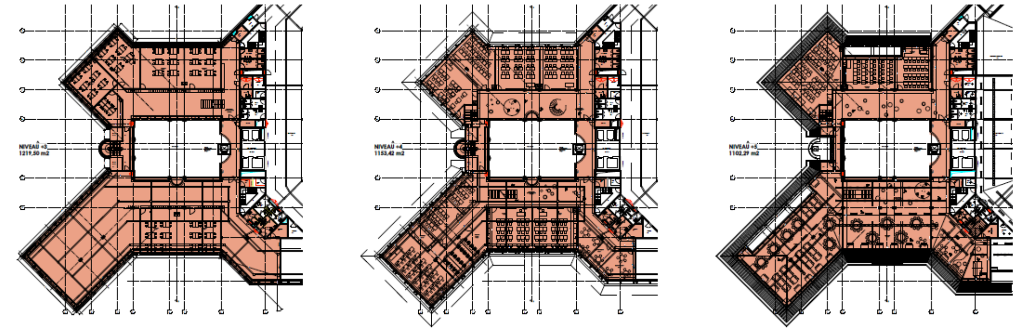


Figure 19: Brussels LL cross section



RDC PLACE : 1470,69 m2 RDC WAVRE : 1359,36 m2 NIVEAU +1 : 1218,20 m2

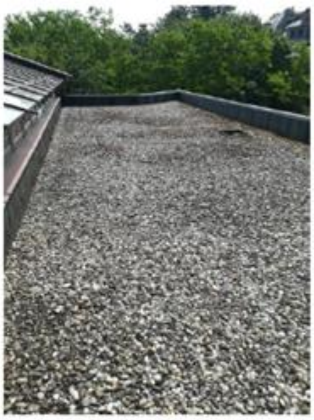


NIVEAU +2 : 1219,50 m2 NIVEAU +3 : 1153,42 m2 NIVEAU +4 : 1102,29 m2

Figure 20: Brussels LL floor plans

3.4.2 Envelope passive elements

External Roof (A, B, …) If needed, add additional external roofs and components	
U-value [W/m²·K]	4m²K/w
Representative picture	

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GUTEX Multiplex-top ist die regensichere Unterdeckplatte mit einschichtigem homogenen Rohdichteprofil.

- hergestellt nach DIN EN 13171
- regensichere Behelfsdachfunktion ab 15° Dachneigung
- winddicht
- diffusionsoffen
- natureplus zertifiziert

Kantenausbildung	Nut [illegible]
Format (cm)	250 x [illegible]
Dicke (mm)	18/22/[illegible]
λ_D (W/mK)	0,045
λ (W/mK)	0,047

10/2017

Table 75: Brussels LL External roof

Window type If needed, add additional windows and components	
Type	Double first generation
U-value [W/m²·K]	5.9 W/m²K
g-value [solar factor]	2 to 2.9 W/m²K
Shading elements	none
Frame (material, U-value)	aluminium
Description (in which window apply, e.g. north, south, east, west)	
All the same	
Representative picture	

Table 76: Brussels LL Windows

3.4.3 Energy. Active elements

Service/Source	Heating	Cooling	Ventilation	Lighting	Appliances	DHW	Other
Electricity			x	x	x		
Renewable energy (ST, PV, Biomass, etc)	x					x	

Table 77: Brussels LL Energy active elements summary

Heating system If needed, Add additional Generation equipment tables	
Generation equipment A	
Type (e.g. Gas Boiler, gasoil boiler, biomass boiler …)	gas boiler
Centralized or individual	centralised
Number of units	5
Manufacturer and model	Dietrich (MCA 115)
Nominal Power (kW)	1,125

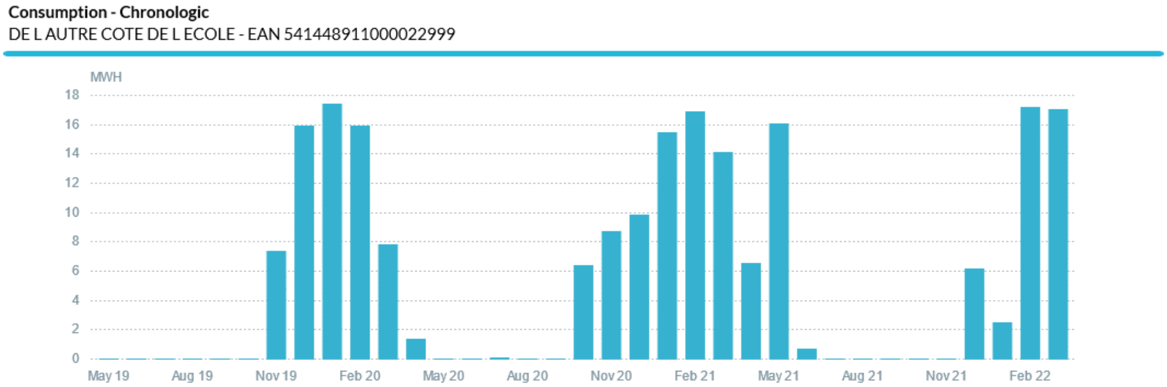
Type of fuel	Natural gas
Year of installation	2018
Tª set point (indoor temperature) (ºC)	20
Location	4th floor
Additional info (if needed)	Climate control system
Terminal units A	
Type (e.g. radiators, fancoils, radiant floor …)	Fan coil units
Heated zones	Classrooms, administrative area

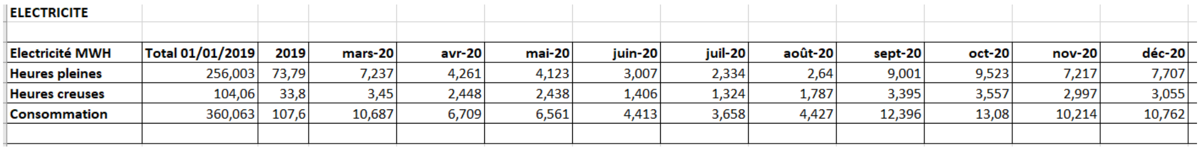
Table 78: Brussels LL heating system technical details

Domestic Hot Water "DHW" system If need it, Add additional Generation equipment tables	
Generation equipment A	
Type (e.g. Boiler, heat pump, …)	boiler
Same generator as heating? (Y/N)	Y
Centralized or individual	centralised

Table 79: Brussels LL DHW system technical details

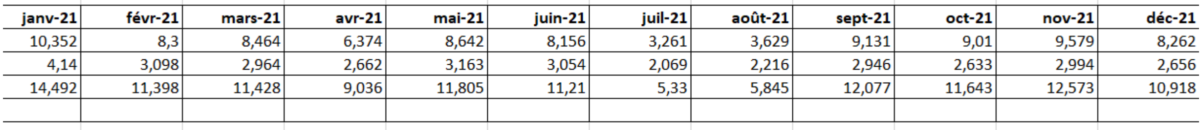
3.4.3.1 Electricity consumption





ELECTRICITE

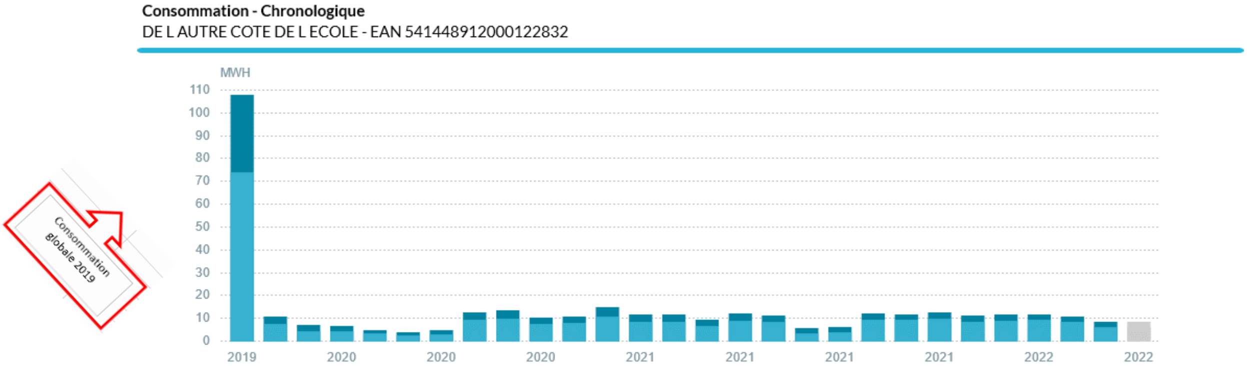
Electricité MWH	Total 01/01/2019	2019	mars-20	avr-20	mai-20	juin-20	juil-20	août-20	sept-20	oct-20	nov-20	déc-20
Heures pleines	256,003	73,79	7,237	4,261	4,123	3,007	2,334	2,64	9,001	9,523	7,217	7,707
Heures creuses	104,06	33,8	3,45	2,448	2,438	1,406	1,324	1,787	3,395	3,557	2,997	3,055
Consommation	360,063	107,6	10,687	6,709	6,561	4,413	3,658	4,427	12,396	13,08	10,214	10,762

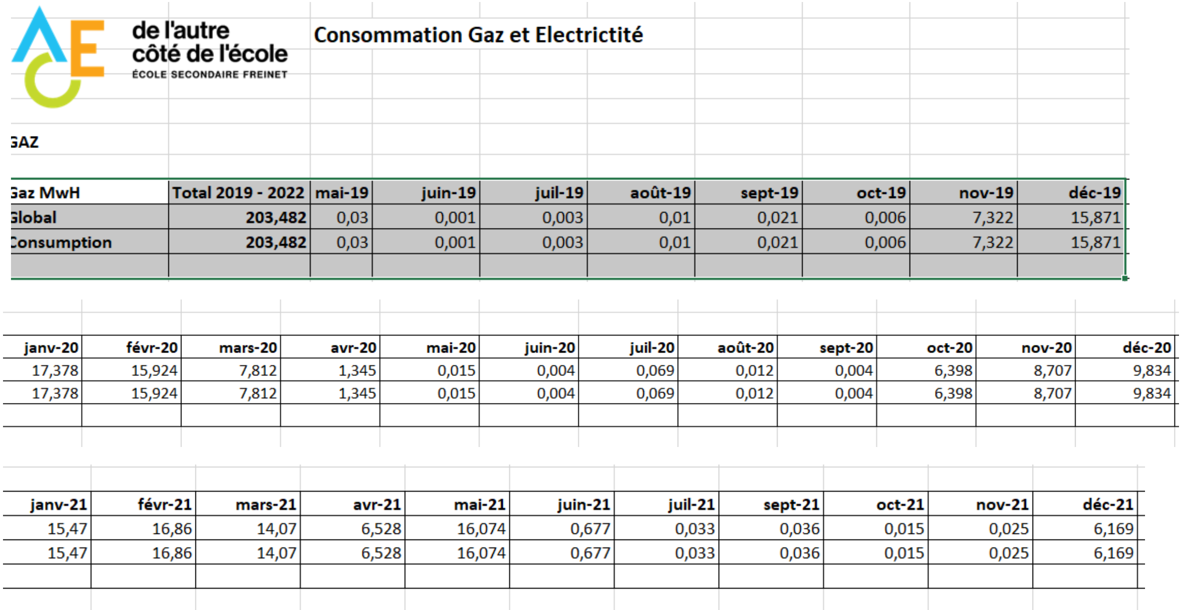


janv-21	févr-21	mars-21	avr-21	mai-21	juin-21	juil-21	août-21	sept-21	oct-21	nov-21	déc-21
10,352	8,3	8,464	6,374	8,642	8,156	3,261	3,629	9,131	9,01	9,579	8,262
4,14	3,098	2,964	2,662	3,163	3,054	2,069	2,216	2,946	2,633	2,994	2,656
14,492	11,398	11,428	9,036	11,805	11,21	5,33	5,845	12,077	11,643	12,573	10,918

Table 80: Brussels LL Electricity consumption for the years 2020-2021-2022

3.4.3.2 Gas consumption





de l'autre côté de l'école
ÉCOLE SECONDAIRE FREINET

Consommation Gaz et Electrictité

AZ

az MwH	**Total 2019 - 2022**	**mai-19**	**juin-19**	**juil-19**	**août-19**	**sept-19**	**oct-19**	**nov-19**	**déc-19**
lobal	**203,482**	0,03	0,001	0,003	0,01	0,021	0,006	7,322	15,871
onsumption	**203,482**	0,03	0,001	0,003	0,01	0,021	0,006	7,322	15,871

janv-20	**févr-20**	**mars-20**	**avr-20**	**mai-20**	**juin-20**	**juil-20**	**août-20**	**sept-20**	**oct-20**	**nov-20**	**déc-20**
17,378	15,924	7,812	1,345	0,015	0,004	0,069	0,012	0,004	6,398	8,707	9,834
17,378	15,924	7,812	1,345	0,015	0,004	0,069	0,012	0,004	6,398	8,707	9,834

janv-21	**févr-21**	**mars-21**	**avr-21**	**mai-21**	**juin-21**	**juil-21**	**sept-21**	**oct-21**	**nov-21**	**déc-21**
15,47	16,86	14,07	6,528	16,074	0,677	0,033	0,036	0,015	0,025	6,169
15,47	16,86	14,07	6,528	16,074	0,677	0,033	0,036	0,015	0,025	6,169

Table 81: Brussels LL Gas consumption for the years 2020-2021-2022

Monitoring system	
ENERGY SYSTEM	**Y/N**
Heating	N
Cooling	N
DHW	N
Ventilation	N
Lighting	N
Appliances	N
INDOOR VALUES	**Y/N**
Temperature	N

Relative Humidity %	N
Illumination level	N
CO_2 concentration	Y
Occupancy sensors	N
EXTERNAL VALUES (Weather station)	**Y/N**
Temperature	N
Relative Humidity %	N
Illumination level	N
Radiation	N
Wind Speed	N
Wind Direction	N
Rain	N

Table 82: Brussels LL monitoring systems availability summary

Maintenance Total Building	
Year	**Price (€)**
2019	60,796
2020	56,524
2021	82,165

Table 83: Brussels LL maintenance costs for the total building

Building Energy Rating BER
B+ in 2023

Table 84: Brussels LL Building Energy Rating

E-Mobility	
MOBILITY SYSTEM	**Y/N**
E-Vehicles	N
Infrastructure/Charger	N

Table 85: Brussels LL E-mobility aspects

3.4.4 Life Cycle Assessment related data

Object of Assessment	Building, material, appliances etc.
Goal Definition	Comparing various material and appliances, energy consumption, pollution etc

Who is the target audience?	Students, teachers, and on a larger scale, the neighbours
Scope of Assessment / System Boundary	All stage of the transformation to abide by the Brussels gov rules for environmental building, retrofitting, works, permits...
Impact Categories to be analysed	The building works
Functional Unit	New spaces, light, etc
Software and database	none
Timespan	From 2024 till the end of works

Table 86: Brussels LL Life Cycle Assessment

3.5 Aarhus LL baseline data collection

In the case study of Aarhus LL, four buildings are part of the PROBONO project: two renovated and two new buildings. All these constructions belong to the BSS Business School at the University City (the former hospital grounds).

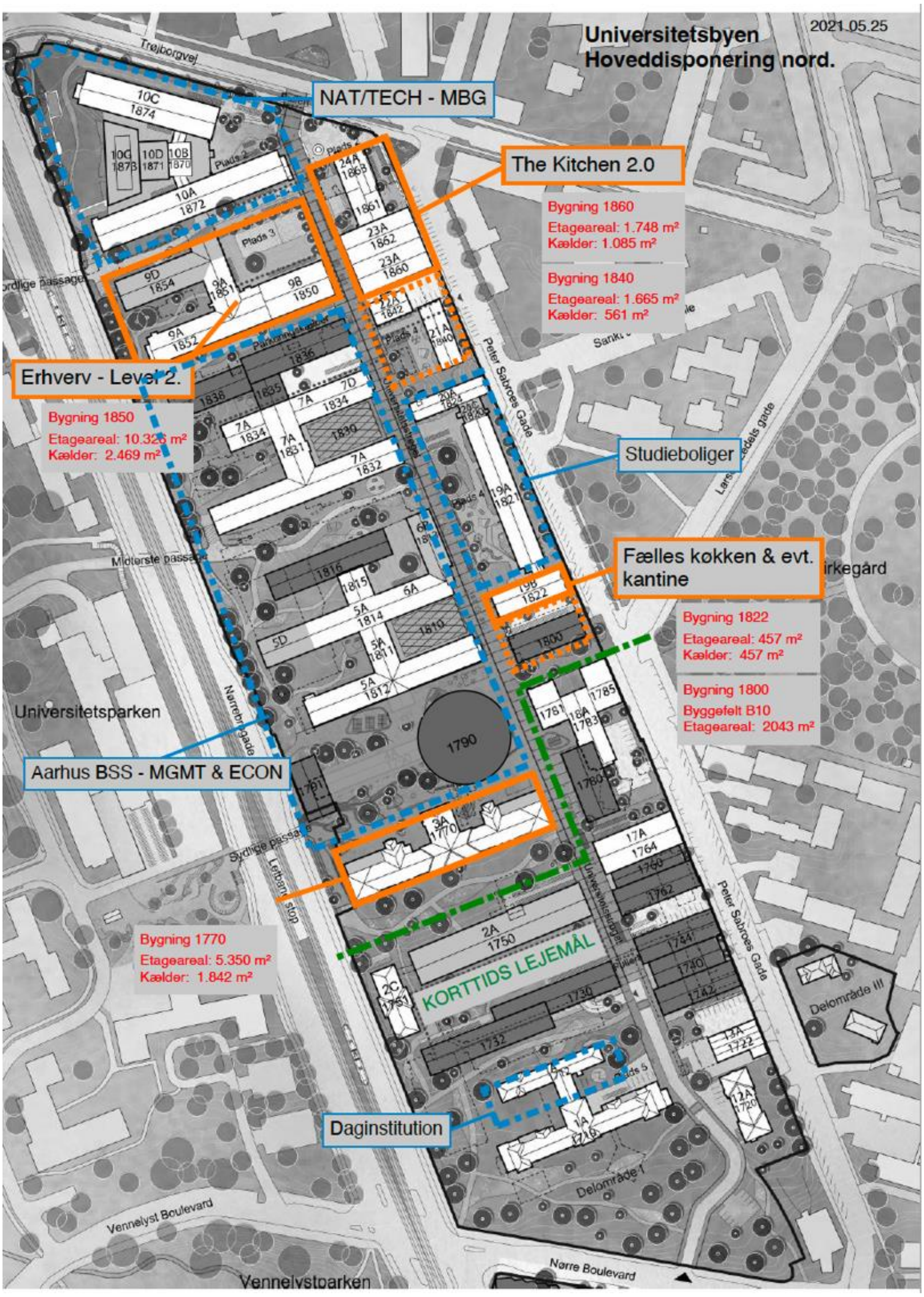


Figure 21: Aarhus LL overall picture

3.5.1 General info for the buildings baseline

Some information about the four Aarhus LL buildings is described below: The new buildings are the 1790 and 1791, while the 1810 and 1830 correspond to the refurbished ones.

3.5.1.1 Building 1: 1790 info

Name of the Building	1790
Address	Nørrebrogade 44
City	Aarhus
Country	Denmark
Owner/Partner in charge of the building	FEAS
Year of construction	2021-2025
Year of renovation (if any)	New (round) building
Building main use	Auditorium, op to 800 persons
Number of floors above the ground (including ground floor)	2
Number of floors below the ground	2

Table 87: Aarhus LL building 1 general info

Figure 22: Aarhus LL building 1 representative picture

Figure 23: Aarhus LL building 1 Interior section

Figure 24: Aarhus LL building 1 illustration 1

Figure 25: Aarhus LL building 1 illustration 2

3.5.1.2 Building 2: 1791 info

Name of the Building	1791
Address	Nørrebrogade 44
City	Aarhus
Country	Denmark
Owner/Partner in charge of the building	FEAS
Year of construction	2021-2025
Year of renovation (if any)	New (round) building
Building main use	Auditorium, op to 800 persons
Number of floors above the ground (including ground floor)	2
Number of floors below the ground	2

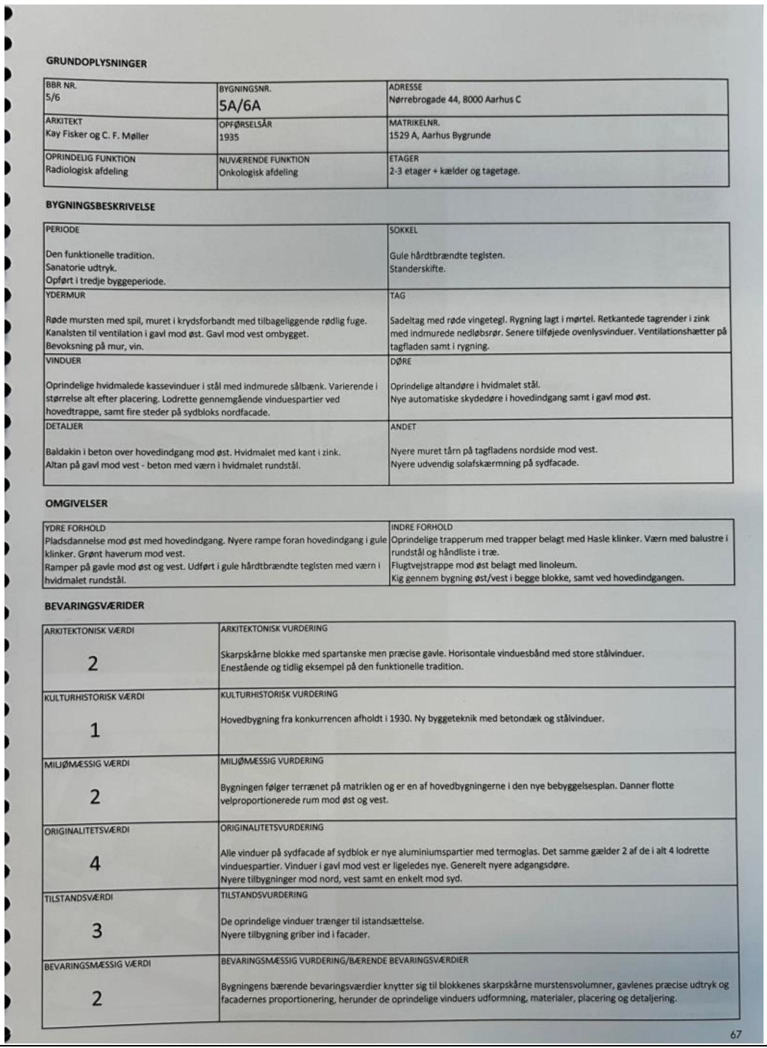
Table 88: Aarhus LL building 2 general info

Figure 26: Aarhus LL building 2 representative picture

Figure 27: Aarhus LL building 2 background

3.5.1.3 Building 3: 1810 info

Name of the Building	1810
Address	Nørrebrogade 44
City	Aarhus

Country	Denmark
Owner/Partner in charge of the building	FEAS
Year of construction	1935
Year of renovation (if any)	reoccurring, as a hospital
Type of building	Brick two layers, no insulation
Building main use	Hospital
Number of floors above the ground (including ground floor)	3
Number of floors below the ground	1
	

GRUNDOPLYSNINGER

BBR NR. 5/6	BYGNINGSNR. 5A/6A	ADRESSE Nørrebrogade 44, 8000 Aarhus C
ARKITEKT Kay Fisker og C. F. Møller	OPFØRSELSÅR 1935	MATRIKELNR. 1529 A, Aarhus Bygrunde
OPRINDELIG FUNKTION Radiologisk afdeling	NUVÆRENDE FUNKTION Onkologisk afdeling	ETAGER 2-3 etager + kælder og tagetage.

BYGNINGSBESKRIVELSE

PERIODE Den funktionelle tradition. Sanatorie udtryk. Opført i tredje byggeperiode.	SOKKEL Gule hårdtbrændte teglsten. Standerskifte.
YDERMUR Røde mursten med spil, muret i krydsforbandt med tilbageliggende rødlig fuge. Kanalsten til ventilation i gavl mod øst. Gavl mod vest ombygget. Bevoksning på mur, vin.	TAG Sadeltag med røde vingetegl. Rygning lagt i mørtel. Retkantede tagrender i zink med indmurede nedløbsrør. Senere tilføjede ovenlysvinduer. Ventilationshætter på tagfladen samt i rygning.
VINDUER Oprindelige hvidmalede kassevinduer i stål med indmurede sålbænk. Varierende i størrelse alt efter placering. Lodrette gennemgående vinduespartier ved hovedtrappe, samt fire steder på sydbloks nordfacade.	DØRE Oprindelige altandøre i hvidmalet stål. Nye automatiske skydedøre i hovedindgang samt i gavl mod øst.
DETALJER Baldakin i beton over hovedindgang mod øst. Hvidmalet med kant i zink. Altan på gavl mod vest - beton med værn i hvidmalet rundstål.	ANDET Nyere muret tårn på tagfladens nordside mod vest. Nyere udvendig solafskærmning på sydfacade.

OMGIVELSER

YDRE FORHOLD Pladsdannelse mod øst med hovedindgang. Nyere rampe foran hovedindgang i gule klinker. Grønt haverum mod vest. Ramper på gavle mod øst og vest. Udført i gule hårdtbrændte teglsten med værn i hvidmalet rundstål.	INDRE FORHOLD Oprindelige trapperum med trapper belagt med Hasle klinker. Værn med balustre i rundstål og håndliste i træ. Flugtvejstrappe mod øst belagt med linoleum. Kig gennem bygning øst/vest i begge blokke, samt ved hovedindgangen.

BEVARINGSVÆRIDER

ARKITEKTONISK VÆRDI 2	ARKITEKTONISK VURDERING Skarpskårne blokke med spartanske men præcise gavle. Horisontale vinduesbånd med store stålvinduer. Enestående og tidlig eksempel på den funktionelle tradition.
KULTURHISTORISK VÆRDI 1	KULTURHISTORISK VURDERING Hovedbygning fra konkurrencen afholdt i 1930. Ny byggeteknik med betondæk og stålvinduer.
MILJØMÆSSIG VÆRDI 2	MILJØMÆSSIG VURDERING Bygningen følger terrænet på matriklen og er en af hovedbygningerne i den nye bebyggelsesplan. Danner flotte velproportionerede rum mod øst og vest.
ORIGINALITETSVÆRDI 4	ORIGINALITETSVURDERING Alle vinduer på sydfacade af sydblok er nye aluminiumspartier med termoglas. Det samme gælder 2 af de i alt 4 lodrette vinduespartier. Vinduer i gavl mod vest er ligeledes nye. Generelt nyere adgangsdøre. Nyere tilbygninger mod nord, vest samt en enkelt mod syd.
TILSTANDSVÆRDI 3	TILSTANDSVURDERING De oprindelige vinduer trænger til istandsættelse. Nyere tilbygning griber ind i facader.
BEVARINGSMÆSSIG VÆRDI 2	BEVARINGSMÆSSIG VURDERING/BÆRENDE BEVARINGSVÆRDIER Bygningens bærende bevaringsværdier knytter sig til blokkenes skarpskårne murstensvolumner, gavlenes præcise udtryk og facadernes proportionering, herunder de oprindelige vinduers udformning, materialer, placering og detaljering.

67

Table 89: Aarhus LL building 3 general info

AARHUS KOMMUNEHOSPITAL

Bygning 5A/6A

Bygningens ankomstrum mod øst

Gavl mod vest

Gavl mod øst

Facade mod syd

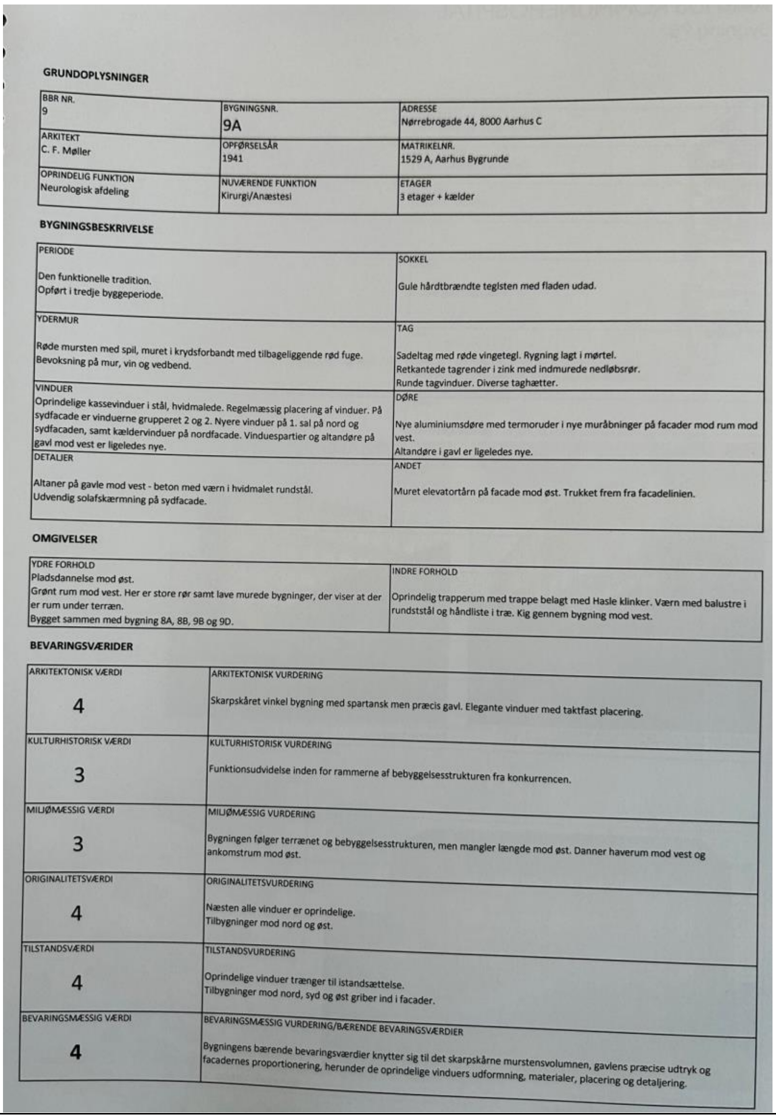
Kortudsnit 1:2500

66

Figure 28: Aarhus LL building 3 representative pictures

3.5.1.4 Building 4: 1830 info

Name of the Building	1830
Address	Nørrebrogade 44
City	Aarhus
Country	Denmark
Owner/Partner in charge of the building	FEAS
Year of construction	1944
Year of renovation (if any)	reoccurring, as a hospital
Type of building	Brick two layers, no insulation
Building main use	Hospital
Number of floors above the ground (including ground floor)	4
Number of floors below the ground	1



GRUNDOPLYSNINGER

BBR NR. 9	BYGNINGSNR. 9A	ADRESSE Nørrebrogade 44, 8000 Aarhus C
ARKITEKT C. F. Møller	OPFØRSELSÅR 1941	MATRIKELNR. 1529 A, Aarhus Bygrunde
OPRINDELIG FUNKTION Neurologisk afdeling	NUVÆRENDE FUNKTION Kirurgi/Anæstesi	ETAGER 3 etager + kælder

BYGNINGSBESKRIVELSE

PERIODE Den funktionelle tradition. Opført i tredje byggeperiode.	SOKKEL Gule hårdtbrændte teglsten med fladen udad.
YDERMUR Røde mursten med spil, muret i krydsforbandt med tilbageliggende rød fuge. Bevoksning på mur, vin og vedbend.	TAG Sadeltag med røde vingetegl. Rygning lagt i mørtel. Retkantede tagrender i zink med indmurede nedløbsrør. Runde tagvinduer. Diverse taghætter.
VINDUER Oprindelige kassevinduer i stål, hvidmalede. Regelmæssig placering af vinduer. På sydfacade er vinduerne grupperet 2 og 2. Nyere vinduer på 1. sal på nord og sydfacaden, samt kældervinduer på nordfacade. Vinduespartier og altandøre på gavl mod vest er ligeledes nye.	DØRE Nye aluminiumsdøre med termoruder i nye muråbninger på facader mod rum mod vest. Altandøre i gavl er ligeledes nye.
DETALJER Altaner på gavle mod vest - beton med værn i hvidmalet rundstål. Udvendig solafskærmning på sydfacade.	ANDET Muret elevatortårn på facade mod øst. Trukket frem fra facadelinien.

OMGIVELSER

YDRE FORHOLD Pladsdannelse mod øst. Grønt rum mod vest. Her er store rør samt lave murede bygninger, der viser at der er rum under terræn. Bygget sammen med bygning 8A, 8B, 9B og 9D.	INDRE FORHOLD Oprindelig trapperum med trappe belagt med Hasle klinker. Værn med balustre i rundststål og håndliste i træ. Kig gennem bygning mod vest.

BEVARINGSVÆRIDER

ARKITEKTONISK VÆRDI 4	ARKITEKTONISK VURDERING Skarpskåret vinkel bygning med spartansk men præcis gavl. Elegante vinduer med taktfast placering.
KULTURHISTORISK VÆRDI 3	KULTURHISTORISK VURDERING Funktionsudvidelse inden for rammerne af bebyggelsesstrukturen fra konkurrencen.
MILJØMÆSSIG VÆRDI 3	MILJØMÆSSIG VURDERING Bygningen følger terrænet og bebyggelsesstrukturen, men mangler længde mod øst. Danner haverum mod vest og ankomstrum mod øst.
ORIGINALITETSVÆRDI 4	ORIGINALITETSVURDERING Næsten alle vinduer er oprindelige. Tilbygninger mod nord og øst.
TILSTANDSVÆRDI 4	TILSTANDSVURDERING Oprindelige vinduer trænger til istandsættelse. Tilbygninger mod nord, syd og øst griber ind i facader.
BEVARINGSMÆSSIG VÆRDI 4	BEVARINGSMÆSSIG VURDERING/BÆRENDE BEVARINGSVÆRDIER Bygningens bærende bevaringsværdier knytter sig til det skarpskårne murstensvolumnen, gavlens præcise udtryk og facadernes proportionering, herunder de oprindelige vinduers udformning, materialer, placering og detaljering.

Table 90: Aarhus LL building 4 general info

AARHUS KOMMUNEHOSPITAL

Bygning 7A

Oprindeligt stort vinduesparti.

Gavl mod vest og facade mod syd.

Oprindeligt vindue mod syd.

Bygningens ankomstrum mod øst.

Facade mod syd og gavl mod øst.

Kortudsnit 1:2500

86

Figure 29: Aarhus LL building 4 representative pictures

Figure 30: Aarhus LL building 4 visualization after deep refurbishment

3.5.2 Life Cycle Assessment benchmark methodology

The actual LCA calculations will be performed by the project Architect and DGNB Auditor. In the next sections there are information about the LCA approach describing the calculation method. As there is less data on the old hospital building, it is more accurate to use the “Build study on 60 houses” calculated benchmark.

For LCA benchmarking, Aarhus LL has described the LCA method used in Denmark, with some examples of where there are problems/possibilities for improvement, especially how it is calculated with recycled materials.

The LCA will be performed in accordance with the requirements in the Danish building regulations and the method outlined in the Danish DGNB 2020 manual (Green Building Council Denmark, 2021).

The LCA will be performed using the tool ”LCAbyg5” which builds upon the method in EN 15978. LCAbyg supports LCA calculations based on the modules: A1-A3, A4, A5, B4, B6, C3, C4, and D[27]. The modules A4, and A5 are not included in the benchmark values listed below.

Lifetimes of building materials will be addressed based on the *DGNB 2020 manual* (Haugbølle et al., 2021), which contains the standardized lifespans used in the Danish construction industry when performing LCA’s using the tool LCAbyg.

An important Aarhus LL finding is that implementing reused and upcycled materials has a massive impact on the LCA calculation. In a renovation project if a material is reused in the same building the material does not add CO_2eq to the LCA calculation, but if the same reused material is used in another project, the up/recycled material computes to the same CO_2eq. as a new virgin material.

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[27] LBAbyg 5 userguide: https://lcabyg.dk/en/usermanual/user-manual-lcabyg/

Aarhus LL finds that using the data developed in a in depth survey (explained further down) as benchmark gives the best accuracy.

Understanding the scope of an LCA is essential when comparing buildings and determining the best practices for achieving low-carbon buildings. Unfortunately, the scope of an LCA varies significantly across countries and certification schemes, making it difficult to compare apples to apples. As a result, this poses a significant challenge and business risk for developers and asset owners who want to benchmark and decarbonize their portfolios as part of their ESG reporting.

In order to be able to pin out specific sustainable improvement in a product the ESG and the LCA need to be harmonized and also the specific material including production and transport is needed, generic data does not reveal the most sustainable product when comparing. For example, the production of steel that is performing equally but the production and transport etc. is quite different. The specification on the details gives the industry the possibility to choose and promote the most sustainable product.

The LCA method, defined in the Danish DGNB (Green Building Council Denmark, 2021)., the Danish building regulations, and the Danish Voluntary sustainability class, does not provide specifications for addressing the emissions from reusing or re-utilising building materials in the LCA. The existing practice in the Danish construction industry is to distinguish between: The direct reuse or re-utilisation at the construction site, and the reuse or re-utilisation of a material from another construction site.

In the first case, the material will not be added to the LCA because the material's emission in the modules A1-A3, C3 and C4 should be addressed in the material's first life cycle, and that these emissions therefore shall be omitted in the LCA for the renovation/refurbishment of the building to avoid double counting.

In the second case, the material will need to be added to the LCA. When the reused/re-utilised material is acquired through a company or distributor that has developed a product-specific EPD for the material (e.g. Gamle Mursten[28]), product-specific data can be used in the LCA, as per the description in the Danish building regulation. It is required to use the generic data provided in the Danish building regulations[29], if a product-specific EPD for the product has not been developed. The generic data are based on the emissions from newly produced building materials. Using the generic data provided by the Danish building regulations has the effect that the embodied carbon materials are added to the building's LCA. This results in double counting of the embodied carbon since the embodied carbon from the material's production should only be included in the LCA for the material's first life cycle.

I. INVESTIGATION (I) (in Danish): Document that describes the possibility of **saving by reusing or recycling/upcycle building materials** (Larsen et al., 2022).
II. INVESTIGATION (II): Research article that concludes that there is **no fixed/applicable method for sLCA[30]**
III. INVESTIGATION (III): Research article Methodological Framework to Foster **Social Value Creation** in Architectural Practice[31]

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[28] *Bygnings Reglementet [Building Regulations] §* 297 stk. 6. https://bygningsreglementet.dk/

[29] Bygnings *Reglementet [Building Regulations]* https://bygningsreglementet.dk/

[30] https://kornforum.nlr.no/files/documents/Fagforum-Korn/Temaark/Temaark-1-Planlegging-av-vekstsesongen.pdf

[31] https://www.mdpi.com/2071-1050/15/3/1849

Energy value benchmark

Possible benchmark values for the LCA calculation can be:

1. The Danish building regulations maximum permitted emission of 12 CO_2-eq/m^2/year.
2. The maximum emission of CO_2-eq/m2/year at which any DGNB points could be received in the Danish DGNB 2020 manual [Green Building Council Denmark, 2021] 13,79 kg CO_2-eq/m^2/year.
3. Chosen reference buildings from (Zimmerman et al., 2020) which contains LCA reference values for 60 different Danish buildings.

Energy use benchmark

A benchmark value for the buildings energy use could be made using an existing building from the University Park (Universitetsparken) which has been constructed in the same time period as the buildings which are being renovated in the University City (Universitetsbyen).

Since the University City contains renovations of existing buildings the LCA calculation and corresponding report should contain a description of how the emissions from existing constructions, which are going to be present in the new building are going to be addressed to be in accordance with relevant standards and avoid the risk of double counting.

Method Description

The method to be followed is described in the "DGNB 2020 manual" (Green Building Council Denmark, 2021). DGNB indicates which phases are included, and has a precedent for "cut-off", although it is not always clearly stated.

The LCA calculations are based on **buildings 1790 and 1791** (new build, and part of BSS) and in the document "ENV1.1 – LCA – nybyggeri_præ2".

It should be mentioned under calculation assumptions that DGNB 2020 requires that an uncertainty factor of 30% be imposed on all generic data, which affects the results to a great extent, since the LCAs in present state are made with generic data from the German database "Økobau". In order to give producers a possibility to differ in their EPD or their LCA calculation (including upcycling or other relatively less LCA heavy production methods and transport etc.) there has to be a possibility to use more specific material data.

One method could be looking on another ISO standard or adding product specific LCA calculations, parallel the generic Økobau database.

Investigate: would it be more relevant to use carbon footprint ISO 14067:2018 (https://www.iso.org/obp/ui/#iso:std:71206:en) this is not the normal standard and it also will require more intense work due to the in detail assessment on every material.

Calculation method for renovation projects

In the BSS project the LCA calculations will focus on: **building complex 1810** and **building complex 1830** (Clarification, all buildings starting at 183x are called 1830 complex).

Renovation LCA calculation - there is not yet a standard, development is based on innovation development and the DGNB 2020 manual.

Comparison with new build projects building 1790 and building 1791

- The calculation is based on the method described in the DGNB 2020 manual (Green Building Council Denmark, 2021), however with the following clarification. Materials that are already part of the building are not included in the LCA, as the environmental impact of these registers should be attributed to the building's "first life" (the building's time as a hospital).

- COWI development with the twist on "design for disassembly" -starting with the actual built house and evaluates the different building parts potential for a re-assembly (disassembly design process, as presented in GA, Chania). If the building is made with assemblies that can be disassembled again, points can be obtained in DGNB (10% calculated reduced discharge). Example, by actively finding materials in constructed buildings, it could give extra points, if the material is reused keeping the high embedded energy into "next use". The "embedded energy" scale encourages the reuse of material in the high energy class (structural element reused in the same embedded energy class, gives more points, instead of degrading the material to e.g., gravel)
- Resilience thinking prolong the embedded energy when it is easier to change the use of the building throughout the building lifespan. DGNB's alternative planning solutions or differentiated use do not need to be considered directly in the LCA. DGNB criteria:
    - SOC3.3 - Floor layout: typically documented with floorplans and possibly photos
    - ECO2.1 – Flexibility and adaptability: typically documented with floorplans.

Reference building:

Investigation: to see if there are "old buildings in the University Park" that has had a LCA calculation. The regurgitative just came into the Danish building code so there are maybe none already calculated.

Status: We have not found any LCA calculations in the University Park and there in no relevant data to compare with. The New Danish regulations asking for LCA calculations has only been active in 2023 and there has not yet started any new project in 2023 in the University Park.

In relation to the choice of reference building/value, there are four options:

AU LL is referring to option 3, as the benchmark-method that gives the highest accuracy.

1. We can refer to the requirement in the building regulations and use it as a reference. This currently means that both buildings in the LCA calculation fall outside the requirement. By mentioning DGNB's safety factor on generic materials, it can be argued that the LCA calculations with generic data should have an environmental footprint of less than 15.6 kg CO_2/m^2/year. However, this still means that the 1970 building has a CO_2 emission of more than the reference value.

2. "CO_2 payback time" for the renovated buildings by looking at:

The environmental impact from energy consumption before and after the renovation. The environmental impact of renovating versus building new and having to comply with building regulations. (With this approach, we must focus on the challenges with the buildings' static system, which means that the environmental impact will be greater than expected).

3. We can possibly refer to the with "LCA calculations for 60 buildings" Build report, that also has its limitations in Build's calculation basis. There are not any buildings in the Build report that can be directly compared to the round 800 persons auditorium in University City, Building 1790).

https://build.dk/Pages/Whole-Life-Carbon-Assessment-of-60-buildings.aspx

4. The "Build" report Assessment and approaches in the Build report on renovation describes for different time-eras. Danish context, is one of the broadest research projects up to date. https://vbn.aau.dk/da/publications/build-levetidstabel-version-2021

Life Cycle Assessment

Object of Assessment	The assessment will be performed at the scale of the buildings. The environmental impact of each building in the LL will be calculated individually.
Goal Definition	The goal is to document compliance with the Danish building regulations, which require a maximum emission of 12 kg CO_2-eq/m^2/yr with a calculation period of 50 years. The LCA will also be used to document the buildings' environmental impact as a part of the DGNB certification of the individual buildings.
Scope of Assessment / System Boundary	The following phases will be included in the LCA: A1-A3, B4, B6, C3, C4, and D.
Impact Categories to be analysed	GWP (kg CO_2-eq/m^2/yr)
Functional Unit	kg CO_2-eq/m^2/yr (With a calculation period of 50 years)
Normative /Standards	The LCA will be performed in compliance with the guidelines laid out in the Danish building regulations. The requirements in the Danish building regulations are based on the standard DS/EN 15978:2012, with minor clarifications and modifications. Some details of the calculation basis are still in the process of being defined, based on the limited experience, and guidelines, and related to the performance of LCAs for renovations in a Danish context. The service life of the individual building parts will be based on the lifetimes that have been defined in the 2021 report from AAU Build (Haugbølle et al, 2021). Thereby ensuring that the calculation complies with the in Denmark standardized LCA method.
Software and database	The assessment will be based on the tool LCAbyg , which performs LCAs in compliance with the Danish building regulations and the Danish DGNB.
Timespan	50 years

Table 91: Aarhus LL Life Cycle Assessment

3.6 Prague LL baseline data collection

Prague LL is composed by 4 existing buildings from the CTU but the Faculty of Civil Engineering (Building B) is the main one in PROOBNO and therefore Baseline data is collected for this specific building. Prague LL is the follower of Aarhus LL in the PROBONO project.

3.6.1 General info for the buildings baseline

Name of the Building	Building B of Faculty of Civil Engineering
Address	Thákurova 2077/7
City	Prague

Country	Czech Republic
Owner/Partner in charge of the building	The Czech Technical University in Prague
Year of construction	1970's
Year of renovation (if any)	-
Brief description of the renovation (if any)	-
Type of building	Higher Education School
Building main use	University classrooms and teachers' offices
Number of floors above the ground (including ground floor)	9
Number of floors below the ground	1
Number of dwellings/rooms in total	1,632
Number of dwellings/rooms per floor	181
Other services within the building (if any)	-
Number of people in the building (average)	N/A
Total building surface [m^2] Groos area	23,862
Please indicate surface Gross area definition (it can vary depending on the country, local regulations, etc.)	total gross area including the thickness of the building envelope
Total building surface [m^2] Net floor area	22,719
Please indicate net floor area definition (it can vary depending on the country, local regulations, etc.)	Floor area excluding walls
Total building volume [m^3]	2,231,037
Weather conditions (Köppen climate classification)	Humid continental climate
Altitude [m]	221
Location [coordinates]	Thákurova 2077/7 – Mapy Google

Table 92: Prague LL general info

Dwellers/Occupancy profile	
Average age - Select from 0 (Young people) to 10 (Old people)	3
Average educational level - Select from 0 (Low educational level) to 10 (High educational level)	10
Workers/Unemployment - Select from 0 (100% Unemployed people) to 10 (100% Employed people)	10
Tenants/Owners - Select from 0 (100% Tenants) to 10 (100% Owners)	0

Table 93: Prague LL Occupancy social info

Occupancy												
Indicate the typical % of monthly building occupation (being 0% not occupied; 50% partially occupied; 100% fully occupied)												
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Week days	100%	100%	100%	100%	100%	50%	5%	5%	30%	100%	100%	100%

Weekends	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Indicate the typical % of daily occupation for the building (being 0% not occupied; 50% partially occupied; 100% fully occupied)		
Hourly	**Week day**	**Weekends/Holidays**
0 - 6	0%	0%
6 - 7	2%	0%
7 - 8	30%	0%
8 - 9	100%	0%
9 - 10	100%	0%
10 - 11	100%	0%
11 - 12	100%	0%
12 - 13	100%	0%
13 - 14	100%	0%
14 - 15	100%	0%
15 - 16	50%	0%
16 - 17	50%	0%
17 - 18	20%	0%
18 - 19	10%	0%
19 - 20	2%	0%
20 - 21	0%	0%
21 - 22	0%	0%
22 - 23	0%	0%
23 - 24	0%	0%

Table 94: Prague LL occupancy profile

Figure 31: Prague LL representative pictures

Figure 32: Prague LL surroundings areas

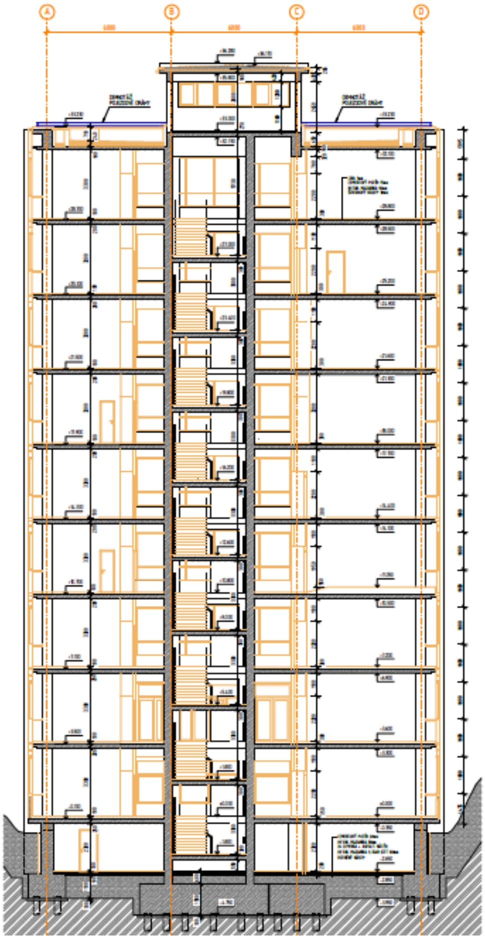


Figure 33: Prague LL cross section

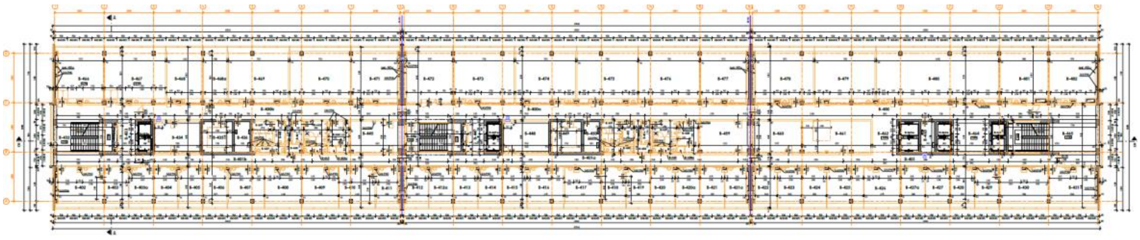


Figure 34: Prague LL floor plans

3.6.2 Envelope passive elements

<table>
<tr><td colspan="2">**External Wall (A, B, …)**
If needed, add additional external walls and components</td></tr>
<tr><td>**U-value [W/m²·K]**</td><td>2.1</td></tr>
<tr><td colspan="2">**Description** (in which wall apply, e.g. north, south, east, west)</td></tr>
<tr><td colspan="2">Light weight curtain wall from 1970's</td></tr>
<tr><td colspan="2">**Representative picture**</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Table 95: Prague LL External wall

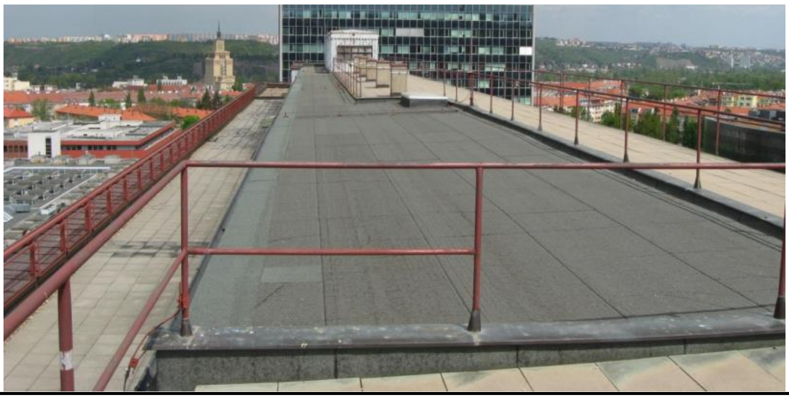
External Roof (A, B, …) If needed, add additional external roofs and components				
Layers from inside to outside	**Thickness [m]**	**Conductivity [W/m·K]**	**Density [kg/m³]**	**Specific heat [J/kg·K]**
concrete with reinforcement	0.18	1.58	2,400	1,020
mineral thermal insulation	0.14	0.037	140	800
U-value [W/m²·K]	0.248			
Representative picture				
				

Table 96: Prague LL External roof

Ground floor (A, B, …) If needed, add additional ground floor and components				
Layers from inside to outside	**Thickness [m]**	**Conductivity [W/m·K]**	**Density [kg/m³]**	**Specific heat [J/kg·K]**
Concrete	0.05	1.3	2,200	1,020
concrete with reinforcement	0.25	1.58	2,400	1,020
U-value [W/m²·K]	1.863			

Table 97: Prague LL ground floor

3.6.3 Energy. Active elements

Service/Source	**Heating**	**Cooling**	**Ventilation**	**Lighting**	**Appliances**	**DHW**	**Other**
Electricity			x	x	x		
District heating/cooling	x					x	
Renewable energy (ST, PV, Biomass, etc)			x	x			

Table 98: Prague LL Energy active elements summary

Heating system If needed, Add additional Generation equipment tables	
Generation equipment A	
Type (e.g. Gas Boiler, gasoil boiler, biomass boiler …)	District heating
Centralized or individual	centralized
Number of units	N/A
Manufacturer and model	N/A
Nominal Power (kW)	N/A
Performance (%, COP)	99%
Type of fuel	steam
Year of installation	1970’s
Tª set point (indoor temperature) (ºC)	20
Terminal units A	
Type (e.g. radiators, fancoils, radiant floor …)	radiators
Number of units	N/A
Manufacturer	N/A
Power (kW)	N/A
Heated zones	classrooms, corridors, offices
Year of installation	1970’s

Table 99: Prague LL heating system technical details

Domestic Hot Water "DHW" system

If need it, Add additional Generation equipment tables

Generation equipment A	
Type (e.g. Boiler, heat pump, …)	Local water heaters
Same generator as heating? (Y/N)	N
Centralized or individual	individual
Number of units	N/A
Manufacturer and model	N/A
Nominal Power (kW)	N/A
Performance (%, COP)	99%
Type of fuel	electricity
Year of installation	1970's - 2010's
Storage (Y/N)	N

Table 100: Prague LL DHW system technical details

2019					
District Heating			**ELECTRICITY**		
Timestamp	**Consumption (MWh)**	**Price (€)**	**Timestamp**	**Consumption (MWh)**	**Price (€)**
January	**445.64**	**39,011**	**January**	**48.04**	**5,799**
February	**384.76**	**33,681**	**February**	**41.36**	**4,992**
March	**267.06**	**23,378**	**March**	**46.74**	**5,641**
April	**194.43**	**17,021**	**April**	**44.63**	**5,387**
May	**160.22**	**14,026**	**May**	**45.18**	**5,454**
June	**23.05**	**2,018**	**June**	**45.23**	**5,459**
July	**22.17**	**1,941**	**July**	**39.82**	**4,806**
August	**14.59**	**1,277**	**August**	**32.86**	**3,967**
September	**49.87**	**4,365**	**September**	**39.65**	**4,785**
October	**112.24**	**9,826**	**October**	**45.36**	**5,475**
November	**280.92**	**24,591**	**November**	**45.64**	**5,509**
December	**460.44**	**40,307**	**December**	**41.97**	**5,066**
Primary Energy factor (kWh nPE/kWh)		**0.9**	**Primary Energy factor (kWh nPE/kWh)**		**2.6**
Emission (kgCO₂/kWh)		**0.39**	**Emission (kgCO₂/kWh)**		**1.01**

Table 101: Prague LL energy consumptions year 2019

Monitoring system		
ENERGY SYSTEM	**Y/N**	**Location**
Heating	Y	Within building but for all buildings A, B, C and D

Cooling	N	-
DHW	N	-
Ventilation	N	-
Lighting	Y	Within building but for all buildings A, B, C and D
Appliances	Y	Within building but for all buildings A, B, C and D
INDOOR VALUES	**Y/N**	**Location**
Temperature	N	-
Relative Humidity %	N	-
Illumination level	N	-
CO_2 concentration	N	-
Occupancy sensors	N	-
EXTERNAL VALUES (Weather station)	**Y/N**	**Location**
Temperature	Y	-
Relative Humidity %	Y	-
Illumination level	N	-
Radiation	N	-
Wind Speed	Y	-
Wind Direction	Y	-
Rain	N	-

Table 102: Prague LL monitoring systems availability summary

Building Energy Rating BER
G

Table 103: Prague LL Building Energy Rating

E-Mobility	
MOBILITY SYSTEM	**Y/N**
E-Vehicles	N
Infrastructure/Charger	N

Table 104: Prague LL E-mobility aspects

4 Conventional construction processes references

The construction industry is considered as one of the largest consumers of material resources, water, and energy, and it accounts for up to 39% of total CO_2 emissions to the environment and generates approximately 35% of the total landfill waste (I.Z. Bribian et al., 2011). Concurrent engineering ensures that product life-cycle requirements such as service, quality, production, and time-to-market, are considered at the design stage (G.G. Rogers et al., 1997). This approach sets the framework for unlocking considerable benefits and the development of novel construction methods such as modular construction. The concept of designing products specifically for the simplification of manufacturing results in significant reductions in manufacturing costs and product lead-times when applied to the context of buildings. Its implementation requires close coordination of multiple stakeholders and supply chain processes. However, recent advances in communication, collaboration and information exchange, enable concurrent construction and seamless supply chain integration.

When compared to conventional material production and construction methods, modular construction results in lower project costs for a variety of building types that can reach up to 20% in capital costs savings with most projects savings being roughly 5-10%. Several projects developed in the 1990s and early 2000s illustrated the benefits of modular construction in an applied setting confirming its potential to significant cost and scheduling savings. Since that period, advances in monitoring, analytics and computing, in terms of the optimization of supply chain performance can further improve the performance of modular construction. In cases even higher savings were reported as in the case of modular construction of power plants where it is found to reduce capital costs by 20% and scheduling costs by approximately 40%. The efficiency benefits of modular construction arise from:

- Work performed indoors in a more controlled environment, rather than outdoors on-site in an unpredictable and frequently unsuitable environment, and
- From shop labour rates, which are usually lower than those onsite.

This results in reduced costs from the following cost-related activities:

- Fewer onsite construction man-hours,
- Less onsite management,
- Lower financing costs from decreased construction time,
- Reduced site mobilization effort,
- Completing the project early, and
- Increased domestic/international competition for fabrication and assembly contracts.

Labour rates in fabrication facilities are also normally lower than onsite construction because of the uncertainties involved in onsite work. Furthermore, the reduction of onsite man-hours decreases the need for onsite management as well as the overall construction time. It also reduced the amount of equipment and labour located in remote construction sites, and reduces the need for housing and other living facilities onsite.

Time savings in modular construction arise because the design and procurement activities usually overlap. This overlap is possible due to the fact that the general contractor of a modular construction project is involved at an early point in the project, during the design and engineering phase, rather than becoming involved later, such as in the procurement (bid) phase.

Reduced schedule is an advantage that develops from several specific schedule- effective items such as:

- Performing the design and procurement simultaneously,
- Working in parallel,
- Increasing the control of schedule ,
- Higher productivity from the permanent work force in fabrication facilities, and
- The opportunity to train operators at fabrication facilities rather than on-site.

In modular construction about 85-90% of the work is done off-side and the remaining 10-15%, including the foundation and utility hook-ups, is done on-site on the final project site. In all phases of the life cycle of a building, materials and energy are used, such as the raw material extracting and processing, product and component manufacturing, transportation of products and components, and energy used for heating, cooling, and lighting of the building. While there are some identical tasks in the life cycle of conventional and modular buildings, there are also many differences, which can be opportunities for reducing the consumption of energy and material.

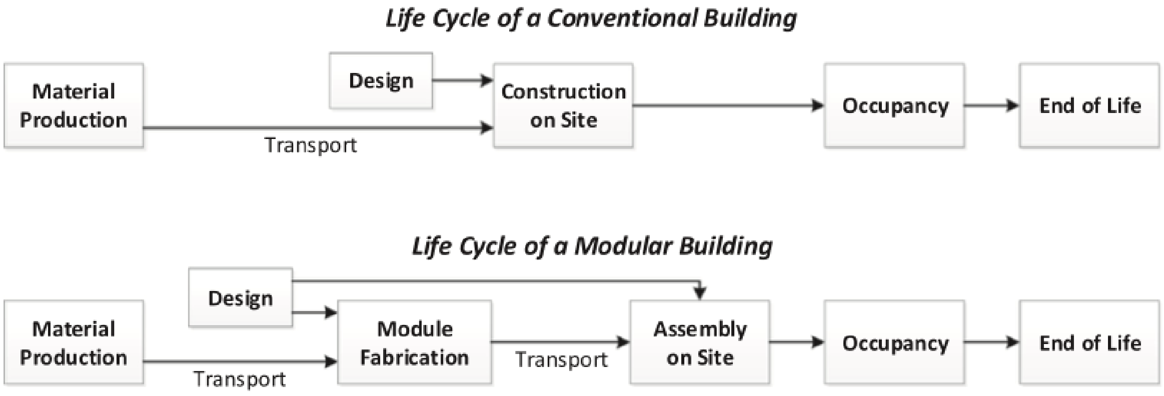


Figure 35: Life cycle of modular versus conventional buildings (M.Kamali et al., 2019)

As illustrated in Figure 35, the life cycle of a conventional building consists of four main phases including the material production phase, the design and construction phase (henceforth the construction phase), the occupancy (also called use or operation) phase, and the end of life phase. Similarly, in case of a modular building, there are four phases; however, the tasks in the construction phase comprises building design, module fabrication, transportation of modules to the project site, and assembly on site. In order to perform a LCA to evaluate the environmental impact of modular construction (M. Kamali et al., 2019), the characteristics of the material production and construction phases are further examined:

- Material Production Phase
    - The material extraction and process phase involve the primary resources such as wood, concrete, and iron ores are harvested/ extracted. Then, they are converted into processed materials and engineered products usable for certain construction purposes.
    - The material transportation phase involves shipping the extracted raw materials to manufacturing plans for processing or the construction site for building.
- Conventional Construction Phase

  - Construction and installation phase comprise all on-site activities lead to the construction of the final building on the project site (e.g., foundation, structure, flooring, roofing, finishing).
  - Product and worker transportation include the delivery of the processed materials and products to the project site as well as the workforce commuting to and from the project site.
- Modular Construction Phase
  - Construction and installation include all off- site activities towards fabrication of the building's modules in the modular manufacturing center (i.e., modular factory) and on-site activities related to the site work.
  - Product and worker transportation comprise the delivery of the required materials and products to modular factory and the delivery of the completed modules to the project site as well as the employee's commute to and from work (off-site and on-site).

To analyse the six phases in terms of cost and duration savings, data require to be collected on the duration and cost of each phase for various types of buildings and supply chain set-ups as illustrated in the table below.

Construction method	Activity category	Data variable
Conventional and modular	Material Extraction/ Transport	Materials and products (types, quantities)
Conventional	On-site construction and installation	Construction rate and cost per building type, building stage (e.g. foundation, floors, panels) and main construction material (e.g. wood, concrete, steel)
Conventional	Product and worker transportation	Worker transport (number, workdays, commute modes) Material/ product transport (supplier-site, distances, transport modes)
Modular	Off-site construction and installation	Manufacture rate and cost per building type, building stage (e.g. foundation, floors, panels) and main construction material (e.g. wood, concrete, steel)
Modular	Product and worker transportation	Worker transport to factory (number, workdays, commute modes) Worker transport to site (number, workdays, commute modes Material/product transport to factory (supplier-factory distances, transport modes) Module transport (factory-site distance, transportation mode)

Table 105: Data to be collected from the different construction stages

In a detailed review of papers focusing on prefabricated construction (Z.Li et al., 2014), it is observed that the most common data collection methods involve:

- Surveys, which are typically carried out via face-to-face interviews involving industry practitioners with or without the use of standardized questionnaires, and
- Case study analysis in which a particular case is examined in high detail gaining first-hand understanding of one or more building projects.

In the context of PROBONO project, both approaches are viable at there are several LLs that can be used as testbeds for collecting data and achieving in-depth understanding either for modular construction and its potential expansion at a neighbourhood level. Analysis can be complemented with unstructured interviews with project experts that can also provide information on the data describe in Table 105. Furthermore, cost and timing indices can be created by comparing individually the calculated impact on benchmark buildings in the various phases to comparatively evaluate their performance. This can be achieved following the methodology implemented for environmental assessment (M.Kamali et al., 2019), by introducing various cost and timing impact indices and applying analytic hierarchy process (AHP). For performing the AHP, the pairwise comparison method is used for determining the relative importance (weight) of a parameter, such as a criterion or an alternative, with regard to the other parameters. The first critical step in construction of an AHP based framework is to determine suitable parameters to be placed in different levels as the AHP hierarchy including primary goal, criteria and attributes (sub- criteria), and alternatives.

5 LCA/LCC/s-LCA baseline considerations

As described in D6.1 – Evaluation Framework, in PROBONO project the LLs will implement different solutions in the context of Green Building Neighbourhoods (GBN), and the “Life Cycle Methods” are options for assessing the sustainability of each project throughout their life cycle. These assessments include the environmental, economic and socials aspects, by applying the methodologies of the Life Cycle Assessment (LCA), Life Cycle Costs (LCC) and Social Life Cycle Assessment (s-LCA).

Since each Living Lab has its own set of solutions, their evaluation approach and scopes are unique, and therefore, establishing a common baseline means allowing for adaptation and flexibility, so that each partner can fill in the requirements established in the Baseline Template according to their needs. Not all objects of assessment are yet defined, thus, the purpose of the baseline LC template at this moment of the project is to provide the partners with a set of steps that need to be addressed in order to start the assessment process and data collection.

5.1 LCA baseline definition

The Life Cycle Assessment will be performed as part of task T6.4, and the baseline template was developed for each LL to start defining the exact object of assessment and the main goal for this evaluation, which will help understanding the extent of the study. The requirements to be provided at this moment follow the steps of the standard LCA procedure, as defined in EN 15978:2011 (Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method), and ISO 14040:2006 (Environmental management - Life cycle assessment - Principles and framework).

At this stage, it is required that all LL define the type of analysis, impact categories to be evaluated, and set of data that needs to be collected, timeframe of the analysis, and this will guide the study defining the system boundaries and its functional units. Throughout the entire study, transparency is critical to the impact assessment to ensure that assumptions are clearly described and reported.

Object of analysis

Each LL has a different solution or project which will be the object of the assessment, that might differ in the scale and complexity. They may consist of a product, a building, or a district, and for each of them, different and specific normative might apply, besides the before mentioned ones.

Goal Definition

The goal and scope of a LCA should be defined in the beginning, since it provides the general reason why the LCA is being done, and should answer to questions about the intention of the study, such as: why is this LCA being performed? What is my objective with this analysis? And what is the extension of the study?

Within PROBONO, the purpose of the analysis might be comparing different construction methods and materials, identifying the hot spot of the life cycle of a certain building, analysing different scenarios such as before and after a renovation, or developing an Environmental Product Declaration of a new material, to name a few. For each of these goals and objective of analysis, there is a scope that will be most appropriate for the study.

Target audience

Knowing who will be the target audience will influence on how to communicate the results of the LCA, and the extent of details of the study, the level of details that it should be documented, the interpretation of results and its technical level of the reporting.

Scope of Assessment / System Boundary

It defines the activities and processes that will be included in each life-cycle stage for the LCA analysis and those that will be excluded, and the extent and depth of the analysis, specifying the decisions of the process, with corresponding justification from existing normative and Product Category rules.

If a comparative LCA is anticipated, then it is critical that the system boundary be established in the same way for the systems being compared.

At this stage, information about the context of the analysis is also relevant, such as defining the geographical and temporal boundaries and settings of the study and the level of technology that is relevant for the processes in the product system. This will determine the effects of transportation, local energy matrix and climate, supporting the decision-making of choosing certain products and materials that represent less impact to the object of analysis, according to the goal and scope previously defined.

Impact Categories

The impact categories evaluate the significance of potential environmental impacts of the object of the analysis, where the input flows of the life cycle inventory are translated into potential contributions to the different impact categories that are modelled in the study. Depending on the objective of the LCA, different Impact Categories might be selected to be evaluated and interpreted.

Functional Unit

The functional unit can be defined as the unit of comparison that assures that the products being compared provide an equivalent level of function or service. For a building LCA, the functional unit might be "the entire building supplied from design to demolition for a 50-year service life," or it might be computed on a per-square-meter basis and limited to one life cycle stage (e.g., construction).

When it is the case of following an EPD or PCR, the functional unit might already be defined, and must be followed accordingly.

Normative /Standards

Depending on the object of assessment, different normative can be applied to define the scope of the study. The baseline normative to perform an LCA is listed below and described in detail in D6.1 – Evaluation Framework.

- EN 15978:2011 (Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method)
- ISO 14040:2006 (Environmental management - Life cycle assessment - Principles and framework)
- ISO 14044:2006 (Environmental management — Life cycle assessment — Requirements and guidelines)
- EN 15643:2021 (Sustainability of construction works - Framework for assessment of buildings and civil engineering works)
- EN 15804:2012+A2:2019 (Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products)
- ISO 14025:2006 (Environmental labels and declarations — Type III environmental declarations — Principles and procedures)

Additional set of rules or documents may apply for each LL study, such as existing certification schemes (DGNB, BREEAM, LEED), PCR or EPDs. In each specific case, the normative should be referenced as a way to rationalize the choices of the study.

Software and database

Nowadays there are many options of tools and software that facilitate the calculation of the Life Cycle Assessment and operate aligned with the existing standards. These tools might vary in their database, affordability, and user friendliness.

Each Living Lab should choose to assess their work within the project according to the tools and expertise they have available, and due to the extensive market option for calculation tools, the chosen software and database must be declared to ensure it complies with the normative.

State of the Art

When applicable, scientific papers and official documents that will be used as a baseline information for the LCA must be mentioned to ensure transparency.

Timespan / Reference Service Life

The Reference Service Life (RSL) of the object of study defines the expected life service of the object of study in years – and it can be applied from the component (material or product) to an assembly (building elements or building itself). For a building, for instance, 50–80 years is habitually used as reference study period in assessments for the use stage, even though the physical structure of an average building has the potential to last longer.

The components of the building also need to have an estimated life span, and that will be crucial for the calculation of the use stage impacts, regarding the maintenance, repair, replacement and refurbishment phases.

Inventory List

The inventory analysis collects information about the physical flows in terms of inputs of resources, materials, semi-products and products and the output of emissions, waste and valuable products for the product system. The outcome of the inventory analysis is the life cycle inventory, a list of quantified physical elementary flows for the product system that is associated with the provision of the service or function described by the functional unit.

Life Cycle Assessment Stages

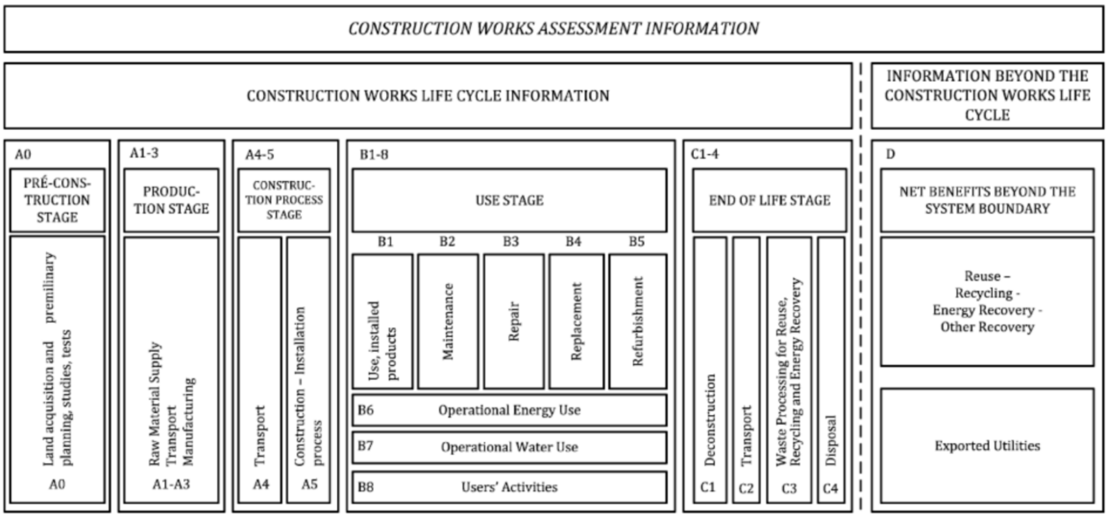


Figure 36: Life Cycle Modules and Stages. Source: EN 15643:2021.

The baseline template includes a table containing all LCA stages. At this moment of the project, it would be enough for each partner to identify the stages that will be part of their scope of study, and what information they will need to collect to finally perform the LCA. As all the requirements, this too will depend on the object and goal of the assessment.

5.2 LCC baseline definition

LCC Purpose

An economic assessment should consider all costs of a product or system throughout its lifetime (Boverket, 2013). However, business models for building renovations are today often limited to the actual investment, disregarding maintenance, operational costs or life span issues.

For energy efficiency renovations, which often have high up-front investments but very low operational costs through reduced energy need, this means that the benefits of the investment risk being left out of the business calculations. In order to further investigate this problem, Life Cycle Costs (LCC) will be calculated for the different LLs of PROBONO project.

LCC Methodology

The LCC methodology will follow ISO standard 15686-5, Buildings and constructed assets - Service life planning - Part 5: Life-cycle costing, 2017 as guidance in the process of defining and developing the LCC models, ISO 15686-8 - Part 8: Reference service life and service-life estimation In addition to that, LCC will take into account the life cycle stages defined in EN 15978:2011 (Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method) and EN 16643:2021 (Sustainability of construction works - Framework for assessment of buildings and civil engineering works), in order to be aligned with LCA cycles stages.

The next figure shows the costs that should be considered in LCC assessment (inside the grey box). On the other hand, the environmental costs (outside the dashed line) have not been included in the LCC models since they are not mandatory and usually negligible for building assets.

In addition, the figure presents wider costs and incomes that should be used for whole life costs (WLC) assessment.

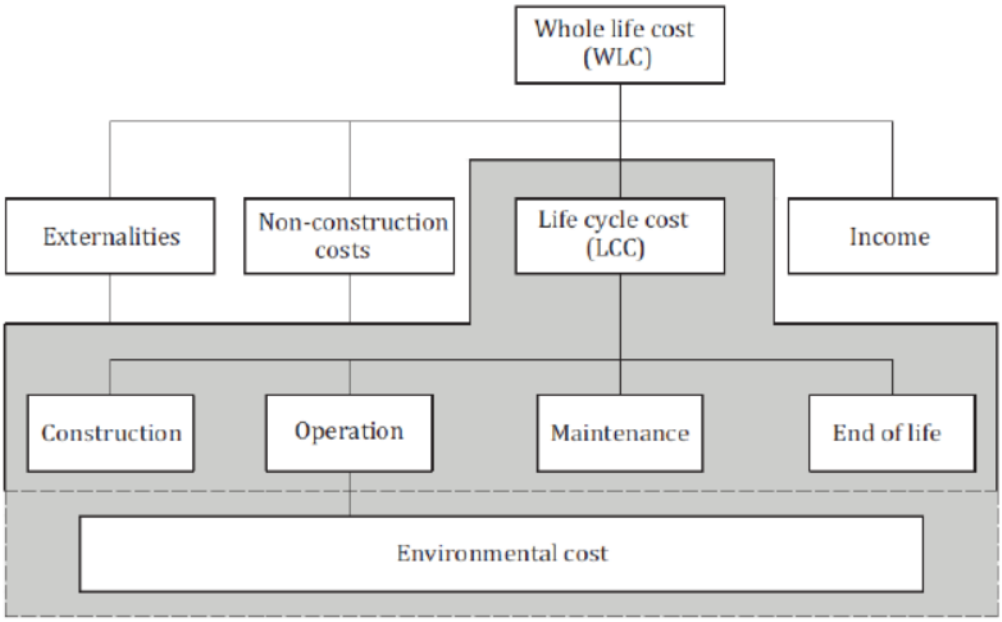


Figure 37: WLC and LCC elements based on the ISO 15686-5.

As a result, the components that make up the project's LCC models are:

- **Construction cost:** the initial construction costs (at time zero). For the PROBONO LCC models, construction costs cover the incurred costs of implementing each renovation action, including materials and components costs, transport to building site, construction and installation costs (including labour, machinery and energy consumption).
- **Operation Cost**: costs incurred in running and managing the facility or built environment. For PROBONO LCC models, operation costs refer to energy costs for heating, cooling and electricity over the period of analysis.
- **Maintenance cost**: total of necessarily incurred labour, material and other related costs incurred to retain a building or its parts in a state in which it can perform its required functions. For PROBONO LCC models it only refers to the replacement/renewal of components at the end of its life.
- **End of Life cost**: net cost or fee for disposing of an asset at the end of its service life or interest period.

Scope

The scope or the present study is to assess only the LCC of the demo sites. Therefore, only the elements inside the grey box have been considered. On the other hand, the environmental costs (outside the dashed line) have not been included in the LCC models since they are not mandatory and usually negligible for building assets.

Regulation / certification

The reference standard for calculating the life cycle costs of each life cycle stage shall be EN 15459, ISO 15686-5 and EN 16627. The reference standard ISO 15686-8 provides a methodology for calculating and estimating the design life of elements and components.

LCC Scenarios

The present analysis will assess two LCC scenarios:

- **Reference scenario:** the "Reference scenario" concerns the situation before PROBONO refurbishment. It is a scenario where nothing is done to the building, and therefore it remains functional only for 15 more years.
- **PROBONO scenario:** the "PROBONO scenario" explores the renovation measures carried out in the demo-sites, allowing the buildings to operate for 30 more years.

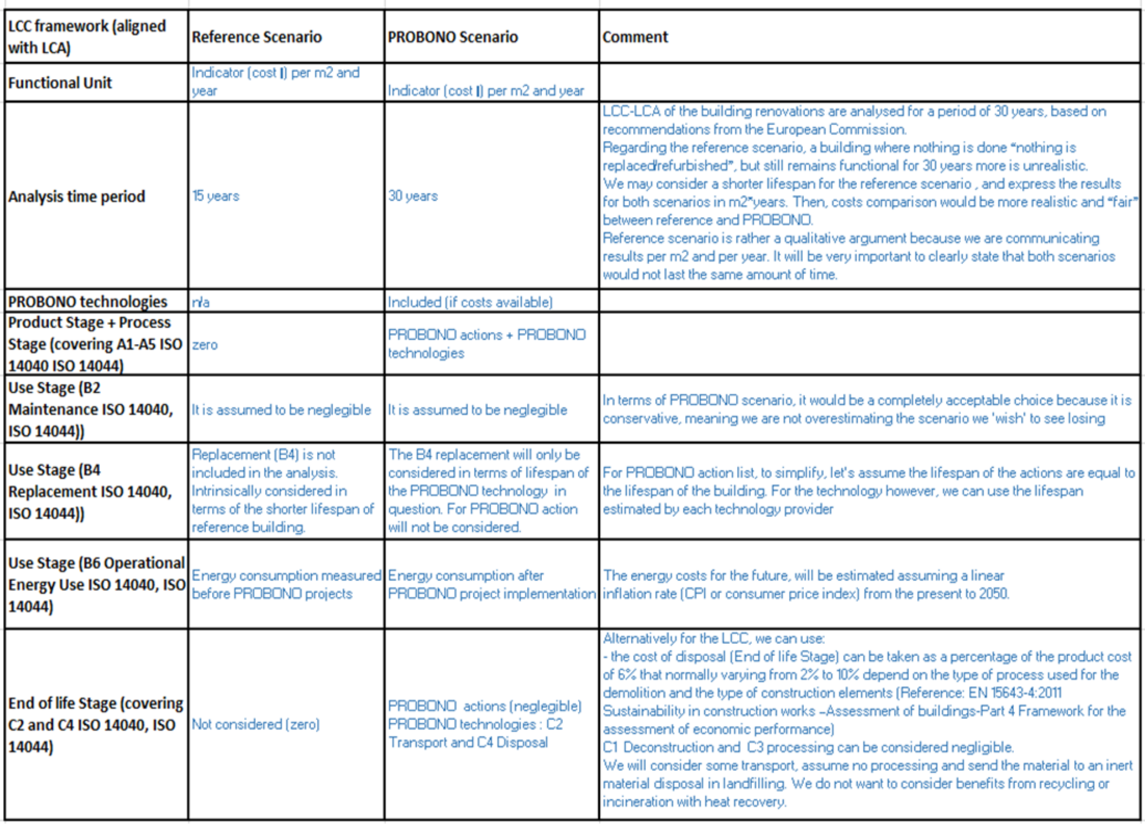
It is important to mention, that usually, an LCC study would compare different alternatives of renovation in order to select the most cost-effective one. However, the present LCC focuses on the comparison of the "non-renovated" and "renovated" building, because the main goal of the project, is to evaluate the energy cost savings introduced by PROBONO renovation project (instead of selecting one renovation alternative among various alternatives).

Functional unit

Typically, LCC analysis of buildings are expressed in estimated costs per square meter (€/m^2). The LCC results referring only to the PROBONO renovation scenario will be presented in €/m^2. However, the results which compares the PROBONO and Reference scenarios will be expressed in estimated costs per square meter per year (€/m^2*year), in order to account for the different duration periods of PROBONO and Reference building scenarios.

Duration of the analysis, system boundaries and assumptions

The table below summarises the duration, system boundaries and assumptions used for modelling PROBONO and Reference scenarios.



LCC framework (aligned with LCA)	Reference Scenario	PROBONO Scenario	Comment
Functional Unit	Indicator (cost I) per m2 and year	Indicator (cost I) per m2 and year	
Analysis time period	15 years	30 years	LCC-LCA of the building renovations are analysed for a period of 30 years, based on recommendations from the European Commission. Regarding the reference scenario, a building where nothing is done "nothing is replaced/refurbished", but still remains functional for 30 years more is unrealistic. We may consider a shorter lifespan for the reference scenario , and express the results for both scenarios in m2*years. Then, costs comparison would be more realistic and "fair" between reference and PROBONO. Reference scenario is rather a qualitative argument because we are communicating results per m2 and per year. It will be very important to clearly state that both scenarios would not last the same amount of time.
PROBONO technologies	n/a	Included (if costs available)	
Product Stage + Process Stage (covering A1-A5 ISO 14040 ISO 14044)	zero	PROBONO actions + PROBONO technologies	
Use Stage (B2 Maintenance ISO 14040, ISO 14044))	It is assumed to be neglegible	It is assumed to be neglegible	In terms of PROBONO scenario, it would be a completely acceptable choice because it is conservative, meaning we are not overestimating the scenario we 'wish' to see losing
Use Stage (B4 Replacement ISO 14040, ISO 14044))	Replacement (B4) is not included in the analysis. Intrinsically considered in terms of the shorter lifespan of reference building.	The B4 replacement will only be considered in terms of lifespan of the PROBONO technology in question. For PROBONO action will not be considered.	For PROBONO action list, to simplify, let's assume the lifespan of the actions are equal to the lifespan of the building. For the technology however, we can use the lifespan estimated by each technology provider
Use Stage (B6 Operational Energy Use ISO 14040, ISO 14044)	Energy consumption measured before PROBONO projects	Energy consumption after PROBONO project implementation	The energy costs for the future, will be estimated assuming a linear inflation rate (CPI or consumer price index) from the present to 2050.
End of life Stage (covering C2 and C4 ISO 14040, ISO 14044)	Not considered (zero)	PROBONO actions (neglegible) PROBONO technologies : C2 Transport and C4 Disposal	Alternatively for the LCC, we can use: - the cost of disposal (End of life Stage) can be taken as a percentage of the product cost of 6% that normally varying from 2% to 10% depend on the type of process used for the demolition and the type of construction elements (Reference: EN 15643-4:2011 Sustainability in construction works –Assessment of buildings-Part 4 Framework for the assessment of economic performance) C1 Deconstruction and C3 processing can be considered negligible. We will consider some transport, assume no processing and send the material to an inert material disposal in landfilling. We do not want to consider benefits from recycling or incineration with heat recovery.

Table 106: Time duration, system boundaries and assumptions used in the LCC models of PROBONO and Reference scenarios

Calculation Tools

A life cycle cost software tool (optional, instead of cost model for the project) can be used to make calculations according to a national cost optimal method, EN 15459 or ISO 15686-5.

Sensitivity Analysis

There is always a risk and uncertainty in the calculation of LCC, as it involves predictions of future behaviour, as well as input data which are often based on estimates or assumptions. ISO 15686-5 defines a sensitivity analysis as a test of the outcome of an analysis by altering one or more parameters from initial value(s). It further recommends it as a suitable technique for indicating the range of uncertainty and risk associated with specific LCC analyses. The sensitivity analysis can be used to investigate how variations in uncertain input data affect the LCC results, thereby indicating the robustness of the outcome and conclusions. According to ISO 15686-5, the selected data variation ranges for the sensitivity analysis should be probable and be examples of key assumptions which may have a significant effect on the LCC result the standard state e.g. assumptions on discount rates (Hedström, 2006).

The LCC calculations in PROBONO contain several parameters that can be decisive for the outcome, however it has been decided to investigate the discount rate and energy price development effects on the sensitivity analysis. The sensitivity analysis will help confirm if the ranking between the different scenarios assuming variation of these parameters.

The discount rate is selected, based on the recommendations of ISO 15686-5, as deciding on a discount rate is a complicated task and there is currently no consensus in how it should be done. Thus, in the sensitivity analysis the discount rate will be set to vary plus minus two percent (corresponding to a discount rate from three to seven percent).

The variable of energy price development is selected as it involves long term predictions affected by future behaviour - events can occur that are impossible to predict, e.g. a war in oil producing countries increasing the oil price, or a draught leading to lower water levels in the reservoirs which will increase energy prices- or can evolve differently to predictions, e.g. renewables penetration in European energy grids, which will lead to lower energy prices. Pace of penetration of renewables may vary, speeding or slowing down the shift in energy prices. Particularly, in the present LCC analysis, the energy price predictions for 2050 (end of PROBONO building lifespan) per country are based in models from literature, which in general, forecast scenarios with high penetration of renewables in the European Energy market, driving to lower electricity and heating prices. In order to consider the possible error of models in price forecast for 2050, in the sensitivity analysis the energy price development will be set to vary plus minus one percent.

5.3 s-LCA baseline definition

The Social Life Cycle Assessment is under ST6.4.3, building on the S-LCA methodology as defined in *D6.1: PROBONO Evaluation Framework,* which is the basis for the following section which is an adapted version of what was published in D6.1. As there are yet no official methodologies or standards for performing an s-LCA, the approach was developed based on the work of UNEP/SETAC. As of June 2022, the International Organization for Standardization, ISO, is working on a publication on the *Principles and framework for social life cycle assessment*. The approach suggested here, attempts to follow the standardized stages for LCAs as defined above, although the object of analysis and hence, the methodologies are very different.

Object of analysis

First step is, as for the LCA and LCC, to define the object of analysis which can span from a component in a product to buildings. However, it is important to keep in mind that if the object of analysis is large, then the complexity of the s-LCA will grow. This is due to the strength of the s-LCA which lies in assessing *all* components in a product, be it a lightbulb or a building, to create a comprehensive assessment throughout the lifecycle. On the other hand, this means that, the bigger the object, the more complex an assessment.

Goal definition

The goal of a specific s-LCA can vary but it should answer to the basic question of why the s-LCA is being conducted. Is it for instance to support sustainable design of products or, to understand how the product value chain contributes to the social development of its stakeholders? Next step is the scope definition which is about clarifying the object of the study, the *system boundaries* (defining which parts of the product system are part of the assessment) and the right methodology to assess this.

Identification of stakeholders

A key part of this first step, is to identify directly and indirectly related stakeholders through each life cycle stage. In this context, stakeholder refers to people who has been/are/will or could be impacted by the product or its components. The main stakeholder categories suggested in the UNEP framework are *workers, local community, society, users/consumers* and *value chain actors*. In some cases, it will also be relevant to consider *children* as an isolated stakeholder group. These stakeholder categories will need to be specified in the context of the specific object of analysis, according to the different life cycle stages.

Identification of impact subcategories

Next step is to identify the relevant impact subcategories, that is, identify where there will potentially be social or socio-economic impacts along the life cycle. This will require careful consideration of the as-is situation in the specific context. A good starting point is offered in the UNEP guidelines which are summarized in Table 107: List of stakeholder categories and impact subcategories (adapted from UNEP 2020, p. 23). The suggested impact subcategories should be adapted to the relevant sector and context specific social impact categories. E.g., the impact subcategory of “child labour” will very likely not be relevant in all life cycle stages.

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

Table 107: List of stakeholder categories and impact subcategories (adapted from UNEP 2020, p. 23)

State of the Art

This work will include an assessment of existing data sources which should be based on both generic and site-specific data sources as the relevant social impact indicators for the S-LCA will differ across countries. Following the Methodological Sheets (UNEP 2013), generic data refers to existing research and studies or information found on governmental, inter-governmental and multilateral web sites whereas site-specific data will be data or information gathered through site-visits, site-specific, existing research, interviews and surveys (UNEP 2013, p. 11).

As a final step, we suggest to consult the relevant stakeholders to prioritize and refine the impact subcategories. This could be done through surveys distributed to all stakeholders or, through direct engagements.

Inventory analysis

At this stage, the data and information needed to perform the assessment will be gathered. The information gathering should cover social and socio-economic issues related to the specific stakeholder for each of the social impact indicators.

The s-LCA will depend on three types of data: Quantitative, semi-quantitative (yes/no or rating scale responses) and qualitative (descriptive text) (UNEP 2013, p. 10). These data types should not be regarded as exclusive as they will often supplement each other. When defining the scope of the s-LCA and the assessment methodology for each social impact indicator, it is necessary to consider carefully the optimal solution. This should include ethical considerations of engaging with stakeholders in sometimes vulnerable contexts. Hence, the choice of methodology for performing the analysis of any given aspect of the S-LCA will have to be described and justified to ensure transparency and the possibility to go back and verify results. More details on the inventory analysis can be found in *D6.1: Evaluation Framework*, section 4.2.2.5.3.

6 Conclusions

D6.2 reports the baseline evaluation for the LLs of the PROBONO project in order to define for each of them the reference conditions to assess the impacts of the innovations once implemented. The first step on the baseline evaluation process was to have a clear definition of the baseline concept and to define a general baseline template based on the needs and requirements identified in the Evaluation Framework defined in D6.1. The template was defined considering the complete needs of the evaluation framework but it is relevant to mention that the specific scope of each of the LLs is different and therefore the information collected for each of the LLs depends on the final needs in their specific assessment process, the final impacts to be achieved and the availability of the reference data.

The defined template, has been shared with the LLs main representatives and the information has been collected and presented in this document. In general terms the information collected is about the main aspects of each of the LLs and their specific buildings, information about the passive and active elements and reference information needed to deploy the Life Cycle methodologies. It is also worth to mention that for example Madrid LLs is not existing yet and therefore the reference scenario is mainly based on normative. A similar approach applies to the Aarhus LL which is a completely new reconstruction of and old hospital with a completely different end use and therefore the reference scenario is based on normative and similar existing buildings in the campus. In the case of the other LLs they are currently existing and the information collected is the one representing their current conditions but the approach is slightly different for each of them as for example in the case of the Porto LL in which the assessment will be done at a campus level and not at building level as in the other Labs.

This reports also collects reference information related with the conventional construction processes in order to be able to compare then the innovative modular construction processes part of PROBONO with those more conventional and analyse the improvement in terms of time and cost.

In addition to the above, a brief description for each of the Life Cycle methodologies is included by focusing on the reference scenario aspects to be considered in the next stages of the project and once the Life Cycle methodologies (LCA, LCC and s-LCA) are deployed for each of the affected Living Labs.

As next steps, the baseline evaluation of the LLs allows to define the picture of the LLs prior to the implementation of the innovations and therefore will allow to know the effectiveness of the impacts achieved at the end of the project and once the innovations have been implemented in each of the LLs. The assessment process will be done through the different activities in T6.4.

In addition to the above, the baseline evaluation collects some preliminary information about the current status for each of the LLs in terms of monitoring systems already implemented and therefore will allow to define in the next steps of the project the complete monitoring plan needed to cover all the requirements of the evaluation process through the activities deployed in T6.3.

To conclude, it is also relevant to mention that if additional reference data is identified as needed during the project execution for specific activities of the project, the reference data collected will be included as an Annex in future Deliverables of WP6.

7 References

Documento Básico HE [Spanish] [*Basic Document HE*] (2022, June 14). Ministerio de Transportes, Movilidad y Agenda Urbana. https://www.codigotecnico.org/pdf/Documentos/HE/DcmHE.pdf

European Commission (n.d.) *Life-cycle costing*. https://ec.europa.eu/environment/gpp/lcc.htm

European Commission, Joint Research Centre, Gervasio, H., Dimova, S. (2018). *Model for Life Cycle Assessment (LCA) of buildings*, Publications Office. https://data.europa.eu/doi/10.2760/10016

De La Torre, M. L., Sause, R., Slaughter, S., & Hendricks, R. H. (1994). *Review and Analysis of Modular Construction Practices. ATLSS Reports*. ATLSS report number 94-11. http://preserve.lehigh.edu/engr-civil-environmental-atlss-reports/201

Green Building Council Denmark. (2021). *DGNB-manual for nye bygninger og omfattende renoveringer* [Danish] [*DGNB manual for new buildings and major renovations*], https://rfbb.dk/publikation/dgnb-manual-for-nye-bygninger-og-omfattende-renoveringer-2020

Haugbølle, K., Mahdi, V., Morelli, M., & Wahedi, H. (2021). *BUILD levetidstabel: Version 2021*. [Danish], [*BUILD Lifetime table: Version 2021*] Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet. BUILD Rapport Bind 2021 Nr. 32 https://build.dk/Pages/BUILD-levetidstabel.aspx

Hedström, ”Kalkylhandbok för fastighetsföretaget,” Utveckling av vastighetsföretagande i offentlig sektor (U.F.O.S), 2006

JPI Urban Europe. (2018) *SET-Plan ACTION n°3.2 Implementation Plan*. https://jpi-urbaneurope.eu/wp-content/uploads/2021/10/setplan_smartcities_implementationplan-2.pdf

Kamali, M., Hewage, K., & Sadiq, R. (2019). Conventional versus modular construction methods: A comparative cradle-to-gate LCA for residential buildings. *Energy and Buildings, 204.* 109379. https://doi.org/10.1016/j.enbuild.2019.109479

Larsen, V. G., Tollin, N., Sattrup, P. A., Birkved, M., & Holmboe, T. (2022). What are the challenges in assessing circular economy for the built environment? A literature review on integrating LCA, LCC and S-LCA in life cycle sustainability assessment, LCSA. *Journal of Building Engineering*, https://doi.org/10.1016/j.jobe.2022.104203

Li, Z., Shen, G. Q., & Xue, X. (2014). Critical Review of the research on the management of prefabricated construction. *Habitat International, 43*, 240–249. https://doi.org/10.1016/j.habitatint.2014.04.001

Real Decreto 1027/2007 (2007, June) *Reglamento de Instalaciones Térmicas en los Edificios* [RITE] [*Regulation on Thermal Installations in Buildings*]. *Boletín Oficial del Estado*. https://www.boe.es/eli/es/rd/2007/07/20/1027

Rogers, G.G., & Bottaci, L. (1997). Modular production systems: A new manufacturing paradigm. *Journal of Intelligent Manufacturing,* (8), 147-156. https://doi.org/10.1023/A:1018560922013

United Nations Environmental Programme [UNEP], (2013). *The Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA).* https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/social-lca/

Zabalza Bribián, I., Valero Capilla, A., & Aranda Usón, A. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, *46*(5), 1133–1140. https://doi.org/10.1016/j.buildenv.2010.12.002

Zimmermann, R.K., Andersen, C.A., Kanafani, K., & Birgisdóttir, H. (2020). *SBI 2020:04 Klimapåvirkning fra 60 bygninger: muligheder for udformning af referenceværdier til LCA for bygninger* [Danish] [*Climate impact of 60 buildings: options for the design of reference values for LCA of buildings*], https://build.dk/Pages/Klimapaavirkning-fra-60-bygninger.aspx