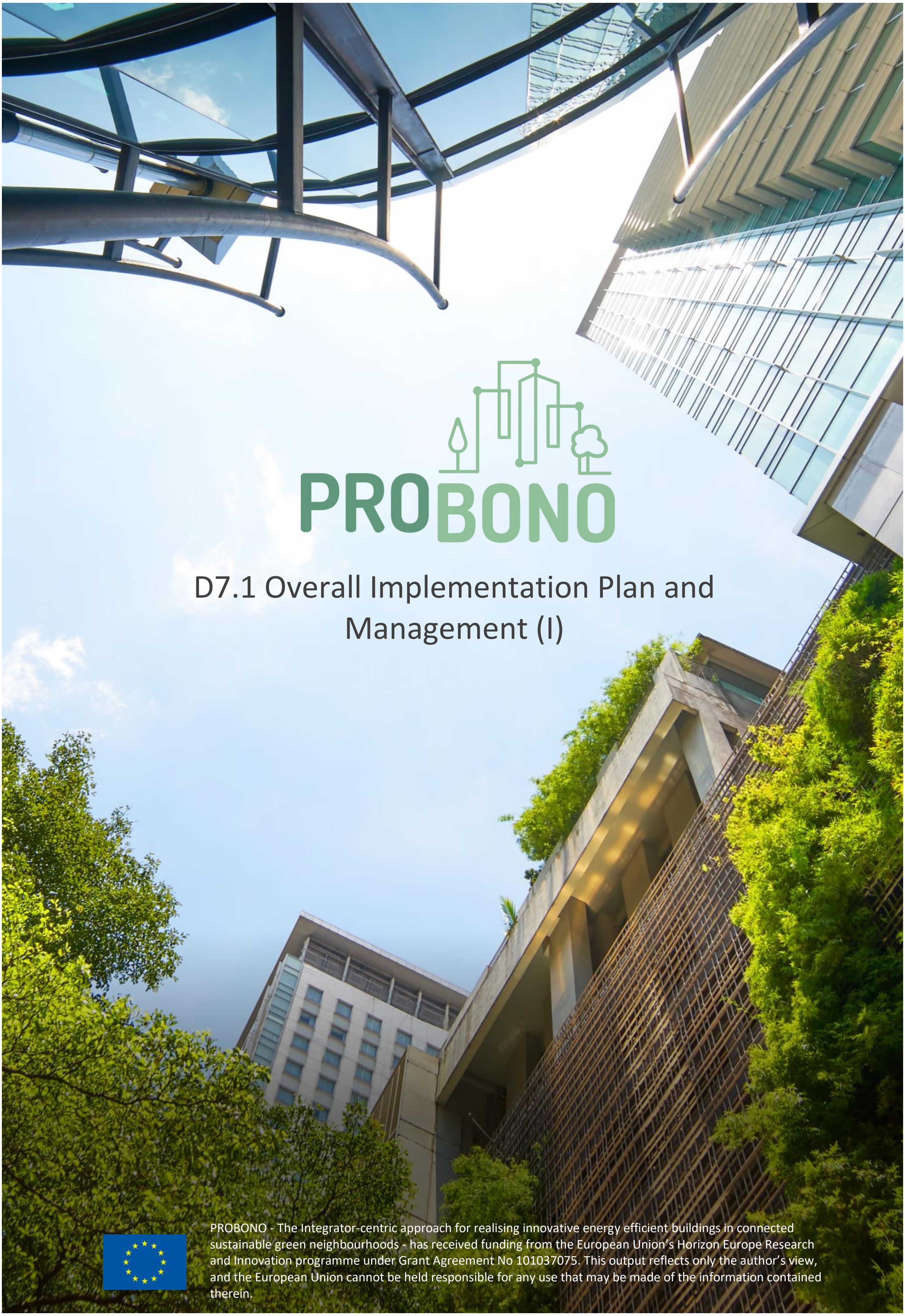

D7.1 Overall Implementation Plan and Management (I)

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 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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Document history:

Version	Date of issue	Content and changes	Edited by
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0.2	24/02/2022	Provision of feedback about the further shaping of chapters 5.1-5.3, 6.1-6.3, 7.1-7.3, 8.1-8.3, 9.1-9.3, 10.1-10.3 through which input for the planning and design tasks is collected.	WP leaders
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0.8	23/5	WP6 input on LL Impacts and KPIs. Chapters 2.5, 5.1.3, 6.1.3, 7.1.3, 8.1.3, 9.1.3, 10.1.3)	CARTIF
0.9	25/5/2022	Chapters 1-3 and comments to LL leaders on v0.8.	INLE
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0.11	27/6	Feedback on the Validation Meeting material	SERCO, SIN
0.12	19/7	Updated version based on Validation Meeting feedback and final comments to LL leaders	INLE
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Partner	Reviewer
VISB	Marta Boaventura
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Degree of relevancy	WP / Task
First:	WP2, WP3, WP4, WP5 and WP6
Second:	WP1
Third:	WP8 and WP9

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[1]. 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.

Green Neighbourhoods aligned with the European Green Deal[2], 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 neighbourhood is a neighbourhood that allows for environmentally friendly, sustainable patterns and behaviours to flourish e.g., bioclimatic architecture, renewable energy, soft and zero-emission mobility etc. Green neighbourhoods are the building blocks of Positive Energy Districts (PEDs)[3] 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[4] and Renewable Energy Communities[5] to be implemented.

Green Buildings and Neighbourhoods (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 behaviours that ensures just transition that maximise the economic and social cobenefits[1] 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[6] has 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 standardised 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.

[1] These definitions are identified in the PROBONO GA no 101037075 and they may be further refined according to the results of the project.

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

Acronym	Description
4G	Fourth-generation wireless
AC	Air Conditioning
AHU	Air Handling Units
API	Application Programming Interface
BSS	School of Business and Social Sciences
BACN	Building Automation and Control Network
BER	Building Energy Rating
BIM	Building Information Modelling
BIPV	Building Integrated Photovoltaics
BMS	Building Management System
BREEAM	Building Research Establishment Environmental Assessment
B2V	Building-to-Vehicle
CAD	Computer-Aided Design
CDD	Cooling Degree Days
CF	Capacity Factor
DGNB	German Sustainable Building Council
DHW	Domestic Hot Water
D	Deliverable
DT	Digital Twin
E	Enabler
EPC	Energy Performance Contracting
EPD	Environmental Product Declarations
ESG	Environmental, Social, and Governance
EU	European Union
EV	Electric Vehicles
GB	Green Buildings
GBN	Green Building Neighbourhoods
GCP	Google Cloud Platform
GHG	Green-House Gas
GIS	Geographical Information System
GSM	Global System for Mobile communication
HDD	Heating Degree Days
HVAC	Heating, Ventilation, and Air Conditioning
IBP	Integrated Business Planning
ICT	Information and Communications Technology
IEQ	Indoor Environmental Quality
IFC	Industry Foundation Class
IPMVP	International Performance Measurement & Verification Protocol
IoT	Internet of Things
ISO	International Organization for Standardization
KPI	Key Performance Indicator

Acronym	Description
LCA	Life Cycle Assessment
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LIDAR	Light Detection and Ranging
LL	Living Lab
LoRa	Long Range Radio
LTE	Long-Term Evolution
LTHW	Low Temperature Hot Water
M	Month
MNN	Madrid Nuevo Norte
M&V	Monitoring & Verification
NBS	Nature-Based Solutions
NGO	Non-Governmental Organisation
NZEB	Nearly Zero Energy Building
PAH	Polycyclic Aromatic Hydrocarbons
PESTEL	Political, Economic, Social, Technological, Environmental and Legal
PIR	Polyisocyanurate
PM	Particulate Matter
PROBONO	The Integrator-centric approach for realising innovative energy efficient buildings in connected sustainable green neighbourhoods
PV	Photovoltaics
PVP	Polycrystalline Photovoltaics
REC	Renewable Energy Community
RES	Renewable Energy Systems
RH	Relative Humidity
R&D	Research and Development
SDG	Sustainable Development Goal
TRL	Technology Readiness Level
UN	United Nations
UX	User Experience
VOC	Volatile Organic Compounds
WP	Work Package

Executive summary

PROBONO brings together a European multidisciplinary consortium of 47 partners, construction and consulting entities, public asset service managers, municipalities, technology solution providers and experts, to turn six European district- and site- level areas into Green Building Neighborhoods (GBN), with positive energy balance and zero carbon emissions. Acting as the PROBONO Living Labs (LLs), two large-scale demonstrators are located in Madrid and Dublin and four business-focused demonstrators, representing business/owner promoters of the green buildings and neighborhoods' transition, are located in Porto, Brussels, Aarhus and Prague.

The PROBONO Living Labs will provide both an experimentation and innovation environment and testbed for GBN innovative solutions. Although having a distinct scope, each Living Lab will follow a common process, the planning elements of which are incorporated in WP3 and WP4 (the technologies), WP5 (the Digital Twin), and WP6 (the monitoring framework).

This report provides, first of all, an overview of the overall PROBONO Living Lab setup and captures the as-is condition of the six PROBONO Living Labs. As-is conditions include the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that can be utilised in PROBONO are also described. Altogether, this information and data forms input to the planning and design work of all PROBONO activities.

Secondly, this report provides a snapshot of the planning and design of the PROBONO Living Labs on Month 8 of the project (August 2022). Namely, the first list of impacts and KPIs to be achieved in each Living Lab as well as Business Plan details, feasibility study of design strategies and management structures are described. Furthermore, a dedicated timeplan along with an optimum implementation plan for adopted scenarios (technologies, construction innovations and co-creation aspects) is provided. Finally, the engineering activities necessary for the modification of each pilot design have been set up in one singular scenario for implementation and execution applying co-delivery and according to local constraints like climatic, technical, economic, social and legal.

The implementation plans will continue to be updated as the planning and design work evolve.

The initial version of this report, due in M6, was presented to the executive board and the Living Labs stakeholders and validated to ensure its feasibility, as well as to achieve buy-in and consensus from all partners and maximise its efficiency. Comments were taken into consideration for the preparation of this final version of the deliverable.

1 Introduction

This report lays out the detailed and tailored Scoping and Implementation Plan that will be carried out in each of the six PROBONO LLs to help meet both the common project as well as the LL-specific objectives.

This plan has been carried out for each LL based on outputs of the WP1-WP6 planning and design tasks (Figure 1 and Annex II), following an iterative and intra-WP collaboration, as well as from information retrieved from external LL stakeholders with the help of the Living Lab leaders and supporting partners (Figure 2).

In WP3-WP5, all engineering activities necessary for the modification of each pilot design, at urban, architectural, energy, electric, and control levels, are being performed to set up in one singular scenario for implementation and execution applying co-delivery (WP2) and according to local constraints like climatic, technical, economic, social and legal. WP1 provides the common GBN framework and definitions to be followed in all PROBONO LLs and activities. The most probable scenarios on month 8 of the project (August 2022) are discussed in this deliverable.

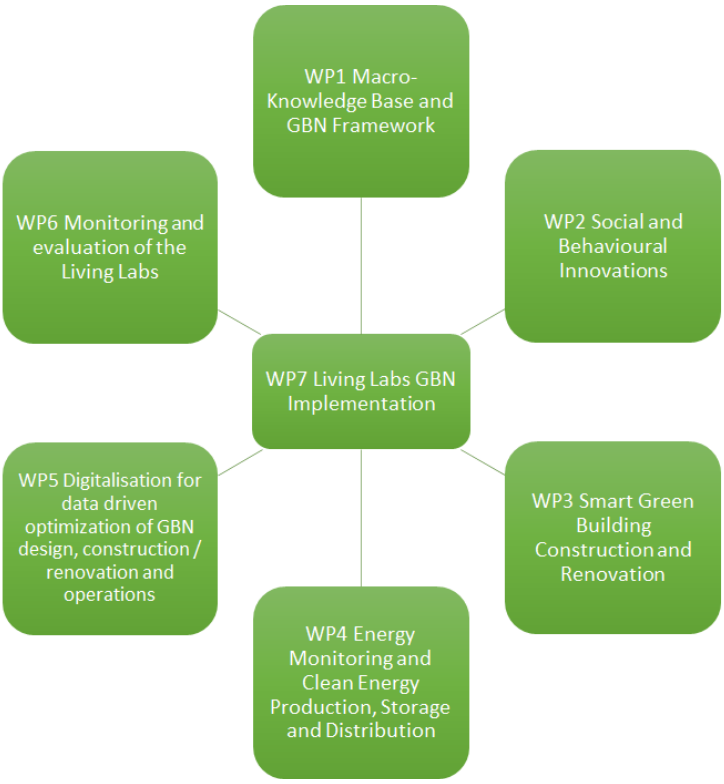

Figure 1 The PROBONO planning and design Work Packages

The presented LLs Scoping and Implementation Plans include a dedicated Construction/Implementation timeplan with relevant details per building and/or selected technology. The implementation plan includes the scenarios considered for adoption (technologies, construction innovations and co-creation aspects) that will be developed together with the targeted KPIs, the integrated co-creation innovations to engage all relevant stakeholders, a definition of the integration needs for manufacturing, construction, and operations processes, the design of the specific construction elements and connections and tools being developed for optimal configuration of all components. Finally, a Business Plan and a feasibility study of design strategies is described.

The Plans presented in this deliverable will continue to be elaborated until they reach their final state.

LL1 - Dublin	
University College Dublin (UCD)	Dún Laoghaire Rathdown County Council (DLR)

LL2 - Madrid	
Ingeniería Especializada Obra Civil e Industrial, S.A. (ACCIONA)	Distrito Castellana Norte, SA (DCN)

LL3 - Porto	
SONAEMC Serviços Partilhados (SONAE)	Capwatt S.A. (CAPW)

LL4 – Aarhus
Aarhus University (AU)

LL5 - Brussels	
Serco Belgium SA (SERCO)	De l'Autre Côté de l'Ecole (ACE)

LL6 – Prague	
Czech Technical University in Prague (CTU)	Prague District 6 (PRAGUE)

Figure 2 Living Lab leaders (left) and key supporting partners (right)

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.

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

GA Component Title	GA Component Outline	Respective Document Chapter(s)	Justification
TASK			
Task 7.1 - Overall Living Labs implementation plan and Management	Early on in the project a detailed and tailored Scoping Plan will be carried out for each LL based on outputs of WP1-WP6 planning tasks as well as more mature and up to date information that will become available at the time of project initiation.	Chapters 5-10	The scoping and implementation plan for each LL captures the outputs of WP1-WP6 planning phase tasks and the information available to the LL leaders until M8 of the project (August 2022).
	This will include the refined Construction/ Implementation plan and a dedicated timeplan (i.e. refined LL Gantt chart (as Figure 35), with relevant details per building and selected technology) along with Business Plan details and a feasibility study of design strategies and associated KPIs detailed in Sections 1 and 2 and Task 6.1.	Chapters 5-10	The timeplan and construction and implementation plan for each Living Lab are outlined in subchapters 5.4, 6.4, 7.4, 8.4, 9.4, 10.4 for each of Dublin, Madrid, Porto, Brussels, Aarhus, Prague LLs, respectively. Business plan details and feasibility study are outlined in 5.5, 6.5, 7.5, 8.5, 9.5, 10.5. Targeted Impacts and KPIs are outlined in 5.1.3, 6.1.3, 7.1.3, 8.1.3, 9.1.3, 10.1.3.

GA Component Title	GA Component Outline	Respective Document Chapter(s)	Justification
TASK			
	Furthermore, an optimum implementation plan for adopted scenarios (technologies, construction innovations and co-creation aspects) will be developed that (a) integrate and cocreate innovations engaging all relevant stakeholders (b) define the integration needs for manufacturing, construction, and operations processes (c) design the specific construction elements and connections (d) develop tools for optimal configuration of all components.	Chapters 5-10	The technologies and construction innovations are described in subchapters 5.4, 6.4, 7.4, 8.4, 9.4, 10.4 for each of Dublin, Madrid, Porto, Brussels, Aarhus, Prague LLs, respectively. Co-creation aspects are described in 5.3, 6.3, 7.3, 8.3, 9.3, 10.3 and 5.4.2, 6.4.2, 7.4.2, 8.4.2, 9.4.2, 10.4.2.
	All engineering activities necessary for the modification of each pilot design, at urban, architectural, energy, electric, and control levels, and performed initially in WP3, WP4 and WP5, will be set up in one singular scenario for implementation and execution applying co-delivery (WP2) and according to local constraints like climatic, technical, economic, social, legal, and other relevant where needed.	Chapters 5-10	Engineering activities, singular scenario and local constraints are described in subchapters 5.4, 6.4, 7.4, 8.4, 9.4, 10.4 for each of Dublin, Madrid, Porto, Brussels, Aarhus, Prague LLs, respectively.
	Once the plan is structured, and prior to Living Labs implementation, it will be presented to the executive board and the Living Labs stakeholders and validated with in order to ensure its feasibility, and to achieve buy-in and consensus from all partners and maximize its efficiency.	Chapter 3	All experts and key LL stakeholders were made part of the preparation of this report from the early beginning of the project (see subchapter 3.3). Validation of the actual populated deliverable was performed in the frame of an online workshop that took place on June 17, 2022.
DELIVERABLE			
D7.1: Overall LL Implementation Plan and Management (I) This report formulates the findings of T7.1 and provides the details of the Scoping and Implementation Plan for each of the six Living Labs as in Month 8 of the project (August 2022).			

1.2 Structure of the deliverable and its relation with other work packages/deliverables

The deliverable is formulated as follows:

- Chapter 1: Introduction.
- Chapter 2: Overview of the PROBONO Living Labs.
- Chapter 3: Overall Living Lab planning, management and monitoring approach.
- Chapter 4: Summary of the LL's scoping and implementation plans.
- Chapter 5: Dublin Scoping and Implementation Plan.
- Chapter 6: Madrid Scoping and Implementation Plan.
- Chapter 7: Porto Scoping and Implementation Plan.
- Chapter 8: Aarhus Scoping and Implementation Plan.
- Chapter 9: Brussels Scoping and Implementation Plan.
- Chapter 10: Prague Scoping and Implementation Plan.
- Chapter 11: Conclusions.

Subsequent deliverables to D7.1 include D7.2 Auditing & Monitoring Report (M18), D7.3-D7.4 Periodic Monitoring & assessment Reports (M36 and M48) and D7.5 Final performance assessment, replicability/transferability and LL certification (M60).

Additionally, each LL will provide documentation of the Initial Design and Construction plans on M24 (Dublin D7.6, Madrid D7.9, Porto 7.12, Aarhus D7.15, Brussels D7.18, Porto D7.21), the Final Design and Construction Plans on M40 (D7.7, D7.10, 7.13, D7.16, D7.19 and D7.22 respectively) and the Final Operational Plans on M54 (D7.8, D7.11, 7.14, D7.17, D7.20 and D7.23 respectively).

The social dimension (as part of the as-is conditions) and the stakeholder engagements (as part of the implementation plan) will be treated in detail in D2.1 (M12) and D2.3 (M18).

The implementation aspects as they relate to GBN transition, including definition and elements of Green Building Neighbourhoods (GBN) such as vision, transition, sustainability, etc., which are naturally a prerequisite for the development and application of next generation (realistic) analysis tools and decision support systems are covered in WP1. This also includes PESTEL analysis and GBN transition challenges and enablers.

The maturing innovation technologies for GBN construction and renovation and GBN green energy are handled by WP3 and WP4, respectively.

Objectives regarding the Digital Twin technology and use cases are to be further defined and developed in WP5 and reported in D5.1 to be submitted on Month 16.

The PROBONO Evaluation Framework, currently under design in WP6-T6.1, will contain the list of KPIs and assessment methodologies (measurement and verification plans and life cycle methods) serving as an evaluation guideline for the impact assessment for each Living Lab. The impacts achieved in the different Living Labs will be reported through WP6 for the construction and the operation activities while the final project evaluation will be reported in D6.8 at the end of the project.

2 The PROBONO Living Labs

PROBONO envisions a people-focused European construction industry working in harmony with the whole value chain to deliver scalable, sustainable, and viable energy positive and zero-carbon Green Buildings and Neighbourhoods (GBN).
In line with this vision, PROBONO is providing five GBN Transition Acceleration Enablers, deployed in six high impact Living Labs, the outputs of which will be feeding into a transferability and innovation replication framework that will enhance the transition capabilities of local communities (Figure 3).

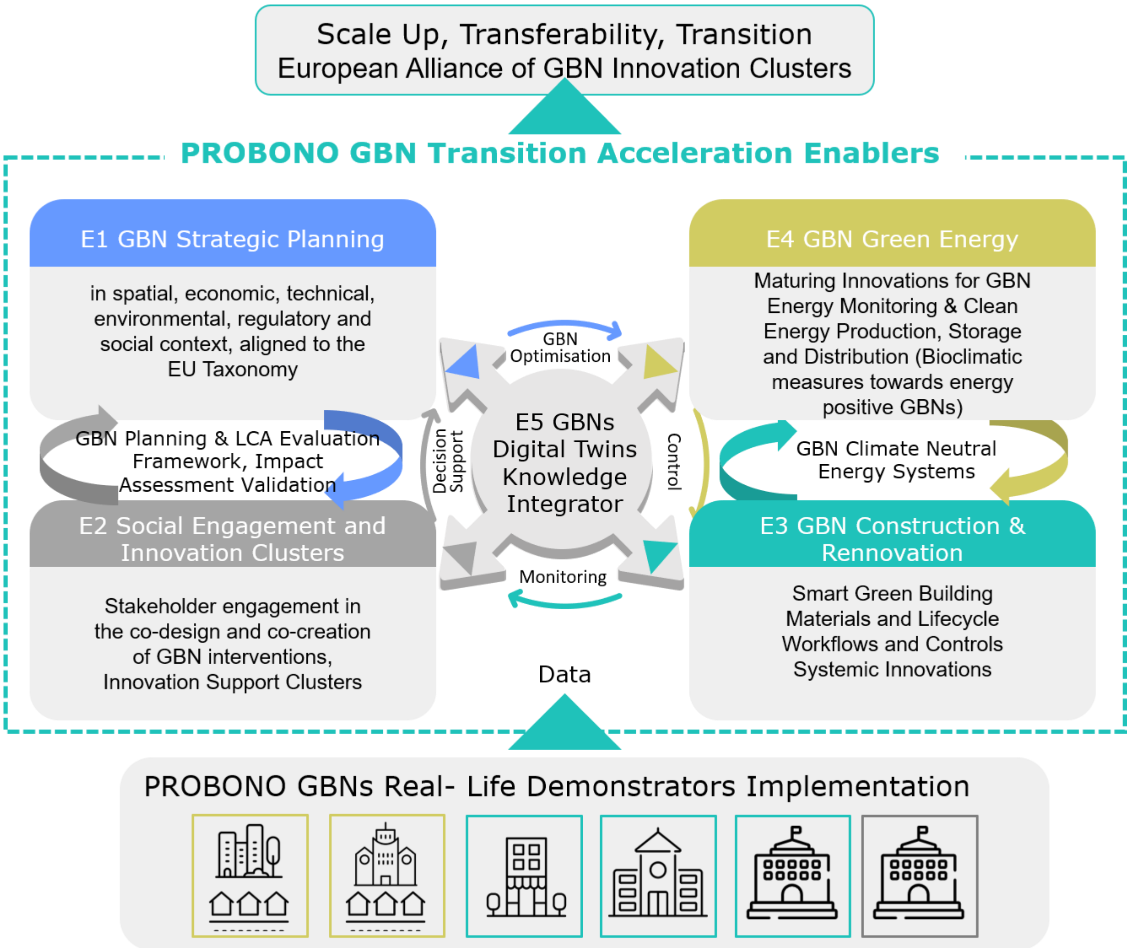

Figure 3 PROBONO Vision and GBN Transition Acceleration Enablers

This chapter provides an overview of the PROBONO Living Labs principles, characteristics, complementarity and interrelationships as well as the Impacts to which the LLs are expected to collectively contribute through the planned measures and innovations.

2.1 PROBONO Living Labs Principles

From their setup, the PROBONO Living Labs are not simply demonstrations of technologies developed by the consortium partners, but aim to increase acceptance, adoption and behavioural change and maximise impact.
They are user-centered, iterative, open-innovation ecosystems, operating in a territorial context (e.g. city, agglomeration, region, or campus), integrating concurrent research and innovation

processes within a public-private-people partnership. The stakeholders will 'collectively' co-design solutions and GBN measures for the LL to promote good habits and good behaviour in local context.

The key aspects of the PROBONO implementation methodology approach are the following:

- **People-focused** and **systems-based**
    - **People** – a focus on outcomes and human flourishing by deploying approaches and solutions to develop a deep understanding of people and communities, and the means by which they actively participate in making their districts better places, through sharing services, can deliver better outcomes.
    - **Green Neighbourhoods** - a focus on interconnected infrastructure that support low energy districts, electrification of mobility, and integration of infrastructures and greening processes.
    - **Sustainability** – a focus on the long-term viability of GBN.
    - **Digitalisation** – a focus on developing the cyber-physical system that supports the GBN.
- **Outcomes-targeted** – robustly evidence-based on sustainability and in line with IBP, acquis Communautaire (EU Taxonomy and wider ESG systems) to facilitate access to green and sustainability finance.
- **Policy-compliant** – recognising and making a significant contribution to the European Green Deal.
- **Capacity-building** – recognising the need for upskilling various local actors.
- **Continuity-oriented** – recognising the need to ensure continuity after the Project completion.

For each LL, at least one building will become a Flagship building, meaning that planning and construction processes and the energy efficiency will be improved in comparison to the existing situation and to other buildings. The integration of sustainable, renewable energy technologies in the context of each LL GBN, showcasing the transition to energy positive buildings (producing electricity, covering their heating, and cooling needs and contributing to the energy grid stability) will also be demonstrated.

Renewable energy sources will be used extensively on the building envelope (solar energy) or in the neighbourhood (geothermal energy). The energy system of the buildings will become smarter and will provide flexibilities to the energy grid (e.g. controlled EV charging, integration of batteries, demand response etc.). The PROBONO LLs will adopt a systemic approach to the mobility-energy system, establishing the ground for data-driven modelling and GBNs design. Decision Support, Optimisation, Monitoring and Control of the GBN will be achieved through the LLs Digital Twins.

Behavioural changes, e.g., to reduce the energy use and support grid stability/enable flexibility will be considered for each LL.

2.2 Living Labs Characteristics and Complementarity

PROBONO demonstrators have been organised in two thematic clusters (Figure 4):

A. **Large-scale demonstrators**, at **district level,** supported by local authorities (Madrid, Dublin) and
B. **Business**-focused, at **site level**, LLs promoted by local stakeholders (Porto, Brussels, Aarhus, Prague).

The sites have been selected to provide coverage of EU Member States with a good balance between public and business driven use cases. In this way the provision of all services under the PROBONO framework/tools can be demonstrated concurrently. For the actual selection of the sites, it was important that they are situated in different contexts, characterised by a high diversity of demographic, cultural and socio-economic backgrounds, and in defined biogeographical regions (e.g. Mediterranean, Atlantic, or Continental).

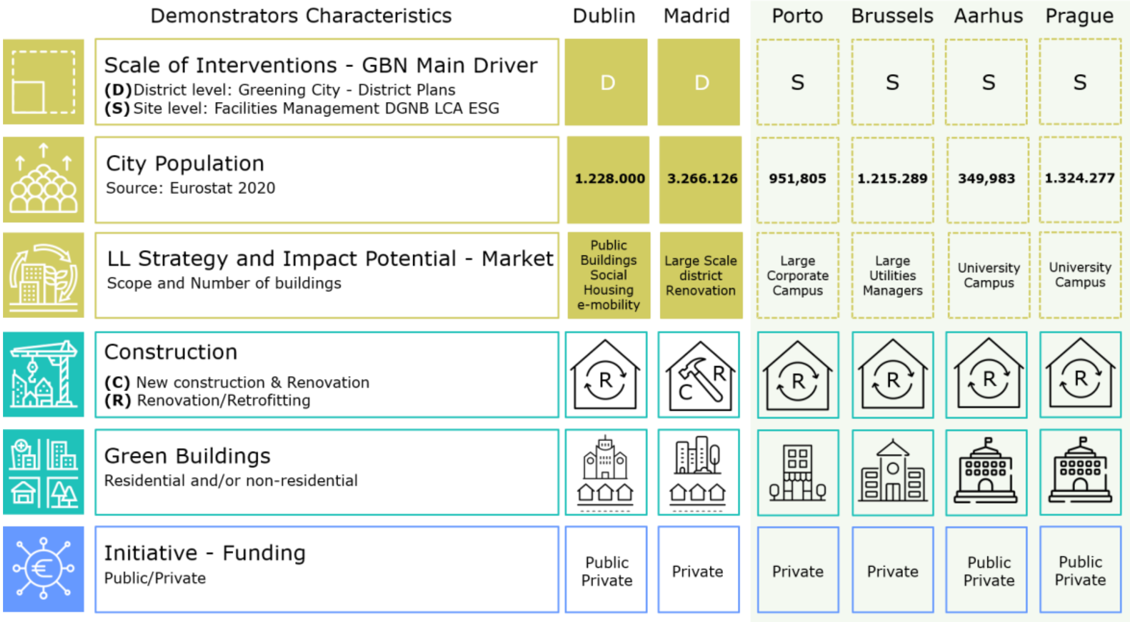

Figure 4 Overview of PROBONO Living Labs

Large Scale Demonstrators (Madrid, Dublin) focus on:

- New Buildings, Retrofitting and Green districts development.
- Planning, Design, Manufacturing, Construction and Operation (demonstrating 1 PROBONO innovation per phase at minimum).
- District level energy optimisation, integration in the grid and electromobility, adaptation to climate change.
- City level support and interaction with citizens.
- Sets clear definition of value proposition (Beneficiaries, Environmental and social KPIs).
- Provides reproducible components to other project ‘demonstrators’ and the industry at large.
- Tests reproducible components from Focused Demonstrators.

Focused demonstrators (Porto, Brussels, Aarhus) focus on:

- Smaller scale business driven renovation or construction projects, demonstrating at least 1 innovation.
- Clear definition of value proposition. Beneficiaries environmental and social KPIs.
- Provide reproducible components to other project ‘demonstrators’ and the industry at large.

Follower sites (Prague as Aarhus LL follower) will demonstrate/validate transferability of the innovations.

LL Clustering for Business-driven non-residential Green Buildings (Porto, Brussels, Aarhus, Prague) will add a multiplication impact.

2.3 Living Labs interrelationships

Each Living Lab will implement a subset of the PROBONO GBN innovations (Table 2). By the end of the project the LLs will help deliver an open directory of more than 40 validated maturing GBN innovations (currently at TRL 5-6) of TRL 8-9.

Table 2 Mapping of enablers against the Living Labs. E-enabler, L-lead, D-Dublin, M-Madrid, P-Porto, B-Brussels, A-Aarhus, P-Prague

Enablers:	D	M	P	B	A	P	Workplan activities
Strategic Planning – Aligned to the EU Taxonomy (E1)							a) **Permits and Tendering Cities' Forum**
							b) **New standards at GBN level** in link to the key technology considered, led by Madrid and Dublin followed by Porto, Aarhus (examples to geothermal grid, and social housing retrofitting set).
							c) **Catalogues and Guidances for Nzet districts,** led by Madrid and Dublin followed by Porto, Aarhus (examples to district infrastructure retrofitting, social retrofitting, and alignment with aims of EU renovation wave).
							d) **Capacity Building´s Forum,** led by Madrid and Dublin followed by Brussels, Aarhus, Prague (examples to the EE building design thermo-activated, governance and policy recommendations and drivers for GBN growth).
Social Engagement and Innovation Clusters (E2)							a) **Workshops and roundtables** (methodology and guides), All involved
							b) **Co-creation Action Plans** (Templates and guides), All involved
							c) **Good practices of citizenship co-creation at International level**, design thinking sessions, All involved
							d) **Co-networking to relevant clusters** and relevant stakeholders and associations, led by Madrid and Dublin followed by Brussel (dialogue with multiple 'green' innovation clusters, New business Models dialogue)
Construction and Renovation Smart Green Building Materials, life cycle Workflows and Controls (E3)	L						a) **GB Insulation** and green and cool roof-centric innovations, led by Dublin, included Porto and Brussels
					L		b) **GBN related Construction and lifecycle processes**, materials and control blueprints, and robots, led by Aarhus, included Dublin and Prague
					L		c) **Building Materials** / upcycling, led by Aarhus, included Dublin, Prague
Energy Monitoring Clean energy Production, Storage, Distribution (E4)				L			a) **Climate neutral energy system** planning and design methodology, led by Brussels, included Porto, Aarhus
				L			b) **GBN demand** and response platform, led by Brussels, included Porto, Aarhus
	L						c) **Building Integrated Photovoltaics (BIPV),** led by Dublin, included Porto
		L		L			d) PROBONO **GB Positive Energy** Package, led by Brussels, Madrid, included Porto
		L	L		L		**e) GBN Energy Storage**, led by Madrid, Porto, Aarhus, included Dublin, Brussels, Prague
	L						f) **Integrated Infrastructure** Mobility Energy, led by Madrid, Dublin, included Porto, Brussels
GBN Digitalization for data-driven investment process and resource optimisation (E5)							a) **Planning and Design Level**, All involved
							b) **Operational and Monitoring Level,** All involved
							c) **City Global Impact Evaluation,** led by Dublin, Madrid

2.4 Expected Impacts and KPIs

All LLs have planned measures and innovations that are expected to collectively contribute to the impacts of the PROBONO project as described in Table 3.
The PROBONO Evaluation Framework is designed and executed in WP6. It is expected to be finalized in December 2022 (D6.1) and will contain the list of KPIs and assessment methodologies (measurement and verification plans and life cycle methods) serving as an evaluation guideline

for the impact assessment for each Living Lab. The impacts for each Living Lab together with the M&V option selected for the verification of energy savings are summarized in sections 4.1.3 (Dublin), 5.1.3 (Madrid), 6.1.3 (Porto), 7.1.3, 8.1.3 (Brussels) and 9.1.3 (Prague) of this report. The M&V option will be based on the IPMVP protocol[10]. The impacts achieved in the different Living Labs will be reported through different deliverables within WP6 (D6.4 and D6.5 covering Impact assessment of construction activities, D6.6 and D6.7 covering Impact assessment of Operation activities, including savings). The final project evaluation will be reported in D6.8 at the end of the project.

Table 3 General PROBONO impacts

Impact Category	Unit	PROBONO Objective
I1. Primary energy savings	**%**	**35% reduction**
Energy savings from resource efficiency improvements	GWh/y	>4GWh/year
Energy savings achieved through smart grid optimization	GWh/y	>3GWh/year
Energy efficiency of construction and retrofitting works	GWh/y	>1GWh/year
Energy savings from use of materials with lower environmental footprint	GWh/y	>0.6GWh/year
Energy savings from innovative insulation solutions	GWh/y	>2GWh/year
I2. Investments in sustainable energy	**€**	-
Investment in innovative solutions	€	>3 mill € invested in the next 5 years after the project end
Investment in renovation projects or new construction	€	>40 mill € invested in the next 5 years after the project end
Investment plans	€	>60 mill € invested in the next 5 years after the project end
I3. Demonstration sites that go beyond nearly-zero energy building performance	-	-
Reduced heating and cooling demand	%	>40%
Building Energy Rating (BER)	Energy Rating	A-rating
I4. High energy performance	-	-
Increase of Renewable energy generated on-site	%	>25%
Increase of Renewable energy covering LLs building energy demand vs other sources	%	>20%
Improved energy efficiency	%	35%-40%
I5. Reduction of GHG emissions for the total lifecycle	**tonCO_2-eq/year or %**	**>65%**
GHG emissions reduction across the life cycle of the innovations	%	20%
GHG emissions reduction achieved across GB/GBN value chain	%	30%/35%
I6. Reduction of the embodied energy in buildings	**%**	**50%**
Reduction of embodied energy in buildings due to circular models	%	10-60%
Reduction of embodied energy in buildings due sustainable design	%	10-60%
I7. Reduction of air pollutants for the total lifecycle	**kg/year**	-
Decreased Sulphur dioxide	%	10% or < 20 μg/m^3
Decreased Nitrogen dioxide and oxides of nitrogen	%	5% or < 50 μg/m^3
Decreased PM10 and PM2,5	%	5% or < 12.5 μg/m^3 and 6 μg/m^3
Decreased Lead	%	5% or < 0.125 μg/m^3
Decreased Benzene	%	5% or < 0.8 μg/m^3
Decrease CO	%	5% or < 2.5 μg/m^3

Impact Category	Unit	PROBONO Objective
I8. Potential for replicability	-	-
Number of follower GBNs	nº	>6
Number of new GBs	nº	>20
I9. Shortened construction/retrofitting time and cost	**%**	**>30%**
Shortened construction/retrofitting time	%	>30%
Shortened construction/retrofitting cost	%	>30%
I10. Improved IEQ	**%**	**>30%**
Reduction in number of complaints regarding air quality	%	>30%
Reduction in number of complaints regarding noise levels	%	>30%
Reduction in number of complaints regarding dust	%	>30%
Reduction of VOCs levels (PM2.5; CO; Radon; PAHs; Formaldehyde; etc.)	%	>30%

3 Overall LL planning, management and monitoring approach

The PROBONO Living Labs although having a unique scope of activities, will use the common toolset/asset of enablers (Figure 3) and follow a common implementation approach (Figure 5). LL leaders will act as GBN integrators as described in Figure 48. The common implementation process for all LLs, elaborating the steps in Figure 5 is summarised in Annex I. This report is an output of the third step of the implementation process: **C. Specify Renovation scenarios** and technical, economic, environmental implementation report of the interventions and associated timelines.

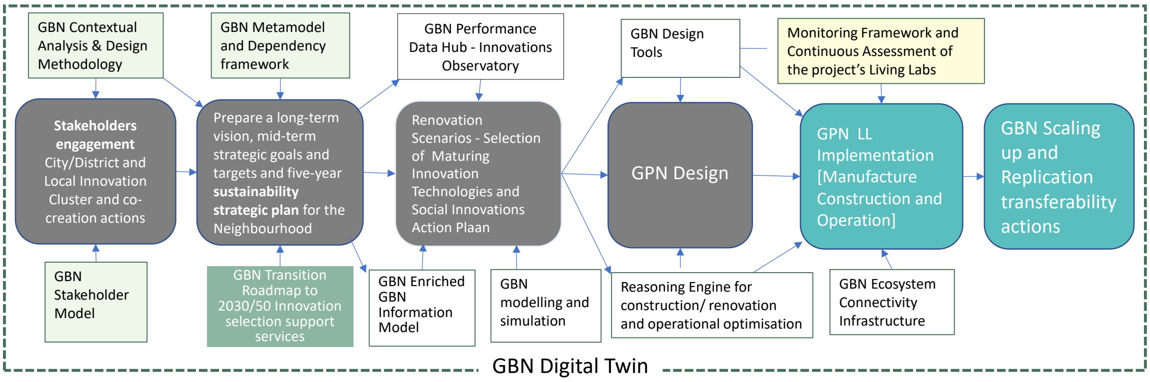

Figure 5 Common LLs Implementation Process

This chapter describes the procedures followed for the planning, management, monitoring as well as formal validation of the Scoping and Implementation Plans for each LL. These procedures helped in the actual planning and design activities of the Living Labs as well as in the efficient preparation of this deliverable.

3.1 Overall planning approach and high-level plan for management and monitoring of the LLs

3.1.1 Management and monitoring process

One of the aims of the task producing this specific report (Task 7.1) is to facilitate and align the planning and design tasks in all technical Work Packages, namely WP3 through WP6, while considering co-creation and co-delivery aspects (WP2), local constraints like climatic, technical, economic, social and legal and staying true to the common GBN framework and definitions (WP1).

Effectively, the work performed for the detailed scoping and implementation plan of the six PROBONO Living Labs was performed in parallel and in collaboration with the planning and design tasks of WP3-WP6 as indicated in Annex II. This report was produced in phases and iterations, aligned with the needs and output planning for the rest of these tasks (Figure 6).

In this process, the LL leaders acted as the intermediaries between the LL stakeholders and the project, while Inlecom, as leader of WP7 and Technical Coordinator of the project, ensured that the communication between the LL leaders and the rest of the project partners (i.e. WP and Task leaders as well as technology providers) was as efficient as possible. This iterative process was already adopted on Month 2 of the project to ensure that no urgent task of the project meets obstacles that lead to undisciplined communication and exchange of information as well as delays that may well be inherited by subsequent or interlinked tasks.

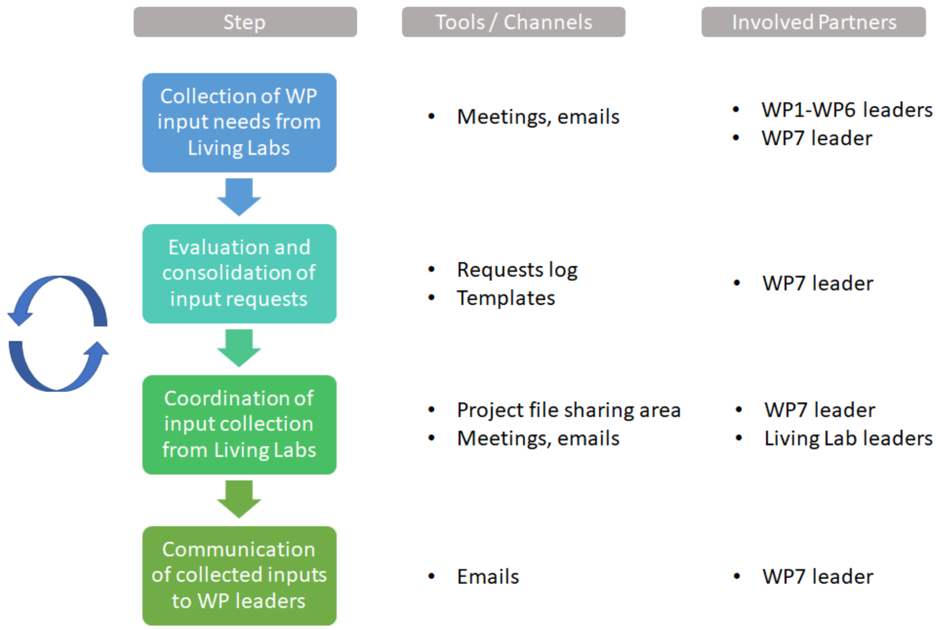

Figure 6 Iterative process for the specification of the LL renovation scenarios

Close monitoring of progress against the work for the scoping and implementation plan was possible through monthly (and in some cases bi-weekly) WP7 meetings where both the LL leaders and WP leaders were present. In these meetings the WP7 leader would summarise the new and pending requests. The LL leaders would report on progress for the planning and design of their LL as well as clarify any questions regarding the requests with the WP leaders. WP leaders had the opportunity to be informed about the relevant progress in each LL and answer or pose any questions.

3.1.2 Tools and methods

3.1.2.1 Requests log

A requests log has been created to help in the monitoring and discipline of requests for information and data towards the Living Labs throughout the duration of the project. This has the form of the table illustrated below (Table 4). It is populated with requests from the project partners, namely the WP1-WP6 partners and Technology Providers, in a periodic manner.
Dedicated folders have been created on the project file sharing system where exchanged documents are saved.
Where relevant, supporting templates that Living Lab leaders can fill-in to improve quality and consistency of provided content are created.
Inlecom, as WP7 leader, is owner of the logbook and acts as the intermediary of the communication between the LL leaders and the other project partners. Other responsibilities include:

- WP leaders collect the requests from the Task Leaders, check them for clarity, prioritise them if they are too many, ask the WP7 leader to log them in the document, manage the WP folder where the request templates/document are added and flag any delays to the WP7 leader.
- LL leaders check the provided information for clarity, provide the information requested at the expected deadline and manage the LL folder where this information is added.
- Task leaders flag any delays in the provision of the requested information to the WP leader and evaluate the comprehensiveness of the provided information and come back with clarification questions, if needed.

- Project Coordinator contacts the LL leaders after the WP7 leader has flagged an issue (e.g. unresponsiveness etc).
- Technical Coordinator supports the Project Coordinator in resolving showstoppers revealed through this process.

Table 4 Requests Log

Request Reference No	Name / Surname	Email address	Partner short name	Relevant WP	Linked Document/ Template (if any)	Document/Template Reference / LINK	Comment / Request	Request Date	Due Date	Response by LL partner	Document Reference / LINK	Response Date	Respondents name / email address	Clarifications	Clarification Date
1															
2															
3															
4															
5															
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3.1.2.2 Timeplan

A common template for the Living Labs to report their dedicated timeplan was also created (Annex IV). Each Living Lab leader has adapted it to the scope of their Living Lab. It includes all major activities and milestones as considered in the PROBONO workplan to facilitate communication between different project stakeholders. Relevant details per building and selected technology are included. They are reported for each LL in sections 5.4.7 (Dublin), 6.4.6 (Madrid), 7.4.6 (Porto), 8.4.6 (Aarhus), 9.4.6 (Brussels) and 10.4.6 (Prague) of this report.

3.1.3 Scoping and Implementation Plans Validation

In order to ensure feasibility, maximise its efficiency and achieve buy-in and consensus, the implementation plan for the adopted scenarios should be validated by experts in the field and involved stakeholders. As a result, all experts and involved stakeholders were made part of the preparation of this report from the early beginning of the project.

A detailed Table of Contents was prepared on Month 2. This included guidelines and templates, where relevant, for each subsection. The Table of Contents was sent for comments and validation to LL leaders and supporters and WP leaders.

Validation of the actual populated deliverable was performed in the frame of an online workshop that took place on June 17, 2022. In this workshop the Implementation Plan for each Living Lab was presented to the PROBONO Executive Board and the PROBONO Living Lab stakeholders. These partners had the chance to ask questions and make comments about how, if at all, the plan could be sharpened. The comments have been addressed in this final version of this report (M8).

Between Month 2 and the validation event in June 2022 (Month 6), all involved partners were systematically included in relevant to them communications and meetings involving the planning, scoping and design activities of the Living Labs as described in 3.2.1, thus remaining informed and involved in the preparation of the scoping and implementation plan presented in this document.

4 Consolidated View of LLs Scoping and Implementation Plans

The PROBONO Living Labs will provide both an experimentation and innovation environment and testbed for GBN innovative solutions. A different mix of technologies, construction/renovation innovations and co-creation aspects are being developed under a single optimum adoption scenario for each Living Lab. As summarised below, each Living Lab has its own ambition and scope.

The **Dublin LL** is envisioned as a sustainable and cost effective, zero-carbon GBN, networking key municipal buildings and optimising prototypical housing retrofit for future, wider replication. The LL will engage local citizens in the design and development of a green town centre and living neighbourhood. Improvement of the energy performance of buildings is a primary target for the Dún Laoghaire-Rathdown County Council (DLR), with challenges identified around energy inefficiency in older municipal buildings.

The **Madrid LL** will be focused on the Development of Las Tablas Oeste, that is part of Madrid New North initiative, and the establishment of common integrated energy infrastructures to fully cover the district's thermal demand through geothermic energy and the electricity demand through solar energy via photovoltaics on buildings and the urban space.

The **Porto LL** will develop the conditions for a more energy efficient corporate campus, focusing on energy management at campus level, coupled with several social innovation and biodiversity initiatives.

The **Aarhus LL** aims to achieve a DGNB Gold Rating for two target buildings, commercialize research and develop evidenced based data and decision-making support, based on the Campus 2.0 guideline, FB23 national regulations, directives for universities on annual energy savings and the AU Climate strategy.

In the **Brussels LL,** 2000 m² of a school building will be renovated, including ground floor office facilities and building roof, out of a total of approximately 7000 m² school area to transition into a near zero emission building and enabling the creation of a green sustainable neighborhood.

The **Prague LL** will explore solutions for further energy production and consumption reduction on the CTU campus with the help of a Digital Twin. It will also include advanced traffic modelling and impact assessment and propose relevant policies to reduce emissions.

The E3 (GBN Construction and Renovation) and E4 (GBN Green Energy) measures and technologies considered to be applied for the achievement of the Living Labs impacts are summarised in Table 5. The expected level of contribution of each of these technologies to the PROBONO impacts is outlined in Annex V .

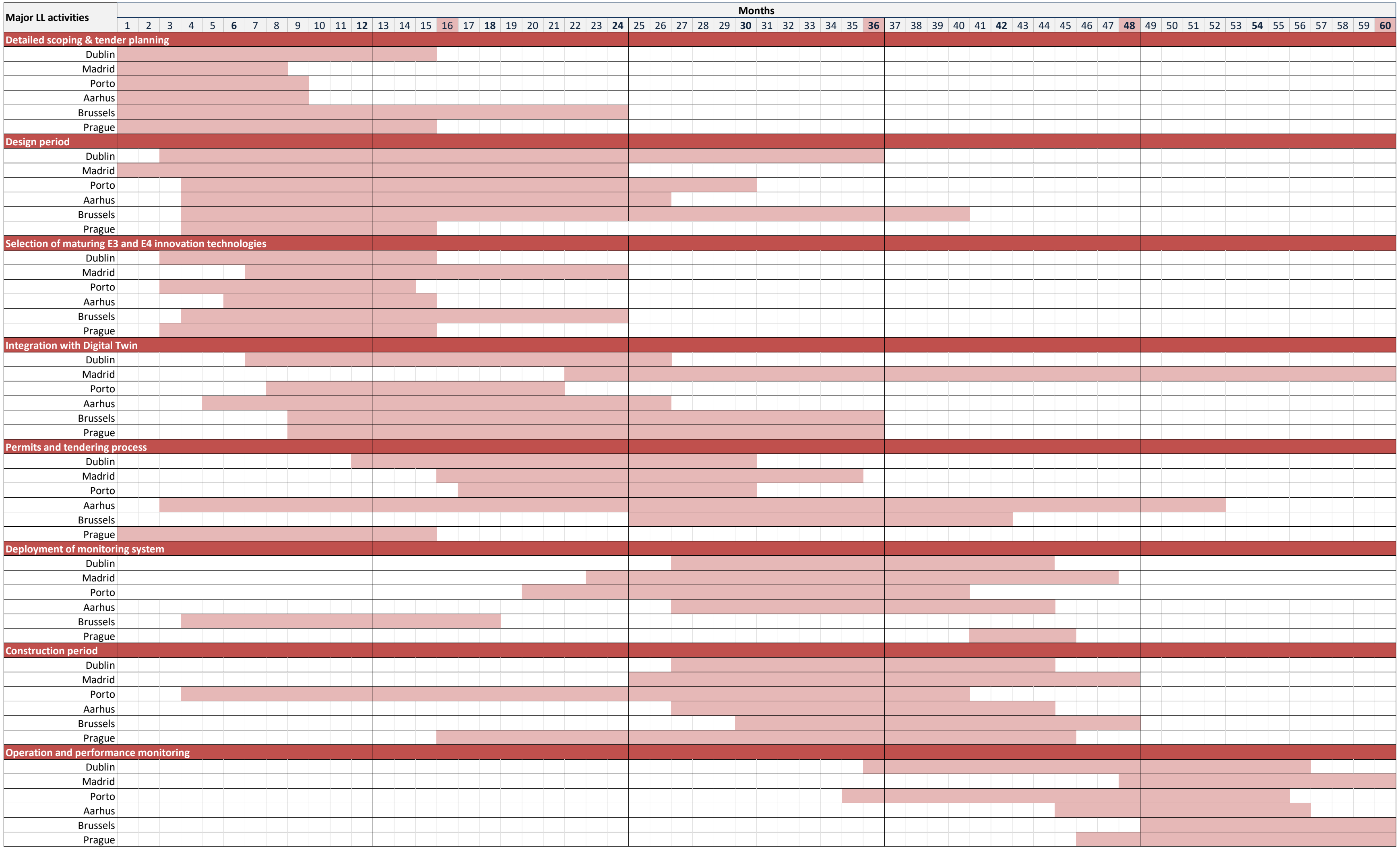
Table 5 Summary of E3 and E4 measures/technologies considered in each Living Lab

Living Lab	Considered measures/technologies
1 - Dublin	• Coloured façade BIPV • Microgrid Battery and connection links • Insulation (vapour permeable option and PIR insulation panels) • GCP cloud infrastructure • Electric vehicle charging infrastructure • Smart lighting retrofit • Energy reporting analysis
2 - Madrid	• GBN related construction and life-cycle processes • Evaporative green roofs • Integrated thermal and acoustic insulation • Recycled materials for insulation • Eco-materials for sustainable road pavement • Mapping drones with LIDAR sensors implementation • Demand Response platform

Living Lab	Considered measures/technologies
	• BIPV • 2nd life batteries • Thermal and Electricity Microgrid • Geothermal, bidirectional charging stations
3 - Porto	• Solar 2 Vehicle • Vehicle to Grid • BIPV • 2nd life batteries • Green Hydrogen production • Solar Heat for Industrial Processes • Phase Change Materials • SMART EV HUB • Cool roof technology for Bi-Facial PV production • Community garden • House of birds • Renewable energy community
4 - Aarhus	• Integration of upcycling into "Consequential LCA" • Sustainable insulation • Advanced energy storage with flow-batteries • Human-centred ventilation simulations
5 - Brussels	• Energy and Water monitoring • Sustainable roof solutions • Prefabricated concrete • EV charging/battery solution
6 - Prague	• Green and cool roof • Recycled materials for insulation and construction • Climate neutral energy system planning and design • BIPV • Pro-cognitive lighting integration with innovative acoustic solutions • Ventilation nano-technology filtration • Metering, Monitoring and Control Center integration • Demand Response platform • EV charging station and EV mobility system

An overview of the most significant PROBONO milestones together with the corresponding timeplan for each Living Lab is provided in Table 6. It is indicative of the different maturity levels in which the Living Labs are. The implementation plans will continue to be updated as the planning and design work evolve and become more detailed.

Table 6 Overview of Living Labs' time plan



5 LL1 Dublin Scoping and Implementation Plan

This chapter details the Scoping and Implementation Plan for the Dublin LL. It begins with an overview of the Living Lab setup and continues with the as-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that cab be utilised in PROBONO are also described, together with the first list of expected impacts and KPIs.
Next, the scenario considered for adoption (technologies, construction innovations and co-creation aspects) as well as the implementation plan are detailed along with the engineering activities necessary for the modification of the LL design according to local constraints like climatic, technical, economic, social and legal. Finally, current Business Plan details and feasibility study of design strategies are described.

5.1 Living Lab setup

5.1.1 Context – Local development plans – Key initiatives

Dún Laoghaire-Rathdown County, DLR, is a coastal suburban town south-east of Dublin city and the traditional port of arrival of cross-channel ferries from Wales. It has the benefit of unparalleled access to public transport, employment opportunities, leisure facilities, education, shopping and an attractive public realm. Dún Laoghaire is undergoing a transformation in terms of use, business types and town design. The County Development plan for 2022-2028 is being reviewed and contains clear climate targets for building usage which will be incorporated into PROBONO.

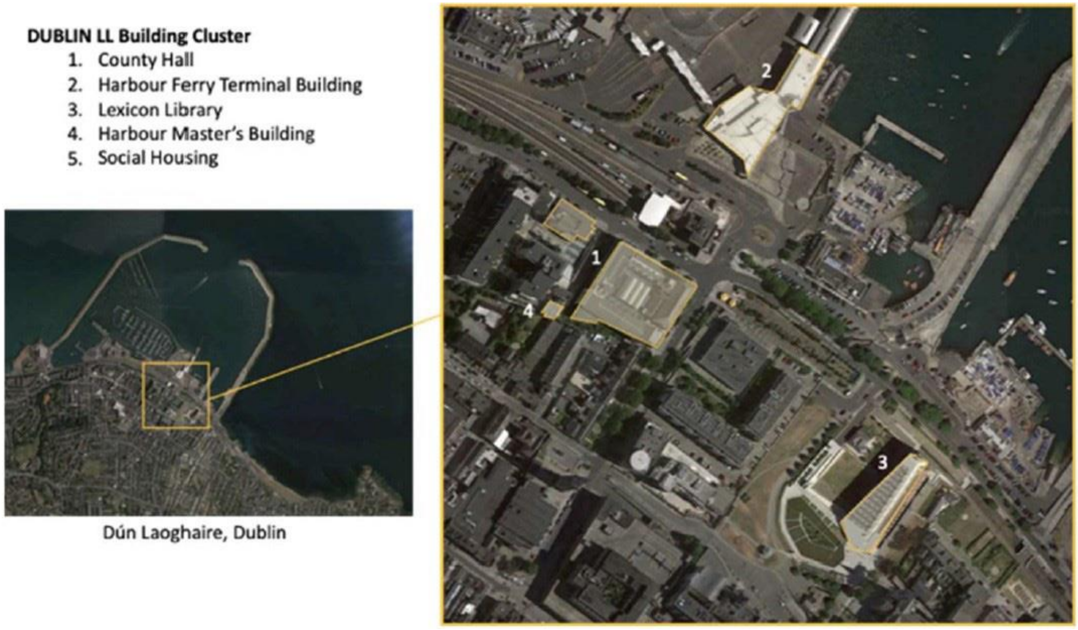


Figure 7 Dublin Living Lab, Dún Laoghaire

The cluster of buildings featured in the LL includes a range of building types, ages, and uses including administrative, community, offices, and housing. Together they form a town centre on the coast of the Irish sea at the heart of community life (Figure 7).
Location and climate: The town's coordinates are 53.2944° N, 6.1339° W. The climate is warm and temperate, with significant rainfall. The average annual temperature is 10.4C, with

average precipitation of 919mm. From 1979 to 2021, Ireland had an average 2800 HDD, and an average 0.03 CDD (the lowest average in the EU).

5.1.2 Vision and challenge to be addressed in PROBONO

The Dublin LL is envisioned as a sustainable and cost effective, zero-carbon GBN, networking key municipal buildings and optimising prototypical housing retrofit for future, wider replication. The LL will engage local citizens in the design and development of a green town centre and living neighbourhood. Improvement of the energy performance of buildings is a primary target for the Dún Laoghaire-Rathdown County Council (DLR), with challenges identified around energy inefficiency in older municipal buildings.
Environment: The aim of the Dublin LL (Figure 7) is to develop a well-integrated GBN, with significant enhancement of the energy efficiency of the buildings in the neighbourhood and their integration into a holistic strategy of energy saving, production, and storage. The strategy will further develop the buildings as prosumers of energy providing renewable clean energy for their operation and for the operation of local transportation fleet of EVs. Interventions will focus on enhancing the performance of case study buildings considerably and developing a positive energy local GBN.
Social: The project will enhance comfort levels for users/ residents of buildings impacted by the energy interventions. Part of the project will deal with low-energy transport, allowing the promotion of e-bikes, electric vehicles, and scooters (legislation pending) to reduce car dependency among DLR staff and residents.
Economic: The project envisages energy cost savings for the Local Authority (DLR) and property owners/ residents of impacted buildings. The results of the project will potentially be replicable by other local authorities and will be disseminated to promote this outcome.
Biodiversity: DLR is developing a County Biodiversity Action Plan following the Irish parliament's 2019 declaration of a National Biodiversity Crisis in 2019. The Plan will aim to protect ecosystem services in the county by enhancing the council's understanding of the area's biodiversity, ensure biodiversity is considered in decision-making, and the protection and enhancement of natural areas within the county. This plan will be in force for the majority of the PROBONO project and will inform the biodiversity initiatives within the project.
Neighborhood approaches to be addressed by the PROBONO LL: Each of the buildings in the cluster are interlinked by their close proximity, work, administration and importance for community, business, and tourism in the area. At the centre of this cluster is County Hall (Figure 8a), where the local council sits and all administrative work for the area is carried out. Recent preliminary research on energy monitoring using IoT sensors has highlighted the inefficiencies in County Hall. Challenges also arise around mixed-use buildings, such as the harbour ferry terminal, social housing, and the Lexicon library (Figure 8b)Figure 7. Opportunities exist to optimise the performance of these buildings, to enable them as prosumers of energy and link them in a wider GBN to sustainable transportation options, via microgrids and innovative local energy stores. While the planning, retrofit and analysis of the buildings themselves is the primary objective of the LL, the nature of this building cluster also offers a unique opportunity to interact with local stakeholders including business, residents, and tourists among others. The cluster of buildings is centred around the harbour entrance. The area is a mobility hub with the Dublin Area Rapid Transit, recent coastal cycling infrastructure project and other road infrastructure all converging in the centre of the LL. Engaging with local stakeholders on how they travel to and between these buildings and then their reasons for visiting will be important baseline information for deciding on interventions and how these stakeholders may interact with them.
The primary objectives of the LL are to:

1) Engage local citizens in the development of an active GBN,

2) Evaluate major energy consumers and potential producers to enable dynamic matching of local renewable generation and neighbourhood consumption,
3) Undertake analysis of town centre municipal buildings, and housing to identify potential efficiency enhancement,
4) Identify optimum strategies for retrofit in the context local climate,
5) Undertake retrofit of key buildings, engaging staff, and building users in the process,
6) Undertake analysis of pre- and post- retrofit intervention in community housing,
7) Engage the community in retrofit strategy and larger sustainability aims to achieve long term sustainable neighbourhoods, and key precedent for other neighbourhoods.

Energy efficiency standard: The project aims at achieving NZEB standard for all buildings: County Hall, Harbour Master's Building, DLR Lexicon, Ferry Terminal, and Social Housing (Figure 7 and Table 8). In addition to this, one building will be developed as an energy-positive building. In collaboration with the technology partners on PROBONO, the project will assess which building is best placed to achieve this goal. The DLR Lexicon Library (Figure 8b) is a strong candidate as the building was completed in 2015 to very high standards. While the building has sophisticated natural ventilation strategies, it has been found to consume a high electricity load in practice (850kKw/year). With effort directed at demand control and renewable capacity installed, this building could achieve net-positive energy through the PROBONO project.

Flagship Building: Dún Laoghaire Rathdown County Hall is the headquarters of the Local Authority (Figure 8a). It is a high-profile public building and local landmark. It is designated the flagship building of the Living Lab as it is the focus of the most intensive measures planned by the PROBONO project. The building is currently extremely energy inefficient and offers potential to radically improve the Local Authority's facilities energy use as well as smart energy management systems using EV charging.

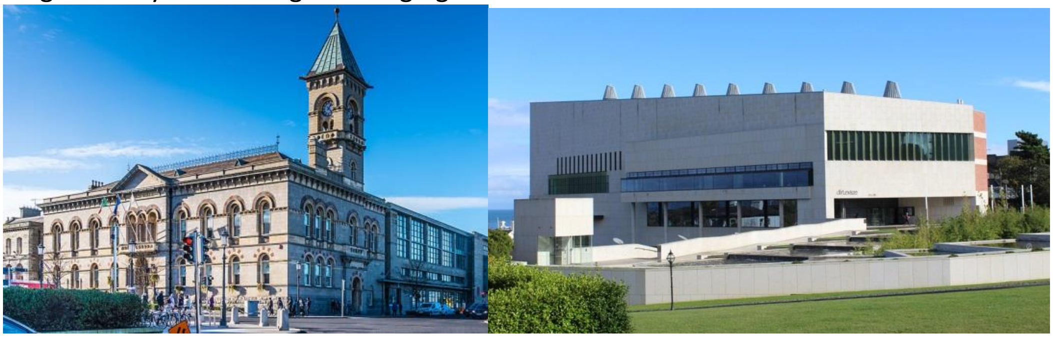


Figure 8 a) Dun Laoghaire County Hall[11] b) DLR Lexicon Library (DLRcc.ie)

Regulatory framework and technical codes:

- EU Energy Performance of Buildings Directive, 2010
- Irish Building Regulations, including:
    - Technical Guidance Document Part L: Conservation of fuel and energy 2021
    - Technical Guidance Document Part F: Ventilation 2019
    - Dún Laoghaire Rathdown Development Plan 2022-2028
- Directive 2001/95/EC of the European Parliament on general product safety
- National Standards Association of Ireland (NSAI) quality standards, as relevant.

5.1.3 Impacts and KPIs

The Dublin LL aims to improve the energy efficiency of the Flagship building, County Hall, while respecting the historic fabric. The project also aims to integrate e-mobility infrastructure with the building's energy system, through the development of a state-of-the-art energy

management system. The Ferry Terminal building offers potential for PV installation on its large areas of flat roof and south-facing façade. The project will examine the effectiveness of the recent retrofit of the Harbour Master's Building. The project will investigate ways in which the recently completed Lexicon Library can enhance its energy performance through a lighting overhaul and energy systems management enhancements.
The expected Dublin LL impacts are summarised in Table 7. Energy savings will be estimated following IPMVP Option C (Whole Facilities). Baseline data for the calculation of savings are available.

Table 7 Dublin LL impacts

Impact Category	Unit	LL Reference	LL Objective
I1. Primary energy savings	GWh/year	Flagship Building energy demand 2 GWh/yr	Flagship Building energy demand 1.2 GWh/yr Flagship Building savings 0.8 GWh/yr
I2. Investments in sustainable energy	million €	-	40 million € invested
I3. Demonstration sites that go beyond NZEB performance	Not defined	Social housing F&G (BER): 380-450 kWh/m2/year	Social housing A (BER) < 50 kWh/m2/year
I4. High energy performance	%	Flagship Building specific heating and cooling demand: 85-100 kWh/m2/year Onsite renewables: 45 kWh/m2/year Social housing specific heating and cooling demand: 120 kWh/m2/year	Flagship Building specific heating and cooling demand: 25 kWh/m2/year Flagship Building specific heating and cooling improvement: 58% Onsite renewables: 260 MWh Social housing specific heating and cooling demand: 50 kWh/m2/year Social housing specific heating improvement: 58%
I5. Reduction of GHG emissions for the total lifecycle	tCO2-eq/year or %	Flagship building GHG emissions (cradle to cradle): 420 tCO2-eq/year	Flagship Building GHG emissions (cradle to cradle): 167 tCO2-eq/year Improvement: 60%
I6. Reduction of the embodied energy in buildings	GJ or %	-	Improvement: 20%
I7. Reduction of air pollutants for the total life-cycle	Not defined	Not defined	Air quality will be monitored in the flagship building and in the housing projects and inform about improvements.
I9. Shortened construction/retrofitting time/cost	%	%	Time/cost shortening period not specified so far. Optimization of the retrofit process will enable significant time and cost reductions.
I10. Improved IEQ	%	-	Improvement: 30%

5.2 PROBONO LL existing infrastructure

5.2.1 Building infrastructure

The characteristics of the buildings forming the Dublin LL are summarized in Table 8. The social housing project has yet to be identified therefore its characteristics are yet unknown.

Table 8 Dublin LL building infrastructure

Building name	Building use	Year of construction	Net floor area (m2)	Heated floor area (m^2)	Occupant capacity	Possibility for BIPV integration (Y/N)
County Hall	Local Government head office	1879; 1996	15528	15528	500	Y
Ferry Terminal	Currently vacant with new uses under consideration	1995	6580	6580	Vacant	Y
Lexicon Library	Public library	2015	8007	8007	Varies	Y
Harbour Master's Building	Office for DLR staff	1820	410	410	Approx. 30	Y
Social Housing	Residential	-	-	-	-	-

5.2.2 Energy infrastructure

County Hall: The facility has a quarter hourly electricity meter and one natural gas meter which both serve space heating, hot water, air conditioning, lighting, general office power, and kitchen. County Hall is served with 4 No. 211kW Beeston boilers which provide space heating and hot water requirement with exception to the new Council Chamber. The LTHW system serves four radiator circuits, a constant temperature circuit for 9 No. Air Handling Units (AHU), an underfloor heating circuit for the ground floor, and Domestic Hot Water (DHW) circuit to a calorifier. There are several split AC units serving various offices through the U-shaped extension. A Cylon Building Management System (BMS) is installed; however, it is not being used to control the heating system and AHUs. The heating system operates in hand and enabled and disabled by security during their walks. AHUs remain on. The new Council Chamber has a dedicated AHU and Heat Pump which are enabled prior to chamber use and switched off afterwards.

Harbour Master Building is located adjacent to the County Hall, but it has its own standalone heating and ventilation plant room, incorporating gas fired central heating. This plant room serves both the original 1900s building and the new extension added approx. 20 years ago.

Lexicon Library: The facility has a quarter hourly electricity meter and one natural gas meter which both serve space heating, hot water, air conditioning, lighting, general power, café and kitchen. However, there are several sub metering points located throughout the facility and linked to the BMS. Heating and hot water are generated using a 550 kW Biomass boiler, operating as lead, and two modulating natural gas condensing boilers, 650 kW and 105 kW. The boilers feed into the main header which serve domestic hot water circuit and calorifier, under floor heating circuit, constant temperature radiator circuit, roof AHU circuit, constant temperature west trench heating circuit, constant temperature east trench heating circuit, constant temperature level 1&2 AHU circuit, and a constant temperature air curtain circuit, and all associated pumps have a variable speed unit. Ventilation is comprised of 14 no. AHU units on the roof that are used to provide passive fresh air into and extracts stale air from the facility. There are also a number of AC split units throughout the facility which serve several meeting and comms rooms. Cooling is provided by 3 no. air cooled 42.5 kW chillers which serve the auditorium AHU, level 2 AHU circuit, and the roof AHU circuit.

Social Housing: the project has not been selected yet.

Ferry Terminal Building has a rudimentary HVAC System which monitors and controls heating, ventilation and air conditioning. The Ferry Terminal building has been vacant for several years and detailed information of the energy systems and energy has not been accessible to date.

The Ferry Terminal has a new design team in place (unrelated to PROBONO teams) and additional information is being sourced from this team.

5.2.3 Monitoring infrastructure

Monitoring system/BEMS already in place:
County Hall has a rudimentary and quite dated HVAC system which Facilities Management have prioritised for upgrading or replacement.
An IoT Energy Monitoring system has been installed in the Canteen area of County Hall (Figure 9) to monitor and collect data across the following metrics: electrical energy usage per appliance in the Canteen Food Preparation Area (ie. Fridges, Cookers, Ovens, Hobs, Freezers etc); Temperature in Canteen area, Humidity in Canteen area, Presence Awareness/people counting in Canteen Area. This system runs on a LoRa Network and the LoRa Gateway is available for further sensors to be deployed as required.

Figure 9 Screenshot of Cognition monitoring interface, County Hall

Harbour Master Building does not currently contain energy monitoring systems.
Ferry Terminal: also has a rudimentary and quite dated HVAC System which monitors and controls heating, ventilation and air conditioning. The Ferry Terminal has a new design team in place (unrelated to PROBONO teams) and additional information is being sourced from this team.
Lexicon Library: has a modern Building Management System, with data being made available to the UCD/ DLR PROBONO teams by the Lexicon Facilities Manager.
Social Housing: 'Climote' remote controlled Thermostats are in place in a subset (circa 1000 out of 5000+) of our Social Housing homes. These remote-control thermostats provide data on house internal temperature and boiler on/off events on a rolling 15-minute cycle. There are also a smaller number of sensors (circa 15) deployed in social housing measuring temperature and humidity. This data is being made available to the UCD/ DLR PROBONO teams by Vijit Chekkala, DLR Internal Energy Consultant.
Additional equipment/infrastructure needed for PROBONO: Further sensors will need to be deployed to gather baseline data on building internal temperature, dissipation, humidity etc. Depending on the interventions selected by the LL, these sensors may be required on any one of the buildings forming the Living Lab.

5.2.4 Non-energy infrastructure

Blue or green spaces: The cluster of buildings in the Living Lab are located in and around a number of green spaces (Figure 10). To the north-west of the Lexicon Library is Moran Park, a green area redeveloped and landscaped as part of the development of the library complex. To the south-east of the library is a green area running along Haigh Terrace, forming a pedestrian link from the seafront to the main street. A linear park runs along a stretch of the waterfront, through the living lab cluster. The Ferry Terminal building has the potential to incorporate a green roof. Overheating and urban heat island effects are not generally currently environmental problems in Ireland. The opportunities for environmental sustainability through green spaces in the LL include shelter, biodiversity, and carbon sequestration.

Other existing infrastructure: Existing mobility hub in County Hall Building, which provides council staff access and charging facilities for battery electric vehicles, e-bikes and potentially scooters (when legislation is passed allowing for their use). Advanced charging facilities and energy storage to integrate with renewable power being generated by the building and an electric vehicle charging value chain (Deployment of smart nodes and creation of the secure, reliable peer-to-peer energy transactions), will be deployed through PROBONO.

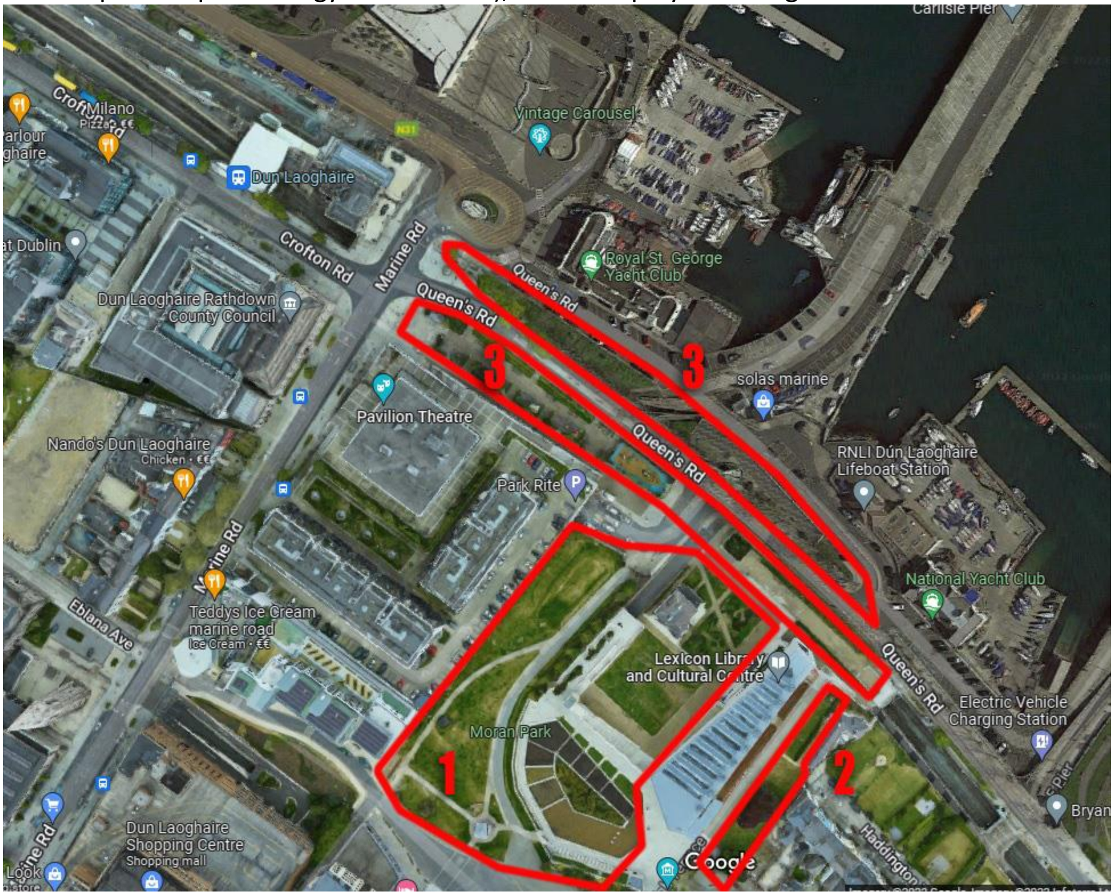


Figure 10 External spaces for improved microclimate and biodiversity support in the Dublin LL: 1 Moran Park; 2 Haigh Terrace 3. Linear Park (Image: google.ie/maps)

COVID plans*:* CO_2 Monitoring sensors have been installed in County Hall in order to provide 'early warning' on when ventilation should be increased. 'Social Distancing' has the overall effect of reducing building capacity and has necessitated the monitoring of the usage on Meeting Rooms and spaces – this work is currently being planned. The buildings affected are County Hall and Harbour Lodge, with this work planned as part of PROBONO and also feeding into the work of the Energy Team, Facilities Management and the Covid Response Team.

5.3 Existing models, data sets and tools

Models already in place: DLR Architects Department will provide architectural and CAD drawings of the buildings in the LL cluster. UCD Master's students will generate Rhino models of the Lexicon Library and County Hall buildings in months 5-8. These models will be used to plan interventions that can be modelled on the Digital Twin.
Digital Twin: The Digital Twin developed in PROBONO will be used to manage energy in the LL buildings, monitoring use, generation, and mobility applications. The DT is being developed by UCD and STAM.
Other IT tools: DLR has a consultation hub called Citizen Space, an online tool for community consultations on proposals from the Council. UCD has access to ESRI ArcGIS tools. PROBONO will further build on the work of the Coastal Communities Adapting Together project (EU INTERREG).
Available data sets: Dún Laoghaire Rathdown County Council as an organisation has been awarded ISO 500001[12] (Energy Management) Certification. All datasets generated and made available via this certification process will be made available to the PROBONO Project.
County Hall Canteen Energy Usage Datasets from the 'Cognition IOT Energy Monitoring Project' are available. These were collected and analysed over two 12-week periods during 2018/2019.
Baseline Building Temperature and dissipation data has been recently gathered by the UCD School of Engineering for the PROBONO Project. This data was collected for County Hall and the Harbour Master Building over a period of a week in early March 2022.
CO_2 Monitoring data is available for County Hall and is being monitored and stored on an ongoing basis since January 2022.
Weather Data from Met Éireann and www.visualcrossing.com is used by DLR's Data Analyst when analyzing various public realm interventions involving vehicle/bike/people counting.
DLR maintains the 'Dún Laoghaire Harbour Weather Station' -
https://www.dlhweather.com/
DLR is a member of and contributes to Dublinked, the Dublin Open Data repository - https://data.smartdublin.ie/
Background info: Occupancy information for all buildings in the LL. Data on baseline energy use for all buildings.
IT collaborative engagement tools and activities: UCD/ DLR LL implementation team members communicate via MS Teams[13] and Trello[14], with a regular schedule of in-person and online meetings. Personnel in UCD and DLR who are not part of the team but represent stakeholders in PROBONO are consulted and invited as necessary to attend these meetings. Document sharing takes place on MS Teams, and project overview boards are maintained on the MIRO[15] platform.
<u>Digital Twin (DT)</u>: The high-level needs of a DT for the Dublin LL are being prepared for inclusion in D1.5. The main purpose of the DT will be energy management systems within buildings, monitoring use, generation, and mobility applications. This data will be available to DLR LL implementation team, UCD research team, and PROBONO technical partners as the project progresses.
<u>Current stakeholder engagement</u>: A stakeholder engagement project in the Lexicon Library building is being performed as part of a student thesis research in the M.Sc. Architecture, Urbanism and Climate Action programme. This research includes survey research of library users to determine user satisfaction with IEQ. The research is also deploying sensors to measure indoor temperature, light, and noise levels.
<u>Stakeholder engagement IT systems capacity</u>: UCD has a range of engagement tools including ArcGIS for data mapping, SPSS[16] for survey data analysis, NVivo[17] for interview coding, and MS Office[18] for report compilation. DLR has a public consultation website for citizens of the local

authority area, https://dlrcoco.citizenspace.com. This website will be used/ developed to assist with stakeholder engagement over the course of the PROBONO project. DLR's engagement strategy will be overseen by DLR's Digital Strategy Officer.

5.4 Implementation plan for adopted scenario

This section describes the singular scenario (technologies, construction innovations, co-creation aspects) considered for implementation and execution in the Dublin LL.

5.4.1 Selected technologies and planned interventions

Up to now, and according to the work carried out in the technical Work Packages of the project so far, the following technologies have been selected for integration in the Dublin LL (Table 9 and Table 10).

Table 9 Selected technologies for County Hall

County Hall	Provider
200kWp coloured façade BIPV Area approx. 1000sq.m.	**Fraunhofer**
Microgrid Battery and connection links, including: Bi-directional electronic battery packs; Battery cells to build swappable battery packs; Second life battery packs for stationary energy storage; Electrical and electronic material for installation.	**Cidaut**
Insulation (vapour permeable option) / **Insulation (PIR insulation panels)** Depending on budget/ technological applicability, an insulation product will be selected and trialled on the County Hall building. This product/ intervention may transfer to the Ferry Terminal building following a feasibility study/ communication with the Ferry Terminal design team.	**Cidaut, Soprema**
Hardware deployment: Physical installation of several "smart agents", to include: Raspberry Pi 3B+ (20 no. Cortex-A53 64-bit @ 1.4GHz; Raspberry Pi GSM Modul LTE; 4G LTE Router TP-Link Router 4G LTE Wi-FI; VPN License 6-32 smart nodes. **GCP cloud infrastructure**, to include: Server for the Bovlabs API; Database server for the marketplace; Scheduler (to schedule the reading of offers and requests); Blockchain nodes; Message Queue; Smart Agent for Reliability Provider; Back Office for charging stations. Monthly data subscriptions (4G LTE)	**Bovlabs**
Electric vehicle charging infrastructure, to include: Chademo loading station (6 no.)'Terminal installation costs. The vehicle charging and B2V aspect of the project will involve UX analysis of end-users.	**Bovlabs**
Energy reporting analysis	**Energy Elephant (external)**

Table 10 Selected technologies for Ferry Terminal, Lexicon Library, Harbour Master's Building and Social Housing units

Ferry Terminal	Lexicon Library	Harbour Master's building	Social Housing
Microgrid connection links Provider: Cidaut	**Microgrid battery and connection links** Provider: Cidaut		**Microgrid connectivity** (for 10 social housing units) Provider: Cidaut
	Smart lighting retrofit Provider: Cidaut		
Energy reporting analysis Provider: Energy Elephant (external)	**Energy reporting analysis** Provider: Energy Elephant (external)	**Energy reporting analysis** Provider: Energy Elephant (external)	**Energy reporting analysis** Provider: Energy Elephant (external)

5.4.2 Stakeholders and their role

In the table below (Table 11) the various Dublin Living Lab internal and external stakeholders and their roles are further outlined, defined, described, and categorized.

Table 11 Dublin LL stakeholders and roles

Stakeholder	Role	Internal (blank) /external ('x')
Users		
Council Staff	Work in the buildings	
Customers	Library members, Council customers	X
Tenants	Tenants of Social Housing and Council Buildings	X
Providers		
Electrical Contractors	Retained to carry out electrical work across estate	X
BMS Providers	Providing BMSs for County Hall, Ferry Terminal, Lexicon Library	X
Influencers		
Dublin Metropolitan CARO	Climate Action Regional Office https://www.caro.ie/the-caros/dublin-metropolitain	
Codema	Dublin's Energy Agency https://www.codema.ie/	
Governance		
DLR Facilities Management	Manage entire DLR estate	
DLR Management Team	DLR Chief Executive and Directors of Service	
DLR Energy Team	Internal Energy Team within DLR	
Others*		
AECOM	Provide the Mobility Hub software platform	X
Smart Dublin	Dublin Region Smart City Project Team https://smartdublin.ie/	

Based on this list of stakeholders relevant to the Dublin LL, they have been mapped according to the methodology described in Annex II. The output is displayed in Figure 11. Compared to the original GBN stakeholder map (Figure 49), an additional category of "Funding" has been added as "Private finance" and "Local authorities" does not include important funding sources.

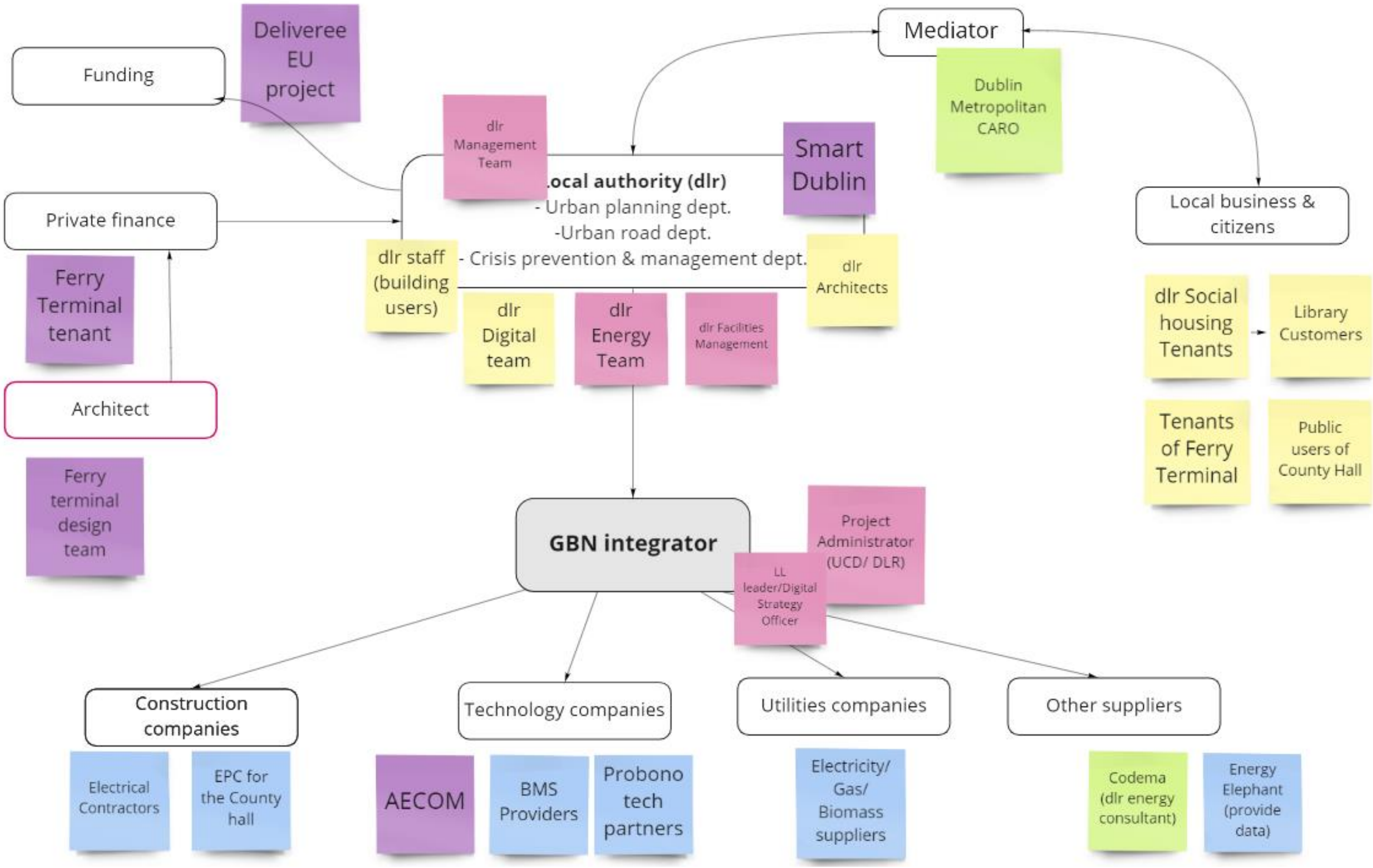


Figure 11 Stakeholder mapping for the Dublin LL

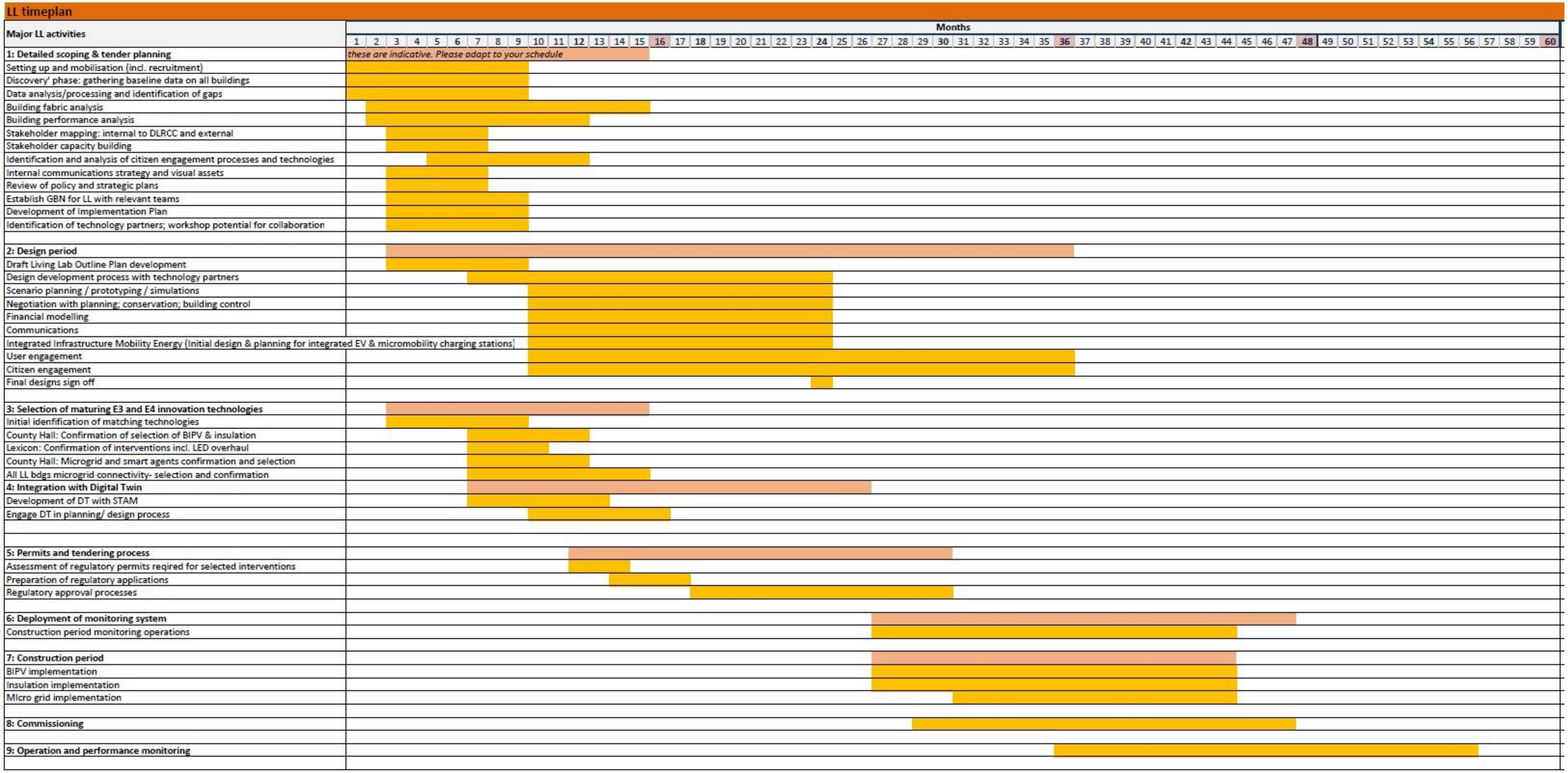


Figure 12 Dublin LL timeplan

5.4.3 Design coordination

County Hall: The proposed interventions at County Hall are BIPV panels, microgrid battery and connection links, insulation, installation of smart agents, and electric vehicle charging infrastructure. Currently the Dublin LL is in discussion with the PROBONO project in relation to which of these can be funded by the project (see 5.5). The County Hall building is also participating in a second EU energy project called Deliveree. This project is being coordinated by DLR's energy team, in coordination with energy consultant Codema. The aims and objectives of the two projects are broadly similar, and both will run in parallel to upgrade the energy efficiency of the County Hall. This will involve a high degree of clarity as to which interventions/ studies are associated with PROBONO and can be credited as a result of the PROBONO project. The County Hall is intended to form the basis of an Energy Performance Contracting process in which a private contractor will bid to raise the energy profile of the building to a standard determined in the EPC tender call. PROBONO initiatives and technologies can assist the contractors in reaching or exceeding their goals with this building. With two EU projects running simultaneously, teams from both projects will need effective communication and management structures to avoid duplication of works and interventions as the projects proceed.

Ferry Terminal: The Ferry Terminal is due to be rehabilitated into an Enterprise Centre by a private operator who has rented the building from DLR, the Local Authority. This presents challenges and opportunities for the PROBONO project. The new tenant will bring a design team together to effect the transformation of the building. This will inevitably involve energy upgrades in order to comply with the building regulations. The Dublin LL intends to liaise and work closely with the design team in order to bring PROBONO expertise and innovations to the rehabilitation of this work, and to integrate the building successfully into the GBN.

Lexicon Library: Interventions planned for the Lexicon Library are on a smaller scale than those at the County Hall, however this building also forms part of the EU Deliveree project, which means it will be subject of the same mechanism for cooperation and intervention planning and management as the County Hall. All interventions will be proposed, designed, and constructed in cooperation with DLR architects' department, DLR energy department, Codema, and the PROBONO project team.

Harbour Master's Building: The PROBONO project will primarily play a role in monitoring energy use in the Harbour Masters Building, which has been recently renovated and extended to accommodate DLR staff. This process will be coordinated with DLR Architects and DLR Energy Department.

Social Housing: The DLR social housing project has yet to be identified. Upon selection of a suitable project, full assessments of energy and building information known to DLR will be carried out. Any gaps in energy monitoring or fabric makeup will be investigated and filled. Planned interventions will be designed in conjunction with DLR Architects department and Social Housing section.

5.4.4 Construction elements and connections

The design element of the project will be a collaborative effort involving the Dublin LL team from DLR and UCD, the DLR Architects Department, the DLR Energy Team, and Codema, DLR's energy consultant who will be overseeing all energy related interventions on two of the LL buildings: County Hall and Lexicon Library. The various elements will be discussed in the context of energy use, conservation, and integration between the buildings. The energy interventions planned as part of the Deliveree project will be assessed to see if they complement the aims of the PROBONO project. Smart energy management systems will be coordinated by the PROBONO team.

Over the coming weeks, the respective roles of the two projects will be defined and clarified. A decision-making hierarchy will be established, with interventions discussed and approved by all relevant stakeholders. DLR Architects will be responsible for the coordination, design and implementation of physical interventions, with oversight from DLR Energy and Codema, and input from PROBONO partners.

5.4.5 Tools for optimal component configuration and integration

The Digital Twin aspect of the PROBONO project will provide a useful tool for assessing the effectiveness of proposed interventions. Advice will be received from technology partners regarding the optimal tools required for components of interventions. These will be implemented in all cases where PROBONO technologies are in place on LL buildings. This process will coordinate with similar component configuration processes employed by DLR Energy Team and the Deliveree project.

5.4.6 Timeplan

The timeplan for the Dublin LL is detailed in Figure 12.

5.4.7 Risks and constraints

5.4.7.1 Risks

Potential risks and associated contingencies considered for the LL realisation are described in Table 12.

Table 12 Risks and associated contingencies for the Dublin LL [P=Probability, I=Impact, L=Low, M=Medium, H=High]

#	Description of risk	P	I	Proposed risk-mitigation measures
During planning/design/technology development (incl. permits and tendering process)				
1	Lack of clarity of project roles	M	M	Ensure consistent communication patterns
2	Misuse/ mismanagement of budget	M	H	Transparent budgetary decision-making processes and management
3	Lack of experience in administering EU funded projects	L	M	Ensure team members with experience are consulted when necessary
4	Expectations management regarding ability of buildings to reach nZEB within budget constraints	M	L	Clear communication with all stakeholders relating to the scope and likely outcomes of the project
During construction/deployment/technology integration				
5	Availability of PV technology from project partners	M	H	Early assessment of technological availability and budgeting constraints
6	Availability of insulation and retrofit membranes from project partners	M	H	Early assessment of technological availability and budgeting constraints
7	Covid-19 restrictions reimposed	M	H	Prepare online working protocols and information sharing. Consistent review of public health guidelines.
During monitoring, evaluation and verification/technology optimisation				
8	Data protection breach	L	M	Put in place adequate security measures and processes
9	Technological failure/ breakdown	M	M	Assess potential for reserve systems/ tech should primary systems fail
10	Lack of time to complete process	M	M	Ensure sound project management results in timeline maintenance

5.4.7.2 Local constraints

Climatic: Urban heat islands/ building cooling not priorities in Irish climate. Water ingress and air tightness are key concerns of building detailing and need to be addressed for all BIPV installations.
Technical: Roof of Ferry Terminal not sufficiently strong to accommodate PV or Green Roof.
Economic: DLR budget for interventions to be established and confirmed.
Social: Social housing project to be selected. Access to social housing for energy monitoring dependent on cooperation with tenants.
Legal: Data protection and building regulations to be observed throughout.

5.4.8 Change management

The Dublin Living Lab is coordinated by DLR and UCD. A Project Administrator who will be employed by UCD using some of the personnel budget originally allocated to DLR will be assigned in September 2022.
Changes identified as necessary by the PROBONO teams within DLR and UCD will be discussed at the regular project meetings held monthly in person and bi-weekly online. Once a change has been identified, communication is made to the PROBONO project to request formal acknowledgement of the change, if necessary. The project risk register is updated to include any risk implications of the change. This risk assessment identifies any threat to deliverables, budget, timetabling, personnel, costs etc.
Once the change is identified, the Project Administrator will take responsibility for the change and tend to all relevant administration and management issues arising from the change.

5.4.9 Cost management

As above, the Dublin Living Lab will employ a Project Administrator who will develop a cost management process for both DLR and UCD to avoid cost overruns as the project proceeds. The Project Administrator will be in place from M10, October 2022. The timeframe of appointing the Project Administrator means that costs for interventions will not have commenced before the position is filled. Costs for personnel are monitored through timekeeping logbooks by all PROBONO staff.

5.4.10 Business Plan and feasibility study

The interventions planned for the group of buildings in the Dublin LL will contribute to energy savings and energy efficiency among the municipal building portfolio of DLR. The financial return on these investments will extend beyond the lifetime of the PROBONO project and contribute to continued reductions in the municipality’s energy expenditure over succeeding years. This effect will be particularly impactful in the current era of increasing fossil energy costs, The effectiveness of these measures will be calculated and disseminated among the public, with the project acting as demonstrator of energy efficiency cost savings.
The Dublin LL has been granted budget for the following items:

- 145kWh Second Life Batteries €32,625.00
- Assembly of power boxes for second life batteries €1,950.00
- Funding for Social Sciences expert €60,000.00
- Funding for construction €50,000.00
- Funding for Cloud Infrastructure from Bovlabs: €17,670.00
- Materials and implementation of Soprema technologies €70,000.00
- Directional electric vehicle chargers: €60,000.00

- Battery cells to build swappable battery packs: €5,000.00
- Second life battery packs for stationary energy storage: €30,000.00
- Electrical and electronic material for installation: €15,000.00.

The Dublin LL will proceed with DLR Energy Department, the EU Deliveree project, and the design team for the Ferry Terminal to assess the scope of interventions for the LL buildings, and which interventions will be associated with the PROBONO project. At the time of writing this process is getting underway and a full feasibility study will be dependent on the outcome of this process.

6 LL2 Madrid Scoping and Implementation Plan

This chapter details the Scoping and Implementation Plan for the Madrid LL. It begins with an overview of the Living Lab setup and continues with the as-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that cab be utilised in PROBONO are also described together with the first list of expected impacts and KPIs.
Next, the scenario considered for adoption (technologies, construction innovations and co-creation aspects) as well as the implementation plan are detailed along with the engineering activities necessary for the modification of the LL design according to local constraints like climatic, technical, economic, social and legal. Finally, current Business Plan details and feasibility study of design strategies are described.

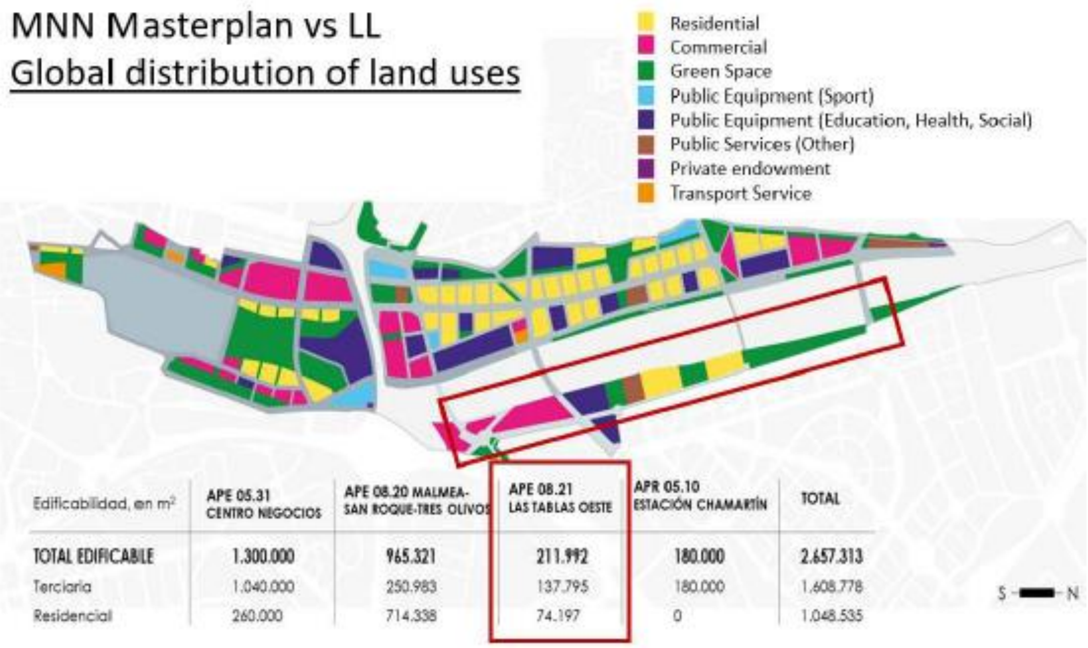
6.1 Living Lab setup

6.1.1 Context – Local development plans – Key initiatives

Madrid New North (MNN) is a part of a public initiative of Madrid City Council aiming to regenerate 300 hectares of land in the North of the Spanish Capital and close the gap that Madrid has historically in that area due to the railway tracks that come out of Chamartin Station (Figure 13).

Figure 13 Madrid LL site (google maps view of Las Tablas Oeste)

MNN envisions the creation of a new sustainable city model, structured around green areas, with an extensive public transport network, including the total renovation of the Chamartín railway station. It will address the area segregation, recover the degraded and derelict spaces, connect isolated neighbourhoods, and improve the quality of life of the residents. Figure 14 shows the global distribution of land uses in Madrid New North and the PROBONO Living Lab. The LL area, Las Tablas Oeste (APE.08.21), has common infrastructures to the rest of the areas, Chamartin Station (APR. 05.10), Chamartin Business District (APE.05.30), Malmea-San Roque-Tres Olivos (APE.08.20), that must be planned jointly, such as energy infrastructure, telecommunications, drinking water supply and irrigation, wastewater, and mobility infrastructure, leaving local networks as the sole competencies of each compensation board. However, the 4 areas have independence in their development and will be executed by independent Compensation Boards (Association of owners) and the Madrid City Council with responsibility for carrying out the constructive design of the project and its execution, over the course of the whole process, including all infrastructures, parks and public space.



Edificabilidad, en m²	APE 05.31 CENTRO NEGOCIOS	APE 08.20 MALMEA-SAN ROQUE-TRES OLIVOS	APE 08.21 LAS TABLAS OESTE	APR 05.10 ESTACIÓN CHAMARTÍN	TOTAL
TOTAL EDIFICABLE	1.300.000	965.321	211.992	180.000	2.657.313
Terciaria	1.040.000	250.983	137.795	180.000	1.608.778
Residencial	260.000	714.338	74.197	0	1.048.535

Figure 14 MNN Masterplan vs LL Global distribution of land uses

Location and climate: The Madrid LL (40°29'43.7"N 3°40'33.0"W) and its metropolitan area has a Mediterranean climate (Köppen climate classification: Csa) which transitions to a cold semi-arid climate (BSk). Sunshine duration is 2,769 hours per year, from 124 (4 hours per day in average) in December to 359 (above 11.6 hours per day in average) in July. Madrid has an annual average of 1440 HDD and 2956,8 CDD.

Public/private business model and funding: Distrito Castellana Norte (DCN) will be the main private partner of the project with more than 50% of the land in MNN and the majority partner in the areas of Las Tablas Oeste (97%). DCN will be in charge of executing the common infrastructures.

In 1993, DCN was awarded of a public tender to buy the land of the Spanish Railroads Authority (ADIF) with the condition of the approval of the MNN area urban planning phase. This means that once the urbanization projects are executed, DCN will have the ability to build buildings to recover its investment according to the percentages mentioned above.

6.1.2 Vision and challenge to be addressed in PROBONO

Madrid LL will be focused on the Development of Las Tablas Oeste (APE.08.21) and the establishment of common integrated energy infrastructures to fully cover the district's thermal demand through geothermic energy and the electricity demand through solar energy via photovoltaics on buildings and the urban space.

In Spain there is no regulatory model for hot and cold networks, with examples existing but giving rise to difficulties when it comes to scaling solutions, so it is expected that this pilot will allow the standardization of the necessary elements in the public space for their approval. As part of the certification/standardization analysis and benchmarking the use of Level(s)[19] will be implemented, besides DGNB[20], demonstrating the project's focus on resource-efficiency with the whole lifecycle in mind, promoting a circular economy in the construction sector. MNN is already registered to achieve LEED Cities and Communities and BREEAM ES sustainable certifications aiming the highest qualification in both rating systems.

There are two main challenges that the project expects to overcome:

- Use of public plots for part of the infrastructure (geothermal network), which requires a special urban plan for uses' compatibility.
- Buildings in Las Tablas Oeste to be eventually connected to the geothermal network, may be different than the one proposed (plot 04 and plot 08), owing to the fact, that the design of the geothermal network depends on the geothermal network deployment viability (use of public plots needs to be approved). The building design (and their corresponding thermal demand) to be connected is not defined yet.

DCN shall utilize the proposed plots or others in DCN ownership within Las Tablas Oeste as a contingency plan. The strong Advisory Board Members of Madrid LL will consist of: Community of Madrid (supporting all the legal requirements for the geothermal network deployment), NBS local expert (supporting the LL group), Energy suppliers, non-profit with expertise in geothermal technology, EE platforms.

Neighborhood approaches to be addressed by the PROBONO LL: The Las Tablas plant must provide the demand for cooling, heating, and sanitary hot water for 123,795 m^2 of offices, 74,197 m^2 of residential, 4,819 m^2 of commercial facilities and 5,403 m^2 of public buildings. The Living Lab will be focused on 30,000 m^2 of residential and commercial buildings that will be thermoactivated under the pilot.

Effectively, the PROBONO Living Lab will consist of:

- Construction of the geothermal network
- Construction of 2 buildings (commercial and residential building) (*not included in the PROBONO budget)
- Urbanization project development in the area of Las Tablas Oeste (*not included in the PROBONO budget)
- Thermoactivation of commercial and residential buildings connected to the geothermal network

Energy efficiency standard: At least nZEB status will be achieved for all buildings The aim is to achieve Energy Positive building status for the residential building in Plot 04. The new buildings will be designed over the course of 2023 according to the requirements established in terms of energy demand, GHG emissions, etc. During the design phase the building that will form the PROBONO flagship building will be selected.

Regulatory framework and technical codes: MNN follows the General Urban Development Plan of Madrid and the regulations established in Specific Planning Areas (APE) of APEs 05.31, 08.20 and 08.21. The latest modification of the General Urban Development Plan of Madrid of 1997, requested and approved for the urban operation of MNN, includes and promotes the new standards according to the building characteristics, the character of the energy supply, and the European directives. The consumption of non-renewable primary energy (Cep, nren) of the spaces contained within the thermal envelope of a building in the APE, or where appropriate, of a part of the building considered, will not exceed 70% of the limit value (Cep, nren, lim) set in the DB HE of the CTE. The total primary energy consumption (Cep, tot) of the spaces contained within the thermal envelope of a building, or, where appropriate, of a part of the building considered, will not exceed 85% of the limit value (Cep, tot, lim) fixed in the DB HE of the CTE in force at the time or regulations that replace it".

The regulatory framework and technical codes that the LL development needs to comply with is:

- **Electric sector:**

General: Ley 24/2013, Real Decreto- ley 23/2020

Renewables, cogeneration and waste: Real Decreto 413/2014, Orden IET/2212/2015, Real Decreto 947/2015
Own consumption: Real Decreto 244/2019 Real Decreto-ley 15/2018
Transport, distribution and quality of electricity supply: Real Decreto 1955/2000, Ley 2/2007, Decreto 19/2008
Natural gas: Ley 34/1998, Real Decreto 984/2015, Real Decreto 919/2006, Real Decreto 1434/2002 de 27 de Diciembre, Orden 289/2006
Design regulations: Real Decreto 337/2014, Real Decreto 337/2014, Real Decreto 919/2006, Real Decreto 1027/2007de 20 de julio.

- **Normative in the urban framework:**

Initiatives, declarations, and green book**:** Objetivos de Desarrollo Sostenible 2030 de las Naciones Unidas**,** UN Habitat III y la Nueva Agenda Urbana**,** Acuerdo de Paris COP 21 de 2015**,** Agenda Urbana Europea**,** Objetivos medioambientales, energéticos y climáticos para 2030**,** Marco de Políticas de Energía y Cambio Climático 2021-2030**,** Libro Verde Un marco para las políticas de clima y energía en 2030**,** Paquete de propuestas: Energía Limpia para todos los Europeos de 2016**,** New Green Deal de 2019**,** Agenda Urbana Española de 2019
European Directives and Regulations: Directiva (UE) 2019/944, Directiva (UE) 2018/2001, Reglamento 2018/1999
National level legislation: RD Legislativo 7/2015, texto refundido de la Ley de Suelo y Rehabilitación Urbana, Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030, Instrucción Técnica Complementaria "ITC – EA – 01 Eficiencia Energética"
Regional level legislation: Ley 9/2001 del Suelo de la Comunidad de Madrid, Plan Energético de la Comunidad de Madrid Horizonte 2020, ORDEN 665/2014 Estrategia de calidad del aire y cambio climático de la Comunidad de Madrid 2013-2020. Plan Azul +
Local level legislation: Plan de Uso Sostenible de la Energía y Prevención del Cambio Climático de la ciudad de Madrid, Normas Urbanísticas Plan General de Ordenación Urbana de Madrid de 1997, Normas Urbanísticas Particulares de las APEs 05.31, 08.20 y 08.21, Ordenanza Municipal de Tramitación de Licencias Urbanísticas de 2004, Plan A de Calidad del Aire de 2019, Proyecto Madrid + Natural, Ordenanza de calidad del aire y Sostenibilidad (2021).

6.1.3 Impacts and KPIs

In order to fully cover the district's thermal demand through geothermic energy and the electricity demand through solar energy via photovoltaics on buildings and the urban space, the development of Las Tablas Oeste (APE.08.21) and the establishment of common integrated energy infrastructures will be carried out.
The expected Madrid LL impacts are summarised in Table 13. Energy savings will be estimated with the IPMVP Option D (Calibrated simulations). No baseline energy data is available as it is a new neighbourhood.

Table 13 Madrid LL impacts

Impact Category	Unit	LL Reference	LL Objective
I1. Primary energy savings	GWh/year	Flagship Building energy demand 8.8 GWh/year	Flagship building energy demand: 2.76 GWh/year Flagship building savings: 6.04 GWh/year
I2. Investments in sustainable energy	million €	-	4.2 million €
I3&I4. Demonstration sites that go beyond NZEB	-	Flagship Building specific heating and cooling	Flagship Building specific heating and cooling demand: 49 kWh/m2/year Flagship Building improvement: 65%

Impact Category	Unit	LL Reference	LL Objective
performance High energy performance		demand: 140 kWh/m2/year	
I5. Reduction of GHG emissions for the total lifecycle	tCO2-eq/year or %	Flagship building GHG emissions (cradle to cradle): 2,912.8 tCO2-eq/year	Flagship Building GHG emissions (cradle to cradle): 913.5 tCO2-eq/year Improvement: 69%
I6. Reduction of the embodied energy in buildings	GJ or %	Embodied energy in typical buildings: 1,000 GJ	Embodied energy in LL buildings: 500-900 GJ Improvement: 10-50%
I7. Reduction of air pollutants for the total life-cycle	Not defined	-	Measurement will allow the measures definition and final improvement establishment
I9. Shortened construction/retrofitting time/cost	%	Construction/retrofitting typical time: high Construction/retrofitting typical cost: high	Improvement in time/cost expected: 40-50%
I10. Improved IEQ	%	-	Improvement IEQ: 30-40% Improvement Dust and noise during retrofitting: 30%

6.2 PROBONO LL existing infrastructure

6.2.1 Building infrastructure

The two new buildings (commercial building in Plot 08 and a residential building in Plot 04) will be designed over the course of 2023/24 (Figure 15). The concept design for plot 08 has 92.006 m^2 of tertiary use where at least 15.000 m^2 (commercial building) are expected to be included in the project. The rest of the buildings built in these plots shall be connected to the geothermal district grid.

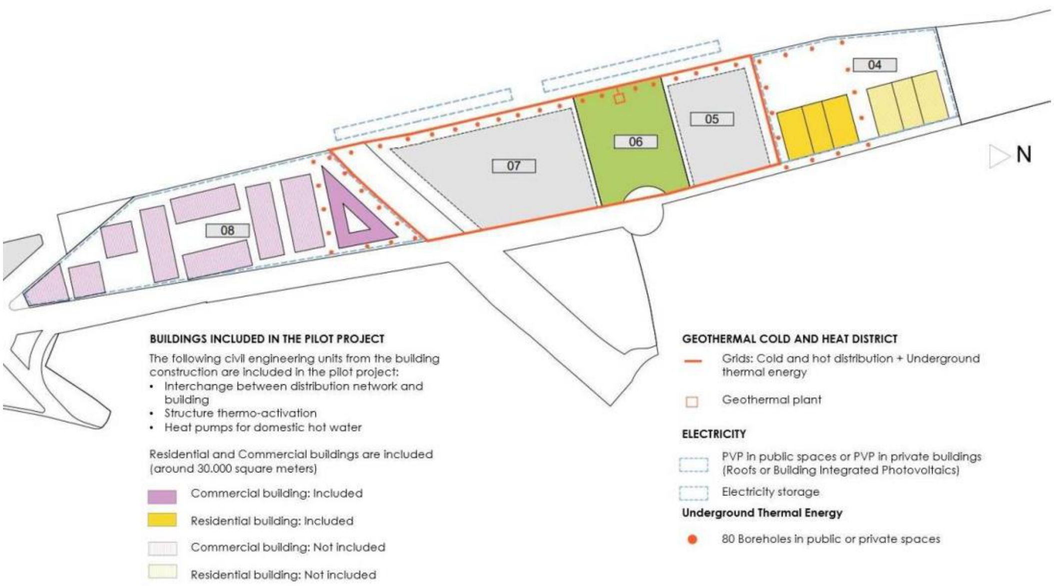


Figure 15 Madrid Living Lab buildings

6.2.2 Energy infrastructure

Existing energy carriers, storage system and interaction with the grid: The new energy structure (geothermal network) is being designed (over the course of 2022) (In progress).

6.2.3 Monitoring infrastructure

Additional equipment/infrastructure needed for PROBONO: The DT covering the operation of the geothermal plant will be constituted by the BIM of the building (static information) and all the information related to the Building Automation and Control Network (BACN) where **the sensors, actuators and controllers monitoring the generation, distribution and demand of the geothermal plant are connected.** BIMtoBACN tool will be used to generate, from the IFC of the building, the automation and control network, and in consequence, the BIM-compliant repository for dynamic data collection feeding the DT. These collected data, together with the BIM model of the geothermal plant, will be used to operate the plan by applying a Model Predictive Control to the DHC network by defining a high-level decision layer to select the optimal operational strategies for the next hours based on short-term predictions of the energy demand and resource availability as well as on simulations of the network performance.
The DT will be completed with the BIM-based data of the new materials and components of the new neighbourhood (data captured during construction and updated during maintenance) to be able to **assess the global material use and embedded emissions during the whole life cycle**.
Impact assessment for Construction activity pollution prevention will be checked thanks to the mapping technology during construction (**drones, and LIDAR sensors**). Heat Island reduction impact assessment will be checked thanks to mapping technology (drones + EGNSS-European Global Navigation Satellite Systems, DT connect.

6.2.4 Non-energy infrastructure

Blue or green spaces: The Tablas Oeste (APE 08.21) area is currently 100% railway infrastructure **(**Figure 13**).**
Other existing infrastructure:

- Telecommunications: https://www-2.munimadrid.es/fsdescargas/VISAE_WEBPUB/NTI/135-2018-00489/contenido_no_modificable/docsMaterializado/98024E4E00B50615_1928%20APE_08_21_I08_4_INFRA_EXIST_TELECO.pdf
- Water: https://www-2.munimadrid.es/fsdescargas/VISAE_WEBPUB/NTI/135-2018-00489/contenido_no_modificable/docsMaterializado/98024E4E00B505F4_1925%20APE_08_21_I08_1_INFRA_EXIST_AGUA.pdf
- Electricity: https://www-2.munimadrid.es/fsdescargas/VISAE_WEBPUB/NTI/135-2018-00489/contenido_no_modificable/docsMaterializado/98024E4E00B504CE_1927%20APE_08_21_I08_3_INFRA_EXIST_ENERGIA_ELECTRICA.pdf
  Gas: https://www-2.munimadrid.es/fsdescargas/VISAE_WEBPUB/NTI/135-2018-00489/contenido_no_modificable/docsMaterializado/98024E4E00B504D1_1929%20APE_08_21_I08_5_INFRA_EXIST_GAS.pdf
- Sewage network: https://www-2.munimadrid.es/fsdescargas/VISAE_WEBPUB/NTI/135-2018-00489/contenido_no_modificable/docsMaterializado/98024E4E00B5060D_1926%20APE_08_21_I08_2_INFRA_EXIST_SANEAMIENTO.pdf

COVID plans: No COVID plans are taken into consideration in this project.

6.3 Existing models, data sets and tools

Models already in place: Topographic terrain model (BIM) and Facilities model (BIM) (water, electricity, gas, sewage, etc).

Digital Twin: PROBONO will apply digitalization techniques and the generation of DTs focused on two different problems and stages of the building process: a DT for the construction/demolition phase and a DT for the operation phase of the building, oriented to the smart operation of a geothermal plant. For the generation of every DT different data sources will be considered, but both of them based on the static BIM representation of the building and on dynamic/in-situ data collection from sensors and human inputs, in the construction/demolition DT, and from sensors, actuators and controllers, in the DT for the geothermal plan operation.

The use of these DTs in the building sector and civil work will allow the synchronization of construction and operation processes in real time with their static BIM versions, fostering a well-informed decision making during the construction and operation of the building. Both DTs will be sustained by a platform able to integrate different data repositories, ontologies, and software tools. To do so, the platform will be based on a microservices oriented architecture that, through an interoperability framework, will be able to offer useful tools and services to update the BIM-GIS models of the building according to the progress of the work and the operation of the building, guaranteeing in this way the consecution of synchronized DTs with the reality of the construction and operation of the building.

This ICT integration and interoperability framework adapted to the construction and operation domain will guarantee the communication, homogenization and synchronization of information in a transparent way to guarantee interoperability and understanding of the various elements involved in improving the construction process and the HVAC operation of the building. In addition, this platform will use the synchronized information of the DTs to generate services assessing and quantifying the impact of the actuations from a sustainable point of view.

Other IT tools: The design team shall use a tool already developed for MNN that classifies existing materials (LER) and provides a guide for deconstruction, treatment, and reuse whenever possible.

The BIMtoBACN tool will be used to generate, from the IFC of the building, the automation and control network, and in consequence, the BIM-compliant repository for dynamic data collection feeding the DT. These collected data, together with the BIM model of the geothermal plant, will be used to operate the plan by applying a Model Predictive Control to the DHC network by defining a high-level decision layer to select the optimal operational strategies for the next hours based on short-term predictions of the energy demand and resource availability as well as on simulations of the network performance.

The starting point will be a tool already developed by DCN to register the exiting material during the demolition phase, within a Geographical Data Base (GIS system) that includes inventory of the existing buildings and infrastructures to be demolished, and the typology and volume of waste materials available for their recycling and reuse.

Available data sets:

- Weather data: Barajas Airport can be taken as a weather station.
- Open data (even if it is not owned by the LL): https://www-2.munimadrid.es/fsdescargas/VISAE_WEBPUB/NTI/135-2018-00489/listado.htm

IT collaborative engagement tools and activities: The Madrid municipality uses an open software platform (Consul) which includes tools for debates, proposals, voting and participatory processes. https://decide.madrid.es/

The website also links to an Open data portal (https://datos.madrid.es/portal/site/egob) and to a Geoportal (https://geoportal.madrid.es/IDEAM_WBGEOPORTAL/index.iam).

6.4 Implementation plan for adopted scenario

This section describes the singular scenario (technologies, construction innovations, co-creation aspects) considered for implementation and execution in the Madrid LL.

6.4.1 Selected technologies and planned interventions

The technologies selected for implementation are grouped under the following four intervention categories and listed in Table 15:

- Construction of the geothermal network
- Construction of 2 Buildings (commercial and residential building)
- Urbanization project development in the PROBONO Living Lab
- Thermoactivation of commercial and residential buildings connected to the geothermal network

6.4.2 Stakeholders and their role

In the table below (Table 14) the various Madrid Living Lab internal and external stakeholders and their roles are further outlined, defined, described and categorized.

Table 14 Madrid LL stakeholders and their role

Stakeholder	Role	Internal (blank) /external 'x')
Users		
Building occupants	Surveys in terms of thermal comfort and occupant behaviour	X
Providers		
ECOFOREST	LL provider geothermal equipment, support design of geothermal central adapted technologies/space	
BeePlanet	LL provider building thermo-activation equipment, batteries PVP	
IDOM INGENIERIA	Support to LL group as designer of specific elements to geothermal grid. LL geothermal grid design, construction- operation supervision, co-design thermoactivated building standard, *Possibly, monitoring, Digital Twin related geothermal (Madrid only)	
ACCIONA ING	LL Leader (WP7 demonstration), support technologies development, LL Madrid management, design, construction, and operation in collaboration to all parties	
ACCIONA (R&D & Departments)	LL technologies development (Digital Twin for construction and materials, LCA, new materials developed with different components from demolition integrated GBN buildings and infrastructure + geothermal plant and roads)	
ACCIONA (ESCO Department)	LL technologies operation, operating the Thermal and Electricity Microgrid to be developed. With the participation of ACCIONA's Digital Energy Services Control Center, in the LL we will be managing: Monitoring of energy consumption, Remote management and control in real time through specific software, Integrated Demand Management and Electricity and Thermal Microgrids, Demand Response and Aggregation Services, Even Services for Energy Communities. Additionally, ACCIONA ESCO will be involved in the Grid design and the monitoring definition and baseline calculation for the LL	
CARTIF	WP6 leader (Monitoring and evaluation), technologies development (Digital Twin for geothermal network operation). Support to LL group as validator of Digital Twin during geothermal network operation and support in the KPIs definition and evaluation.	

Stakeholder	Role	Internal (blank) /external 'x')
CIDAUT	Support to LL group as designer of geothermal, bidirectional charging stations	
Universidad de Santiago	LL technologies development & impact assessment during construction (mapping drones' technologies, LIDAR sensors implementation)	
CELSA	LL eco-materials development (new materials developed with different components from demolition, integrated GBN buildings and infrastructure, geothermal plant, and roads	
STAM	Support to LL group as designer of Digital Twin related geothermal	
SOPREMA	Support to LL group as designer of geothermal, materials for NBS integration	
All Technology providers	Madrid LL is open to include any technology in Madrid LL. The rest of the technologies should be discussed in detail in the next few months according to timeline (design of the building 2023, operation phase of the geothermal plant and the building 2025, etc)	
BLABS	It will be discussed in detail once the design of the building is defined (2023)	
Influencers		
Community of Madrid	Involved in the development of the legal, financial, and technical framework to accelerate and make viable a large-scale development in MNN	X
Madrid Subterra	Advisory Board Member	X
Plataforma Española de Eficiencia Energética	Advisory Board Member	X
ADHAC	Advisory Board Member	X
Governance		
DCN	Local Private Promoter, LL construction and subcontracting	
Municipality of Madrid	Local Municipality, LL legal support, replication	

The stakeholders in the list above have been mapped according to the methodology described in Annex II (Figure 16). In addition to the GBN stakeholder map template (Figure 48) the categories of "Operation and maintenance" and "Monitoring and DT" are added.

6.4.3 Design coordination

Geothermal network (Design will be carried out over the course of 2022): The MNN Energy Master Plan assessed 17 different solutions to provide the thermal demand, including individual systems, systems centralized by buildings and district cooling and heating systems. Conclusions are that the most adequate technology in MNN for a green neighbourhood are geothermal and PVP.

In order to increase the efficiency of the equipment used (geothermal plant), the thermal jump on the hot side has been set at 50 / 40ºC and the jump on the cold focus at 7 / 12ºC. Geothermal energy in Madrid is low enthalpy geothermal energy, being able to extract between 40 and 50 W /m.

The distribution system is made up of the networks that deliver hot and cold water to the different buildings that will demand thermal energy from the district network. A four-tube system has been chosen in which the hot and cold-water circuits run in parallel with no heat exchange between them. Thus, there would be the following terminal points between the distribution system and the generation facility: A cold water discharge tube/A cold-water return pipe. It is a system of pipes pre-insulated in the factory, for the transport of hot or cold fluids at a distance, reducing thermal losses to a minimum; They are provided with a rigid

polyethylene outer casing that provides the necessary mechanical protection to be able to be buried directly in the ground. The pre-insulated piping system includes the supply of all accessories (tees, bends, elbows, expansion absorption elements, valves, union joints, etc.) also pre-insulated at the factory with the same technique.
In terms of the heat pumps (ECOFOREST), the specifications have been selected according to the technical requirements of the geothermal network (power, self-managed, modular, easy maintenance, ventilation, lighting, vibrations, dimensions, etc).
The BEEPLANET second life batteries are not eligible to be in the same room as heat pumps for the geothermal plant owing to safety requirements. For this reason, these batteries will be implemented in the buildings.
The climate neutral energy system planning and design methodology and GBN demand and response platform will be analyzed in the second half of 2022, once the viability of the geothermal network deployment is analyzed and clarified, and therefore the design of the geothermal network phase is in an advanced phase.
Buildings (design will be carried out over the course of 2023/2024): The GB Insulation and green and cool roof-centric innovations (Evaporative green roofs and Integrated thermal and acoustic insulation), Recycled materials for insulation, Building Integrated Photovoltaics (BIPV), GB Positive Energy Package and Integrated Infrastructure Mobility Energy will be analyzed in detail once the design is carried out according to the requirements established, over the course of 2023.
Urbanization project (design will be carried out over the course of 2022 and the beginning of 2023): In order to speed up the compliance process with the legal requirements to use recycled construction materials and industrial waste streams in the LL, Community of Madrid, DCN and ACCIONA will encourage a new law to convert these recycled materials and industrial waste into final products, complying with specific requirements.

6.4.4 Construction elements and connections

Geothermal network (Construction will be carried out over the course of 2024): IDOM as designer will be involved in the LL geothermal grid design, construction- operation supervision, co-design thermoactivated building standard, and DCN play the role as Local Private Promoter, (LL construction and subcontracting). ACCIONA ESCO will be in charge of operating the thermal and electricity microgrid to be developed. ECOFOREST is in charge of providing the geothermal equipment and supports the design of geothermal central adapted technologies/space.
Buildings (construction will be carried out over the course of 2025): Integration of the different PROBONO technologies: the GB Insulation and green and cool roof-centric innovations (Evaporative green roofs and Integrated thermal and acoustic insulation), Recycled materials for insulation, Building Integrated Photovoltaics (BIPV), GB Positive Energy Package , Integrated Infrastructure Mobility Energy) will be analyzed in detail once the design is carried out according to the requirements established, over the course of 2023.
The same applies to the GBN related Construction and lifecycle processes (Modular Construction, Construction and Lifecycle Control Blueprints, Construction and renovation workflows logistical planning, Robots for construction inspection).
Urbanization project (construction will be carried out over the course of 2024): Integration of GBN related Construction and lifecycle processes (Modular Construction, Construction and Lifecycle Control Blueprints, Construction and renovation workflows logistical planning, Robots for construction inspection) will be analyzed in detail once the design is carried out according to the requirements established, over the course of 2023.
In order to optimize the use of secondary raw materials from demolition works (C&DW), ACCIONA R&D proposes to design a sustainable road pavement concept at laboratory scale.

Combined use of reclaimed asphalt (RAP) and steel slags will be investigated for the preparation of new asphalt mixtures in the structural layers (surface, binder, and base). Recycled aggregates from concrete waste will be used in the subbase. Finally, in the subgrade, the use of recycled aggregates, alternative soils and stones will be studied as partial replacement of natural raw materials. CELSA will provide the steel slags for use both in concrete and asphalt.

6.4.5 Tools for optimal component configuration and integration

The Digital Twin will complete the building's whole life-cycle decarbonization assessment and control (innovative use as, usually, only design and operation phases are addressed by DTs). The design process will maximise the use of existing materials in buildings to be deconstructed. The design team shall use a tool already developed for MNN that classifies existing materials (LER) and provides a guide for deconstruction, treatment, and reuse whenever possible.

Table 15 Selected technologies for the Madrid LL

	Location	Objetive	Technology provider
3: Selection of maturing E3 innovation technologies			
3.1 SOTA Reports and DT Models of Innovations for Smart Green Building Construction and Renovation	Building	Desing Construction and operation phase	
3.2 GB Insulation and green and cool roof-centric innovations			SOP
3.2.1 Evaporative green roofs	Building	Energy Efficiency	
3.2.2 Integrated thermal and acoustic insulation	Building	Energy Efficiency	
3.3 GBN related Construction and lifecycle processes			
3.3.1. Modular Construction	Building / Urbanization project	Contruction optimization	VLTN
3.3.2. Construction and Lifecycle Control Blueprints	Building / Urbanization project	Contruction optimization and redcution of carbon footprint	COWI
3.3.3 Construction and renovation workflows logistical planning	Building / Urbanization project	Contruction optimization	COWI
3.3.4 Robots for construction inspection	Building / Urbanization project	Contruction optimization	COWI
3.4 Building Materials / upcycling			
3.4.1 Recycled materials for insulation	Building	Reduction of carbon footprint	CELSA
3.4.2. Upcycling under new modern methods of const.(Smart engineering techn. and materials applied to	Urbanization project	Reduction of carbon footprint	COWI
4: Selection of maturing E4 innovation technologies			
4.1. Climate neutral energy system planning and design methodology	Building/ Geothermanl network operation	Energy system optimization	FRANHOUFER
4.2 GBN demand and response platform	Building/ Geothermanl network operation	Energy system optimzation	TPF
4.3 Building Integrated Photovoltaics (BIPV)	Buildings	Renewable energy resource	FRANHOUFER
4.4 GB Positive Energy Package	Buildings	Energy system optimzation	ANERDGY, ECOFOREST, TPF, SOP, FRANHOUFER
4.5 GBN Energy Storage	Buildings / Goethermal Network	Storage of green energy	VISBLUE/BEEPLANET
4.6 Integrated Infrastructure Mobility Energy	Buildings	Mobility Energy Solutions	BOVLABS, CIDAUT
5: Integration with Digital Twin			
5.1 Digital twin for construction and demolition phase	Building / Urbanization project	Whole life cycle decarbonisation assesment and control	
5.2 Digital twin for operation phase of the gothermal plant and the building	Building / Geothermal network operation	Desing Construction and operation phase	

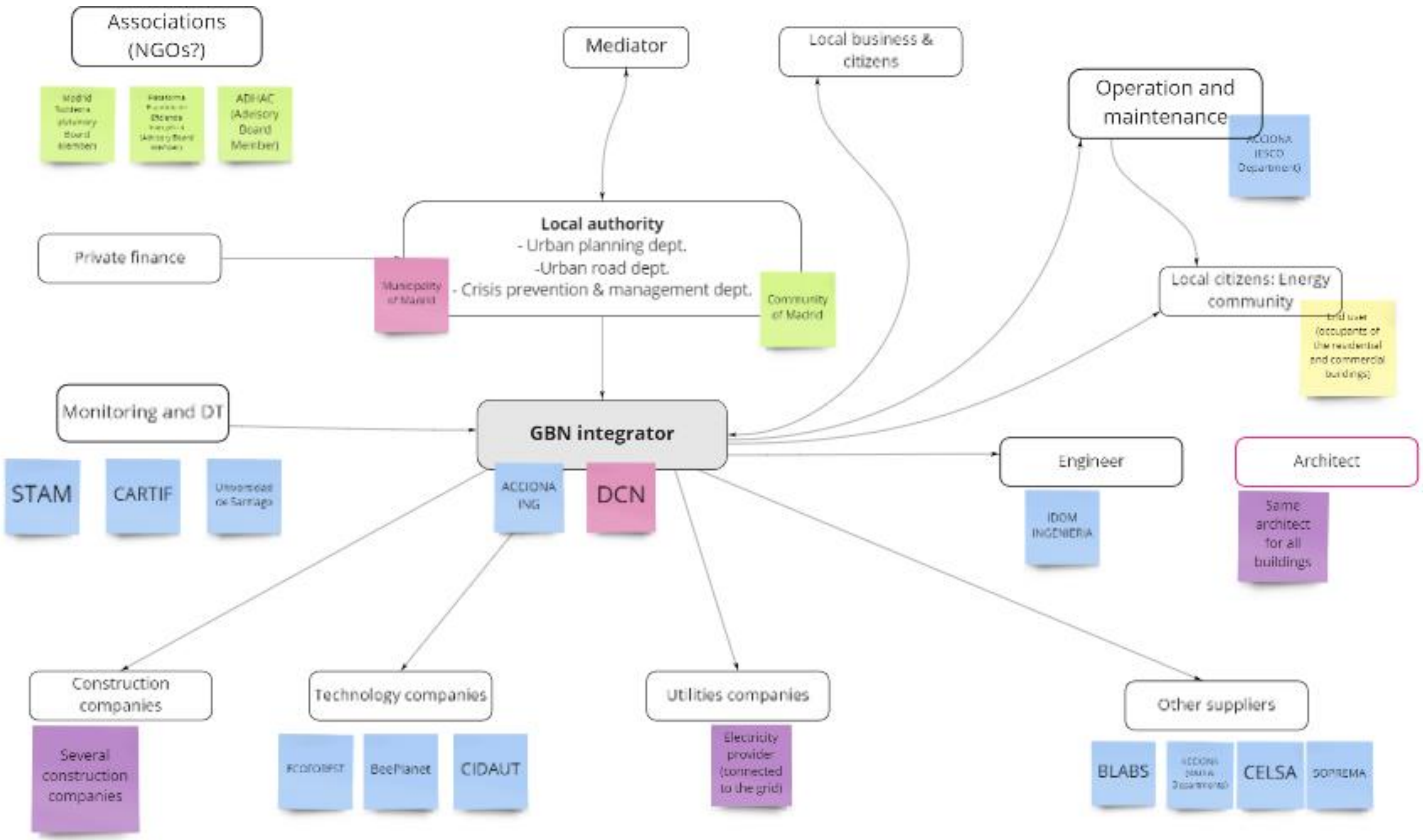


Figure 16 Stakeholder mapping for the Madrid LL

6.4.6 Timeplan

LL timeplan

Major LL activities	Start-End (month)	
1: Detailed scoping & tender planning	1	8
1.1 Preliminary scope		
1.2 Stakeholder mapping		
1.4 Initial digital twin specifications		
2: Design period	1	24
2.1 Initial design of the District Network		
2.1.1 Aternatives of the gothermal plant locations		
2.2 Final designs of the District Network		
*2.3 Development/Urbanization project design (*no included in PROBONO budget)*		
*2.4 Design of the buldings (*no included in PROBONO budget)*		
3: Selection of maturing E3 innovation technologies	7	24
3.1 SOTA Reports and DT Models of Innovations for Smart Green Building Construction and Renovation		
3.2 GB Insulation and green and cool roof-centric innovations		
3.2.1 Evaporative green roofs		
3.2.2 Integrated thermal and acoustic insulation		
3.3 GBN related Construction and lifecycle processes		
3.3.1. Modular Construction		
3.3.2. Construction and Lifecycle Control Blueprints		
3.3.3 Construction and renovation workflows logistical planning		
3.3.4 Robots for construction inspection		
3.4 Building Materials / upcycling		
3.4.1 Recycled materials for insulation		
3.4.2. Upcycling under new modern methods of const.(Smart engineering techn. and materials applied to pavements)		
4: Selection of maturing E4 innovation technologies	12	24
4.1. Climate neutral energy system planning and design methodology		
4.2 GBN demand and response platform		
4.3 Building Integrated Photovoltaics (BIPV)		
4.4 GB Positive Energy Package		
4.5 GBN Energy Storage		
4.6 Integrated Infrastructure Mobility Energy		
5: Integration with Digital Twin	22	60
5.1 Digital twin for construction and demolition phase		
5.2 Digital twin for operation phase of the gothermal plant and the building		
6: Permits and tendering process	16	35
6.1 District heating and cooling tendering process		
6.2 Urbanization project tendering process		
6.3 Building tendering process		
7: Deployment of monitoring system	23	48
8: Construction period	25	48
*8.1 Construction of Distritc Heating and Cooling (*no included in PROBONO budget)*		
*8.2 Urbanization project development (*no included in PROBONO budget)*		
8.3 Construction of the buldings		
8.3.1. Construction of the commercial building (office)		
8.3.2. Construction of the residential building		
8.4 E3 technology implementation		
8.5 E4 technology implementation		
9: Commissioning	46	49
9.1 Thermoactivation of commercial and residential buildings connectied to DN		
10: Operation and performance monitoring	48	60

6.4.7 Risks and constraints

6.4.7.1 Risks

Potential risks and associated contingencies considered for the LL realisation are described in Table 16. Legal procedures and technical risks should be overcome in order to make this project attractive to be scaled up by investors.

Table 16 Risks and associated contingencies for the Madrid LL [P=Probability, I=Impact, L=Low, M=Medium, H=High]

#	Description of risk	P	I	Proposed risk-mitigation measures
Geothermal network During planning/design/technology development (incl. permits and tendering process)				
1	Use of public plots for part of the infrastructure, which requires a special urban plan for uses' compatibility. It depends on the Municipality of Madrid´s decision to approve the deployment of the geothermal network in public plots.	M	H	Meetings with the Municipality of Madrid to reach an agreement in the deployment of the district network in the public plots.
Urbanization project development During planning/design/technology development (incl. permits and tendering process)				
1	CELSA/ ACCIONA/DCN compliance with the legal requirements to use recycled construction materials and industrial waste streams in the LL.	H	H	DCN and ACCIONA will encourage a new law to convert these recycled materials and industrial waste into final products, complying with specific requirements.
2	allegations in terms of non-viability	H	H	Community of Madrid will solve it. The Municipality of Madrid carried out the whole procedure complying with the requirements.
Geothermal network/urbanization project development/ buildings During construction/deployment/technology integration				
1	Delays and extra costs	H	H	Cost management (section 6.5.9) The Tablas Oeste area was selected owing to the likelihood of delay is lower and the decision making of DCN is higher in comparison with the rest of areas.

6.4.7.2 Local constraints

Climatic: In general, climate may influence a geothermal facility in several ways. The first and most obvious one is amount of energy sold. The second is related to peak heat demand, which is the maximal required heat capacity in a geothermal plant. These two contribute to capacity factor (CF), which is crucial to the economic effectiveness of the investment. The last, important, yet poorly described and quantified climate factor is the influence of heat demand oscillations on exploitation, since geothermal wells are not suited to working with high ramp rates. The main reason for this is the reservoir's inertia and related risk of particles being mobilised when production volume is rapidly increased. Particle mobilisation may ultimately decrease permeability, as well as eroding the well casing and surface equipment and increasing their corrosion.

Technical: Owing to the fact that the deployment of the geothermal network in public plots has to be approved, it is possible to divide the geothermal network into 2 parts (to implement the heat pumps in private parts private plots). It should be analyzed in terms of technical viability of the design.

Additionaly the construction project of the whole geothermal network it should be coordinated with the construction project of the buildings or urbanization project in order to avoid space constraints.

The geothermal network should be designed in order to comply with the technical requirements and with the possibility to be scaled-up through Madrid New North.
BEEPLANET's second life batteries are not eligible to be in the same room as heat pumps for the geothermal plant owing to safety requirements. Therefore, they will be implemented in the buildings.
Economic: Owing to the fact that the deployment of the geothermal network in public plots has to be approved, it is possible to divide the geothermal network into 2 parts (to implement the heat pumps in private parts), which would imply an extra budget that would be covered by DCN, this design would include a thermal ring to exchange the thermal excess between the two parts.
Social: The deployment of the geothermal network has a social impact. For this reason the deployment of the components of the geothermal network in green areas is not possible. Additionally, the heat pumps should be called geothermal exchanger modules instead of thermal power plants (owing to the fact that the objective of the geothermal network deployment is to minimize the impact on the citizen.)
Legal: In terms of the deployment of the geothermal network, there is no specific regulation. For this reason an analysis of the viability of this implementation with the municipality of Madrid (that is in charge of authorising the construction projects) is necessary in order to comply with the requirements in terms of urban planning development.
Use of public plots (geothermal network) forces the modification of the design and the budget of the geothermal plant. The geothermal network design must be adapted to the use of public plots allowed. There is a part of the budget under PROBONO project to cover it as a mitigation measure.
The geothermal network design should be scaled up, but it is limited by legal and technical requirements. Meetings with the Municipality of Madrid to reach an agreement in the deployment of the district network in the public plots, will be organized as a mitigation measure.
The room where heat pumps (geothermal network) are placed should be as small as possible to achieve the approval to be installed in the plots. Nevertheless, the space of this room should be enough to allow maintenance operation. As a mitigation measure, analysis will be carried out in detail of the heat pumps system by ECOFOREST and covers will be implemented in the plant to allow access to carry out the maintenance, there is a budget under PROBONO to cover it.
There is not any specific regulation in terms of geothermal network integrated in a Renewable Energy Community. As a mitigation measure, meetings with public authorities will be carried out to solve it. The future tenants of the buildings connected to the geothermal network should be the owners of the Renewable Energy Community

6.4.8 Change management

Changes in construction projects are very common and likely to occur from different sources, by various causes, at any stage of a project, and may have considerable negative impacts on items such as costs and schedule delays. Table 17 defines the stages, sources and impacts of construction changes as these will be considered for the Madrid LL.

Table 17 Summary of construction changes for the Madrid LL

Stage	Stakeholder	Types of changes	Impacts	Actions
Specification	Owner/Client/User or architect	Changes to requirements including specification, scope of projects, design brief, etc.	Changes in design and construction processes	Carefully provide detailed specification documents before bidding.
Design	Design/engineering Consultant	Incomplete/inconsistent drawings; design error/defect; design change; omissions of site conditions and buildability; changes in codes and regulations	Rework of design and drawing; rework in construction; change orders	Better control of design versions, drawings; site investigation; consider buildability in design
Construction	Contractor/sub-contractors	As-builts not confirm with as-design; quality defect; unanticipated site conditions; value engineering; materials or equipment not available; inclement weather	Rework; change orders; changes in design	Quality control; site operational control; coordinated documents and drawings; daily logs

**Owner: DCN Local Private Promoter.*
Designer: IDOM.
Engineering consultant: Acciona ING and Acciona ESCO.
Contractor of the geothermal network: Acciona Construcción (tendering process).
Subcontractors: Technology providers (tendering process)

The change process model for the Madrid LL has the following five stages:

1. Identify changes: focused on the relationships of the requirements, symptoms, malfunctions, and various other aspects of changes.
2. Evaluate and propose changes: based on criteria and options, the evaluation calculates all possible impacts that an identified change can have on other processes and team members, in terms of time and cost. The outcome of the evaluation is a proposal change order (PCO) which summarizes the change itself and the impacts of the hange – a new updated action plan, cost, schedule, etc.
3. Approve changes: Each identified change needs to go through a formal approval process. There is a set of predefined approval processes for different types of changes and construction contracts.
4. Implement changes: An operational system is needed to make sure that all aspects are updated, all parties are notified, and all activities are done properly and coordinated well.
5. Analyse changes: Change analysis and system performance is reviewed based on the data collected during the change implementation phase.

6.4.9 Cost management

Cost management in the Madrid LL will be managed by the contractors (through tendering process), of the construction projects: geothermal network, urbanization project development and two buildings.
The cost management process will consist of four phases that are hierarchically associated with each other aiming to achieve the lowest feasible cost and time spent on the project. Each of these phases consist of three parts: input, processing and output. The output of each section is the input for the next section.

1. **Resource planning** determines resources, including manpower, materials, equipment, and their number in order to complete each of the project's activities.

2. **Cost estimates** are estimates from the costs of the resources needed to complete project activities which are associated with uncertainty.
3. **Cost budgeting**. In the process of cost budgeting the total estimated cost for the project is allocated separately to each of the project activities so that the basis for the cost can be defined.
4. **Cost control** includes identifying changes in the cost of the project, change management and evaluation of changes occurring at the moment of acceptance of changes. For this purpose, the control cost performance is necessary to identify potential disorders and avoided incorrect changes in costs. The cost control is a key activity, which consists of 5 steps:
    i. Determine the desired cost that project costs are controlled under that base
    ii. Calculate the real cost based on planned project
    iii. Compare the real cost and the cost of the project
    iv. Analyse the level, degree of effects and cause of deviations
    v. Recommend ways to correct operation

6.5 Business Plan and feasibility study

The Living Lab aims to develop the legal, technical, and financial framework for the Madrid large scale development (MNN Madrid New North development). The Madrid LL results will be transferred directly to MNN and another project of the city. Knowledge transfer and dissemination activities of the business model and legal, technical, and financial framework proposed is expected to scale the solution to other cities in Spain and Europe. The Living Lab aims to assess the viability of the project for 0,03 million m^2 area (land). Regarding MNN large scale development would be 3 million m^2 area, thereby if results are favourable, the large-scale development (MNN) may catalyse a private investment 45 times larger than the initial investment for this Living Lab. The business model for MNN large scale development is a public concession.

Table 18 Subcontracting (PROBONO budget)

BUDGET SUBCATEGORY	PARTNER	DESCRIPTION	BUDGET
SUBCONTRACT	ACC ING	Thermal response test campaign (TRT) in LLab Madrid	60.000,00
SUBCONTRACT	ACC ING	Geothermal drilling in LLab Madrid	270.000,00
SUBCONTRACT	ACC ING	Works for installing equipment and auxiliaries in LLAB Madrid thermal station.	36.000,00
SUBCONTRACT	ACC ING	Social science expert partner and Local Llpartner to collect the data (feedback)	60.000,00
SUBCONTRACT	ACC ING	LCA performance verification	2.500,00
SUBCONTRACT	DCN	Onsite works for PV installation	60.000,00
SUBCONTRACT	DCN	Onsite works for building-networks heat exchange installation	10.000,00
SUBCONTRACT	DCN	Construction and Installation works for building Thermoactivation	1.800.000,00
SUBCONTRACT	DCN	Onsite works for DHW system installation	19.500,00
SUBCONTRACT	DCN	Onsite works for nature based solution system in LLAB Madrid buildings	150.000,00
SUBCONTRACT	DCN	Monitoring system onsite installation	10.000,00
SUBCONTRACT	BEEPLANET	Assembly	4.050,00
SUBCONTRACT	MAD	Supporting activities related technical and legal regulation services from external and specialized company	75.000,00
SUBCONTRACT	CELSA	Characterisation of the samples of Celsa's byproducts	35.000,00
			1.128.450,00

Table 19 Goods and Services/Equipment (PROBONO budget)

BUDGET SUBCATEGORY	PARTNER	DESCRIPTION	BUDGET
G&Services /Equip.	ACC CONS	Materials for piping (district heating&cooling network)	542.000,00
G&Services /Equip.	ACC CONS	Materials and auxiliaries for installation in LLab Madrid thermal station	54.000,00
G&Services /Equip.	ACC CONS	Materials for construction works in Llab Madrid thermal station	70.000,00
G&Services /Equip.	ACC CONS	Raw materials and transport for the development of low carbon concrete mixes and sustainable road pavements	15.000,00
G&Services /Equip.	DCN	Materials and auxiliaries for PV installation in LLab Madrid	105.000,00
G&Services /Equip.	DCN	Materials for thermal exchange between building and network in LLab Madrid	40.000,00
G&Services /Equip.	DCN	Sensoring and monitoring system for LLab Madrid	30.000,00
G&Services /Equip.	DCN	PV modules (considering 8 years depreciation and 2 years of use within the project)	33.750,00
G&Services /Equip.	DCN	Domestic Hot Water (DHW) system: Heat pumps, thermal storage and auxiliaries (considering 8 years depreciation and 2 years of use within the project)	19.500,00
G&Services /Equip.	ECOFOREST	Material for geothermal heat pumps development and manufacturing	60.000,00
G&Services /Equip.	BEEPLANET	EV modules, enclosure, BMS, electrical protections	67.500,00
G&Services /Equip.	BEEPLANET	Power converter system	11.700,00
G&Services /Equip.	STAM	Platform services and components	10.000,00
G&Services /Equip.	SOPREMA	Innovations cost of materials for implementation	70.000,00
			2.592.050,00

The Madrid LL is open, after appropriate analysis, to include PROBONO technologies irrespective of whether they are covered by the PROBONO budget or not. These costs will be estimated in detail, once the buldings and development projecst are defined and completed.

Business model for the concessionary company: Invest in the infrastructure and provide heating and cooling energy to the buildings connected. A detailed study makes for 1 small grid (16) in MNN shows viability in a 50-year concession with a 7% IRR. The viability of the public concession depends on the development of the technical, legal, and financial framework to be elaborated within the PROBONO Living Lab.

Business model for citizen integration:

- **PVP renewables communities**. A challenge for large scale PVP implementation in MNN buildings is the Spanish law for renewables compensation. The legal framework stablishes a maximum of 100 kW of renewable energy for small producers which disincentives building developers and owner´s communities to invest in more renewable energy. The project aims to solve this challenge applying the model proposed by the European Commission of renewables communities to MNN reality. Thus, to incentive PVP investment of buildings developers, private PVP will adhere to district heating and cooling system, so an investment upper 100 kW per project will be viable.

- **Geothermal renewables communities**. The Living Lab aims to reduce the number of boreholes in public space. Thereby, the initial investment and the impact in public space will be reduced through PROBONO. The project aims to develop a minimum number of boreholes in public spaces. The rest of the boreholes will be executed and invested by the private developer of each building.

7 LL3 Porto Scoping and Implementation Plan

This chapter details the Scoping and Implementation Plan for the Porto LL. It begins with an overview of the Living Lab setup and continues with the as-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that cab be utilised in PROBONO are also described together with the first list of expected impacts and KPIs.
Next, the scenario considered for adoption (technologies, construction innovations and co-creation aspects) as well as the implementation plan are detailed along with the engineering activities necessary for the modification of the LL design according to local constraints like climatic, technical, economic, social and legal. Finally, current Business Plan details and feasibility study of design strategies are described.

7.1 Living Lab setup

7.1.1 Context – Local development plans – Key initiatives

The Porto LL is the headquarters of Sonae in Portugal with a total area of 32,5 ha, receiving more than three thousand employees (Figure 17). The campus has several sustainable features such as efficient water solutions, solar energy production, electric mobility alternatives, LEED certified buildings. The construction area is divided into 60% logistics, 30% offices and 10% industry and storage.
The Sonae Campus also focuses on people's well-being and the support of biodiversity and includes green areas, pedestrian areas and convenience services to facilitate the quality of life of the employees (such as laundry, kiosk, hairdresser and manicure), sports areas (paddle and football courts) and health services (nutrition and clinical analyses) (Figure 18).

Figure 17 Top View of Sonae's Campus

Location and climate: Sonae Campus is located in Maia city, in the Porto Metropolitan area, Northern Portugal, which is the second-largest urban area in Portugal, after Lisbon Metropolitan area. Maia city has a warm and temperate climate, with much less rainfall in the summer than in winter. The average annual temperature is 15.1 °C, and the average annual rainfall is 1285 mm. The average HDD (ref. 18 °C) are 1349 and CDD (ref. 10 °C) are 1670.

Figure 18 Sonae Campus overview

Public/private business model and funding: There is no specific funding business model but being Sonae a private group it can finance – through financial markets – sustainability efforts of its portfolio companies or self-fund their own efforts.

7.1.2 Vision and challenge to be addressed in PROBONO

Sonae aims to advance its Corporate Campus to become a world-class example of climate positiveness, bringing together a complete stack of next-generation options, including biodiversity and social innovations.

Thus, the sustainability path that Sonae has been following in recent years, will now be supported, tested and deployed in the scope of the PROBONO project, through a range of different technologies, tools and solutions enabling Sonae to move forward towards carbon neutrality and create knowledge for the Community.

The challenges to be addressed by the project are the following:

1. Minimize CO_2 emissions;
2. Increase the use of clean (renewable) energy as a fuel;
3. Boost social, community and neighbourhood engagement;
4. Multiply in-campus biodiversity.

Neighborhood approaches to be addressed by the PROBONO LL: The Porto LL intends to be an open innovation space, where stakeholders (e.g., universities, research institutions, innovative start-ups) can develop and test new solutions to address key challenges, such as sustainability, energy resilience, and climate change. LL activities also intend to promote and foster social inclusiveness by empowering citizens to use different products and/or services and integrate them into the process (e.g., develop infrastructure and adequate services necessary to help citizens in the city). The coupling of the Porto LL to other PROBONO LLs can also be an option to exchange ideas and/or provide services.

Green spaces and cool roofs for microclimatic improvements are also being considered.

Energy efficiency standard: On the campus there are already some buildings with high standards in terms of energy efficiency (Sonae Maia Business Centre: LEED Gold in 2010 (Figure 19 (1)) and Tech Hub: LEED Platinum in 2020 (it is in the World Top 100 buildings with this LEED certification) (Figure 19 (2)). These two buildings are important benchmarks in terms of Energy Efficiency, but the further developments introduced in the efficiency framework of the Living will be more related to the optimization of energy consumption of the whole campus.

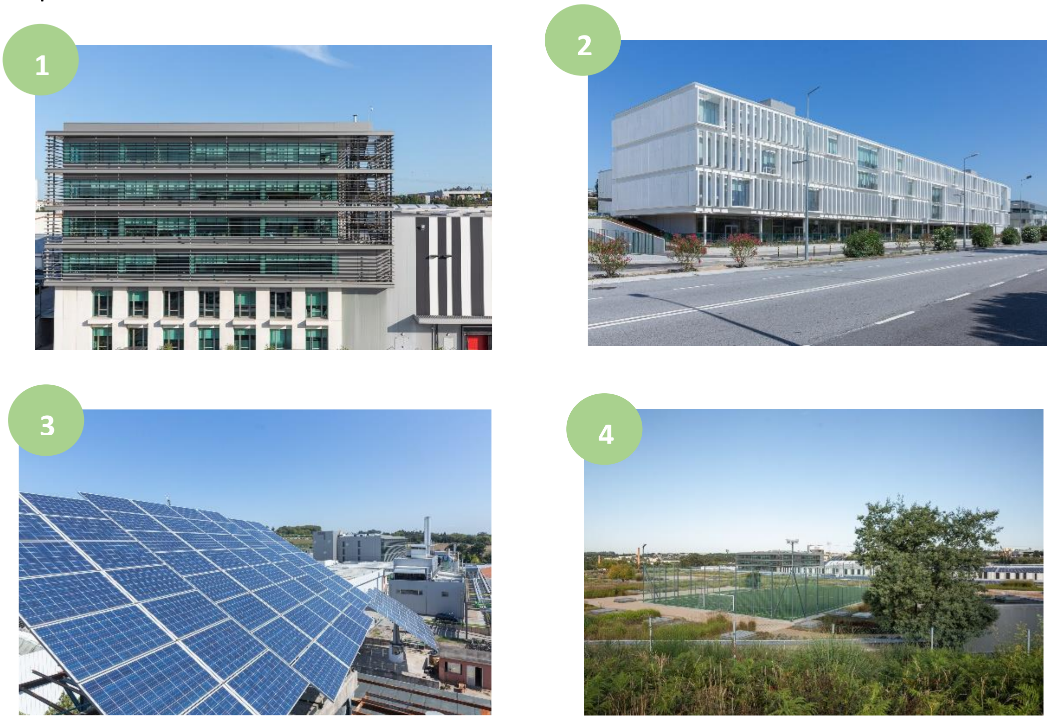


Figure 19 (1) Sonae Business Centre, (2) Tech Hub, (3) Mini generation Unit, (4) Green Area of the Campus

7.1.3 Impacts and KPIs

Through the PROBONO project, Sonae envisions to develop the conditions for a more energy efficient corporate campus coupled with several social innovation and biodiversity initiatives. Those initiatives are:

1. **Renewable Energy Community (REC**). Engaging the companies of the campus, either consumers, producers, or prosumers to create a REC with easy access to green energy, reducing CO_2 emissions, and improving the usability, adaptability and integrity of the different solutions and innovations that will be tested. High potential of exploitation by other campuses.
2. **Energy Tech Hub.** Providing the community with the best future green energy generation tools and innovative solutions to test and develop new emerging technologies.
3. **Monitoring, controlling, AI/forecasting tools development, and study of consumer behaviour**. Analysis, at the Campus control center, of the consumption loads of each type of company. The main idea is to analyse consumption profiles and match them with the curves of renewable energy production. This implies in theory the creation of algorithms that optimize and increase the Campus' renewable energy consumption. This innovation is integrated with the Advanced REC, that will make energy management more flexible, especially coordinating it with renewable energy production and/or tariffs.
4. **Decentralized energy community**. Promoting and spreading awareness to all individual consumers inside the Sonae Campus, about the way they consume energy and influence them towards more sustainable behaviours.

5. **Support of biodiversity**. Making the Campus a greener space, respecting nature and its heritage, creating diverse biodiversity initiatives, including the House of birds and the Community Garden, on premises that serve as a hub for solidarity, team building, learning and empowerment of the communities, impacting also on architecture and spatial dimensions. Creation of a biodiversity example in a corporate Campus in Portugal and in the EU.

The expected Porto LL impacts are summarised in Table 20. Energy savings will be estimated following the IPMVP Option C (Whole Facilities). Baseline energy data for this cause are currently being obtained.

Table 20 Porto LL impacts

Impact Category	Unit	LL Reference	LL Objective
I1 Primary energy savings	GWh/year	Energy demand 15.6 GWh/year	Energy demand 15.0 GWh/year: Savings: 0.6 GWh/year
I2. Investments in sustainable energy	million €	-	3 Million € invested
I5. Reduction of GHG emissions for the total lifecycle	tCO2-eq/year or %	GHG emissions (Cradle to cradle): 3ktCO2-eq/year	Improvement: 30%
I6. Reduction of the embodied energy in buildings	GJ or %	-	Energy savings per year 986.4 MWh/year; Improvement 30%
I7. Reduction of air pollutants for the total life-cycle	Not defined	-	The tech hub projects will have a future impact in the air pollutants

Regulatory framework and technical codes: At this planning stage, based on the proposed work on the living lab, two generic frameworks have been identified:

- EU Energy Performance of Buildings Directive, 2010
- Portuguese National Building Energy Certification System (SCE)

The more detailed framing in the context of the Porto Living Lab will be created once a more comprehensive view, regarding the impacts on the project innovations, is obtained.

7.2 PROBONO LL existing infrastructure

7.2.1 Building infrastructure

The Porto LL will follow the physical naming and organization of the different Lots in which the Campus is divided. The Lots correspond to different areas with different users/companies (Table 21).

Table 21 Sonae campus lot division

Location | Project Code	Internal Reference	Service
Lot 1 / CPE 01	*Arauco*	Industry and Offices
Lot 2 / CPE 02	*MCH*	Office Buildings and Retail Warehouse
Lot 3 / CPE 03	*4A*	Office Buildings

7.2.2 Energy infrastructure

The management of part of the energy supply and production at the Sonae Campus is currently ensured by Capwatt. Essentially there are two main energy needs: electricity and heat.
These two energy vectors will be addressed in the overall planning of the Living Lab by different angles: via the renewable energy community management (which will try to optimize consumption and production) and via the energy tech-hub (that will make small tests of possible new ways of consuming and producing energy).
The current production and consumption facilities of Sonae Campus are organized into 3 lots (Table 21) with Lot 3 corresponding only to green spaces and car parks. Each of these three user facilities is associated with a self-consumption production unit.

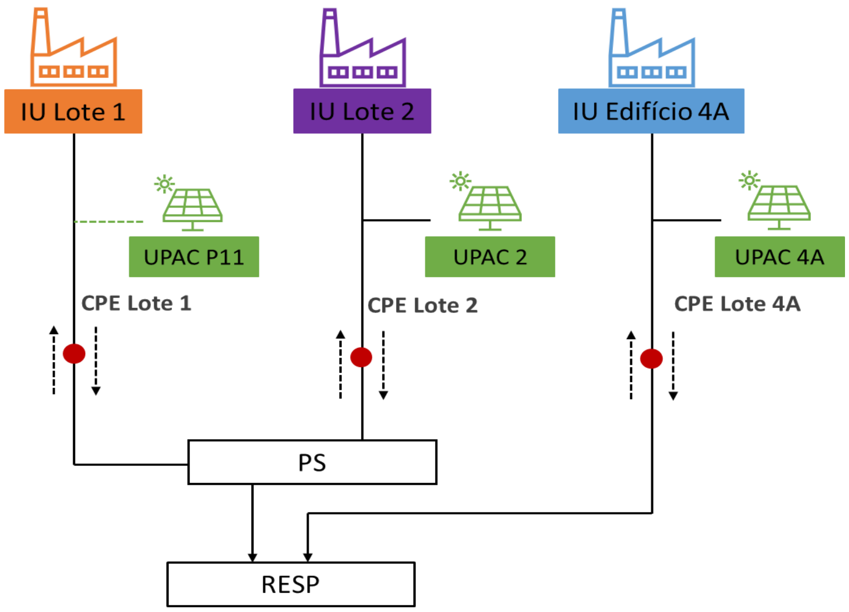


Figure 20 Simplified scheme of the organization of electricity distribution inside the Campus

The Sonae Campus has two access points (CPE – Código Ponto de Entrega) to the National Electricity Grid (RESP):

1. Switching Post (PS)
2. Transformer Station Building 4A (PT4A)

Lot 1 and Lot 2 are connected to the PS (Figure 20).
There are also several production units on the campus, mainly photovoltaic but also a CHP (Combined Heat and Power) Plant. An energy storage system is also active on the campus, providing energy arbitrage services. The main characteristics of those systems are provided below.

- PV plants:
  - Mini-generation with 225 kWp (minigeneration with feed-in tariff – will not be part of the energy community)
  - UPAC2 with 1MWp (auto-consumption, behind-the-meter), under development and construction;
  - UPAC4A with 100kWp (auto-consumption, behind-the-meter)
- Cogeneration Plant: 7,4 MW electrical and 11,1 MW thermal; this plant due to the contracts in place will not be made part of the Energy Community.
- Energy Storage System: 798kWh and 320 kW, behind-the-meter

In the near future, it is planned to install one more photovoltaic production unit (auto-consumption, behind-the-meter) with around 1 MW, a new Electric Storage system of around 100kW and also a UPAC with 2,9 MW.

7.2.3 Monitoring infrastructure

Monitoring system/BEMS already in place: Capwatt's Metering and Control Centre (MCC), located in Maia, is a robust and detailed system, operated by a highly specialized team, which allows 24/7 monitoring of the installations of different technologies. The MCC ensures the remote supervision of the power plants, guaranteeing real-time control and optimization of the assets' operation, including the operation of some power plants. This system thus guarantees transparent and reliable control, providing visibility on the operating conditions of the power plants and, when relevant, of its own industrial facilities.
The MCC gathers the necessary competencies for the collection of meter data and management of a big portion of the internal network.
Additional equipment/infrastructure needed for PROBONO: There are already electricity meters/counters all around the campus, but for the stepping up of the energy management capabilities the inclusion of additional smart metering equipment and dataloggers on strategically chosen places that will be defined during the design phase of the Living Lab will be analysed. This equipment should be able to provide live feedback to the Control Center on the consumptions and productions.

7.2.4 Non-energy infrastructure

Blue or green spaces: The Sonae Campus has a lot of green areas and small gardens (Figure 21). These include a “green rooftop” with a garden on one of the warehouses, a football field and the community garden developed for PROBONO.
In all green areas, the planting of native species is encouraged; autochthonous species with low water requirements and with respect to the habitat typology are considered.

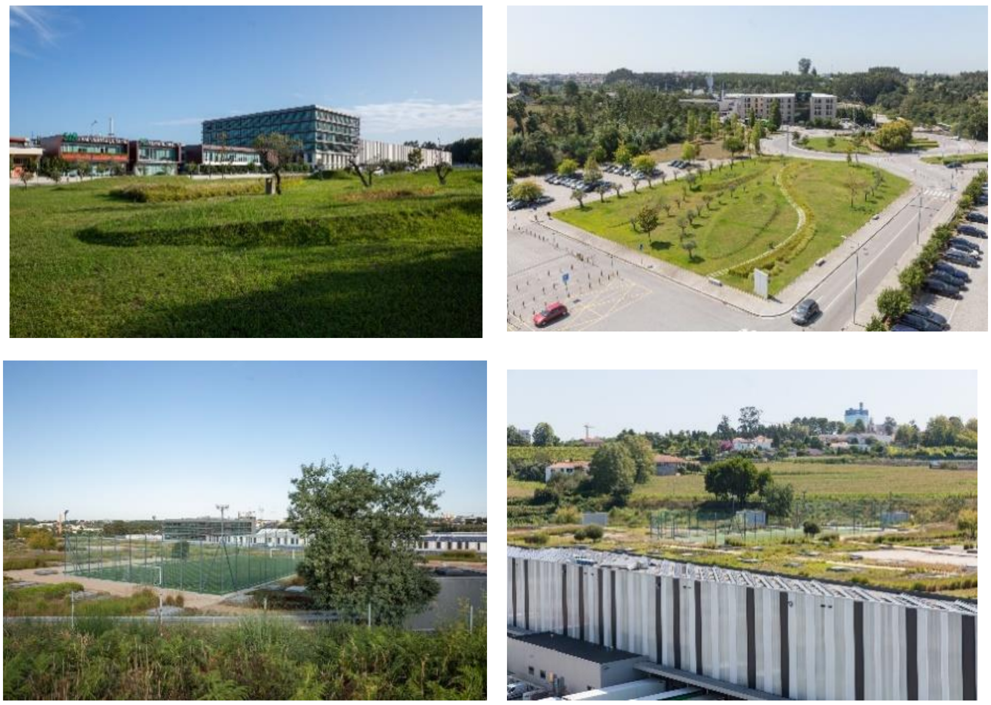


Figure 21 Green Areas in Sonae’s Campus

Other existing infrastructure: Throughout the Campus there are several EV charging stations:
- AC Charging Stations 7,4 kW and 22kW – several units
- DC Charging Station 50 kW – 1 unit (*Fast Charging)*
- DC Charging Station 160 kW – 1 unit *(Ultra-Fast Charging)*

More stations will be installed in the near future to cover for the increasing use of electrical cars.

COVID plans*:* Since the beginning of the pandemic, Sonae Campus facility management team implemented a lot of measures to reduce the risk of contagion of Covid-19 indoors (Figure 22):

- Reinforcement of cleaning plans in all buildings
- Development of isolation areas
- HVAC Systems:
    - 100% fresh air during building operation
    - Disinfection of AHU's/ATU's and increased filter change periodization
    - Open windows: recommendation for companies to open windows during lunch period
- Alcohol gel dispensers in all common areas of the buildings
- Open doors to reduce contact points with surfaces
- Promote distancing:
    - Implementation of maximum number of users in lifts at the same time
    - Maximum number of users in restaurants, cafeterias, lunchrooms and bathrooms
    - Installation of access control system at the entrance of restaurants to delimit the maximum number of occupants
- Communication and signage of security measures in common spaces
- Placement of acrylic protection barriers and delimitation of spaces in the receptions of the buildings
- Installation of an automatic temperature control system in building receptions.

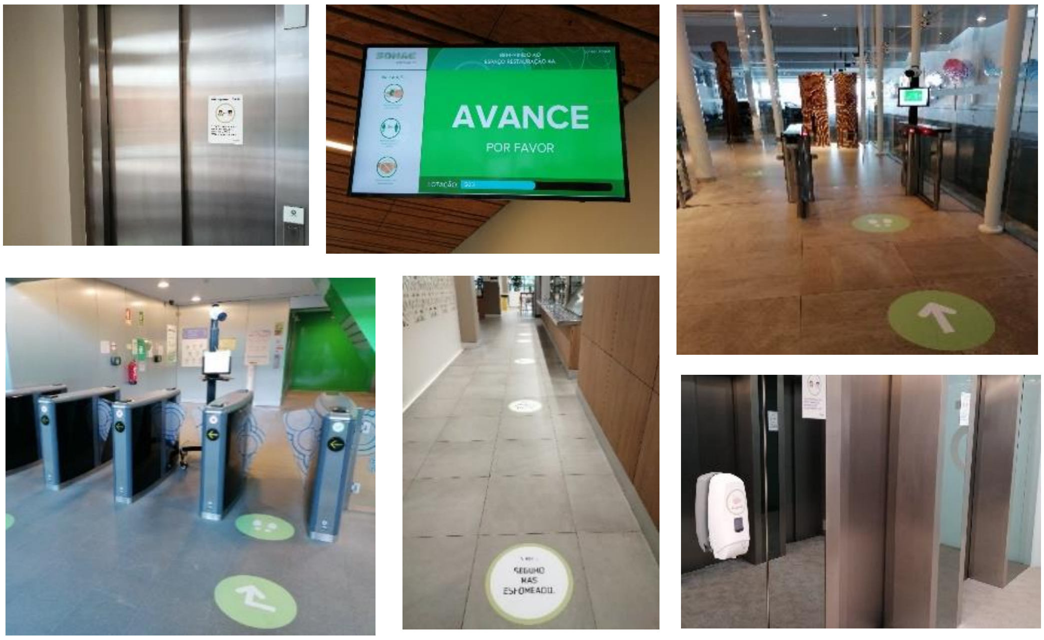


Figure 22 Details of the Covid-19 measures implemented at Sonae's Campus

7.2.5 Existing models, data sets and tools

Digital Twin: As part of PROBONO, the implementation of some tools that can perform the analysis of the consumption loads of each type of company on the Campus control centre will be analysed. These tools should analyse and match the companies' profile with the profile of renewable energy production, creating, if possible, algorithms that optimize and increase the consumption of renewable energy. These features will be intimately connected to the REC. Through the processing of the historical (and new) data, methodologies to try to influence and adapt consumer behaviour and make the consumption more flexible will be designed. For example, the EVs' charging times could be influenced according to the renewable energy production or tariffs.

Available data sets: The data sets available for use in PROBONO are comprised of:

- Monthly energy data, from 2019 until today (Figure 23)

Collected Data	
Installed Power	*MW*
Installed Power - Renewable	*MW*
Consumed Electricity	*MWh/month*
Produced Electricity - Renewable	*MWh/month*
Consumed 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)*
Total Power Installed of EV Charging Points	*MW*

Figure 23 Summary of energy data being collected in the Porto LL

- Weather data: from an on-site weather station.

IT collaborative engagement tools and activities: The Porto municipal website (https://www.cm-porto.pt/) contains a section regarding participation and providing guidelines to engagement in public hearings and on giving suggestions. It also has a contact form in each section (organised by themes such as urban development, planning, culture, municipal updates, society, environment):
https://www.cm-porto.pt/assembleia-municipal/participacao-2
A citizen's portal [Portal do Munícipe] contains forms for requests and authorisations: https://portaldomunicipe.cm-porto.pt/home
There is also an association named "Porto Digital", created by the municipality to promote ICT projects: https://www.portodigital.pt/
The Porto LL uses MS Teams and Miro to facilitate collaboration and engagement within the team. The LL has no ongoing engagement activities, but will develop community engagement strategies with appropriate tools later in the project.

7.3 Implementation plan for adopted scenario

This section describes the singular scenario (technologies, construction innovations and co-creation aspects) considered for implementation and execution in the Porto LL.

7.3.1 Selected technologies and planned interventions

The Porto LL has already selected, and in some cases is investigating, several technologies and interventions as listed below. Some are developed by PROBONO partners and some by external providers.

1. The development and integration of several green energy technologies in a "Energy Tech-hub", namely:
    a. **Solar 2 Vehicle:** implement the best system to provide PV energy directly to an electrical vehicle, managing the best time to charge, according to the renewable energy production.
    b. **Vehicle to Grid:** use electric vehicles as a means of energy storage and to reinject electricity back into the grid, for various services when the EVs are not in use.
    c. **BIPV** incorporation in the Energy Tech-hub. It will need a planning effort due to interfaces with different technical and local regulations and because the technology is of higher cost compared to conventional PV. For the time being support for the implementation and testing of this technology is planned to be requested from Fraunhofer (PROBONO Partner).
    d. **2nd life batteries** allow the access to storage systems, which will have an important role on the energy management, promoting also a circular economy. Support for the implementation and testing of this technology is planned to be requested from BEEPLANET (PROBONO Partner).
    e. **Green Hydrogen production:** a small electrolyzer producing green Hydrogen will be integrated in the campus grid to decarbonize a specific heat consumption. This will allow to also study the role of Hydrogen as a vector for energy storage.
    f. **Solar Heat for Industrial Processes (SHIP):** this package will use solar energy in industrial processes, in the medium temperature range. Its implementation will be a pilot to test how solar power can contribute to thermal industrial processes, producing heat power and, therefore, embracing solar thermal technologies and other eco-efficient solutions in general, still very dependent on the quantification of this type of energy. The system is still under development and will include a thermal solar collector, thermal energy storage and the monitoring and control system.
    g. **Phase Change Materials (PCM):** The use of PCM technology in the Campus will focus on cooling systems, aiming to validate the addition of energy flexibility for optimal management targeting increased self-consumption of local renewable energy as well as mitigation of exposure to energy price oscillations. The introduction of more flexible assets can lead to more efficient energy management and will allow validation of the exploitation of the warehouse flexibility as an infrastructure that positively contributes to the improvement of the overall energy management of the campus.
    h. **SMART EV HUB:** The campus has a vast number of parking lots, many dedicated to collaborators meaning that many EVs are parked for many hours, creating a challenge to charge all of them during the available time slot and an opportunity for improved charging management. In PROBONO, it is intended to build a module for EV charging management with a multitude of criteria, balancing the power delivery according to buildings' power availability, number of cars available to charge, local RES, market price and user preferences. The combination of all these variables will be considered for optimal EV charging management.
2. The biodiversity initiatives, spread throughout the Campus and divided in the community garden and the house of birds, supporting some of the planned social innovations.

3. The implementation of the energy community which will impact a big portion of the campus as it will, via software and hardware implementation, enhance the management of the renewable energy produced and consumed on-campus that will be optimized during the lifetime of the project.

Also, the implementation of a cool roof technology for Bi-Facial PV production (provided by SOPREMA, a PROBONO partner) is currently under investigation. This technology will allow the testing of the possibilities for further increase of the on-campus renewable production. After the scope definition, and confirmation of possible integration, this innovation could be considered for fitting under the Energy Tech-Hub.

On the next phases of the project, the Porto LL will integrate and combine technologies for maximum impact of the intervention and better exploitation of the concepts to be studied and tested.

7.3.2 Stakeholders and their role

In the table below (Table 22) the various Porto Living Lab internal and external stakeholders and their roles are further outlined, defined, described and categorized.

Table 22 Porto LL stakeholders and roles

Stakeholder	Role	Internal (blank) /external ('x')
Users		
Campus Employee Community	Daily users that work of visit the campus can retrieve a better experience from the biodiversity and energy community initiatives.	X
Sonae Companies at the campus	Benefit from better energy management and of the possibility of a better workplace environment.	
Providers		
Technological Providers	Provide best match in terms of the technology to be implemented to reach the goals proposed by the LL.	X
Universities, research institutions, innovative startups	As the LL opens the doors of the campus to the external community, these users are invited to get involved in experimentations. These can develop and implement initiatives aligned with the goals proposed by the living lab.	X
Influencers		
Campus Community	Co-create and provide feedback to the different developments promoted by the project.	X
Universities, research institutes, innovative startups	New possibilities to enhance the different activities listed on the project scope.	X
Governance		
Steering Committee	Provide Guidance to the different teams that are developing actions within the project.	
Sonae Companies Decision Making Bodies	Provide support to the proposed course of actions and approve specific implementation conditions to comply with the PROBONO Porto LL objectives and DoW.	
Other		
Maia City Council	Provide support and collaboration to the implementation of policies and innovative best practices. Be involved in linkages of Sonae Campus initiatives with the neighborhood initiatives, such as green corridors and public parks.	X

Based on this list of stakeholders relevant for the Porto LL, they have been mapped according to the methodology described in Annex II. The output is displayed in Figure 25.
Due to time constraints and some open questions, it was not possible to place a number of the stakeholders identified in the initial questionnaire. These are displayed below in Figure 24 and will be considered in the next step of the stakeholder analysis.

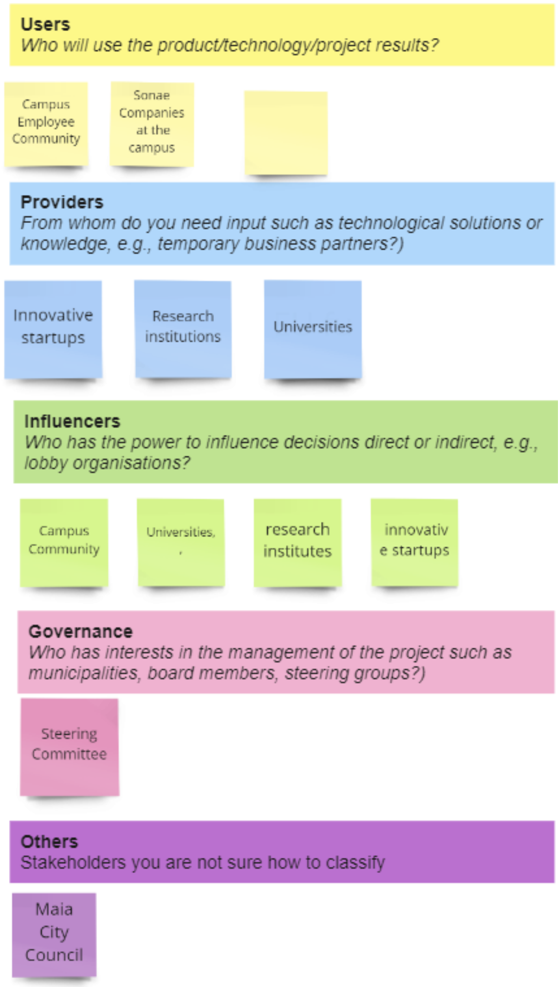


Figure 24 Stakeholders of the Porto LL to be considered in the next step of the stakeholder analysis

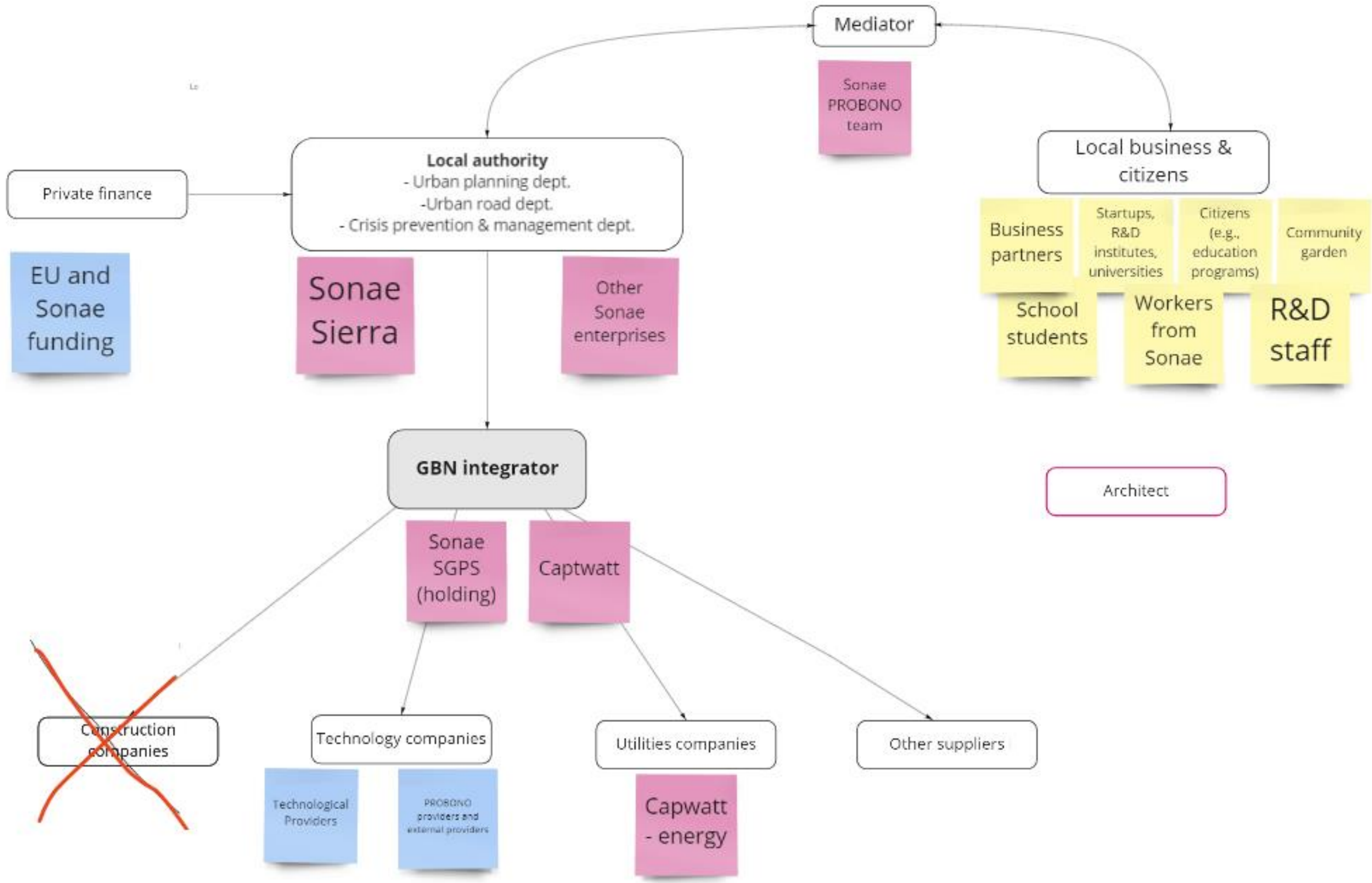


Figure 25 Stakeholder mapping for the Porto LL

7.3.3 Design coordination

Based on the requirements of the technological innovations to be developed during the project, it will be necessary for the team in charge of the Living Lab to interact with the suppliers of the different equipment to correctly size and prepare the installation of all the proposed scope of work. The internal expertise inside Sonae groups guarantees that there are persons able to properly do it, nevertheless it will be necessary to correctly integrate these tasks on their schedule.

The Renewable Energy Community will need a major effort of communication between the operators and the design teams to understand hardware and software needs. Important effort will also be needed to have the internal companies aligned in terms of the way of sharing common information and, at the end, energy between them – according to local regulation. Additionally, an assessment of the already implemented hardware will be important for the Digital Twin development.

Other examples requiring coordination of design with PROBONO technology providers are for instance the design of the BIPV system that will benefit from a previous study of the Fraunhofer Institute to maximise the production of Renewable Energy and also the interaction with BEEPLANET to correctly size the second life batteries to meet the desired performance on the implementation scenario.

7.3.4 Construction elements and connections

As the Porto Living Lab is focused on improvements and innovations that don't require considerable civil works planning, the major question is related to the integration of the innovations with the internal electricity grid. The connection points should be properly chosen to maximise impact and without overpowering the existent network nodes. There should also be an assessment of the needs of licensing the electrical works, if necessary.

For this to happen, several internal teams (from Sonae and Capwatt) should be involved in the detailing phase of the implementation and, if necessary, upgrade some equipment to meet standards and performance.

7.3.5 Tools for optimal component configuration and integration

The optimal component configuration will be achieved by requesting from the technological providers a guideline for the best practices of design, installation, and operation to fulfil the best possible performance of the equipment.

In a later stage of the project, the Digital Twin could also be part of component configuration and optimization, because it will, most likely, simulate processes related with the Energy Community and concentrate information about different developments of the Energy Tech Hub.

7.3.6 Timeplan

7.3.7 Risks and constraints

7.3.7.1 Risks

Potential risks and associated contingencies considered for the LL realisation are described in Table 23.

Table 23 Risks and associated contingencies for the Porto LL [P=Probability, I=Impact, L=Low, M=Medium, H=High]

#	Description of risk	P	I	Proposed risk-mitigation measures
During planning/design/technology development (incl. permits and tendering process)				
1	Planning and design – find the proper space and use case to apply the innovations with the highest possible impact	L	H	Porto LL presents a solid scoping and ambition within PROBONO`s project. Several meetings with WP leaders, and technological partners have already taken place to define, carefully, the plan, design and scope of the overall Porto LL and its connections to all PROBONO`s WPs and diverse innovative solutions that will be tested along the project.
2	Technology development – choose technologies with the right TRL	L	M	Expertise in technology development and deep knowledge about the several innovative solutions that will be tested and deployed within Porto LL. High-levels of engagement of our internal technical and management teams, and related technical partners.
During construction/deployment/technology integration				
3	Technology solutions integration – adjust the technological innovations with the existing infrastructure	L	M	Expertise in developing innovation projects, engagement of several internal teams, technical knowledge, open-innovation culture, detailed plan and scoping regarding the whole Porto LL.
During monitoring, evaluation and verification/technology optimization				
4	Monitoring and evaluation – maintain the information flow stable throughout the project years	L	H	Controlling expertise, internal governance model, results-oriented culture, expertise in deploying innovation projects that compares the AS IS and TO BE scenarios
5	Verification and technology optimisation	M	M	Technical teams involved to ensure the optimal implementation and deployment of the several innovations selected for the Porto LL. Expertise in optimization and deployment of innovative solutions.

7.3.7.2 Local constraints

Climatic: Extreme temperatures (above 40 °C) are becoming more common during summer, increasing energy consumption for the climatization needs, as buildings are not prepared for such climatic conditions. Also, annual pluviosity is (in average) decreasing, making droughts and access to water more difficult.
Technical: To make the best technical choices to magnify the impact of the project on the campus.
Economic: To have sufficient budget for the proposed scope.
Social: To achieve an impact in a context of hybrid workspace, so with less campus occupation.
Legal: Keeping up with the constant updates to regulation within the energy field, especially in the Renewable Energy Communities domain.

7.3.8 Change management

A global coordination body, combining several teams that are part of different companies of the Sonae group, has been designed to act as both quality and change management control for PROBONO. This coordination body makes an internal process of management that can aggregate all the information and proceed with the work in an aligned and proper way without major setbacks. It is similar in some part to a steering committee but also serves as a link between the daily management of the project and the top management of Sonae. The responsibility of each of the levels inside this governance body is clear so, this allows that when a change event occurs it can be managed in an efficient way and all the involved parties are correctly informed as well as the consortium interlocutors.

7.3.9 Cost management

Sonae`s teams have a lot of expertise in developing and implementing innovation projects. The budget for the Porto Living Lab was carefully prepared and balanced by these teams to be capable of delivering the PROBONO vision. Moreover, all internal teams have regular meetings along the project, and report to the central financial teams, in a dynamic perspective, any minor adjustments that the project could potentially face, in terms of budget. It is noted that Sonae, as a private entity, can introduce complementary investments, if it is assessed that the specific and potential use-case could be an additional value-oriented investment to achieve the PROBONO`s vision, particularly within the Porto Living Lab. The internal governance model (see 7.4.9) was clearly defined from the beginning of PROBONO and has been implemented by several teams involved. Implementation includes monthly global coordination meetings and steering committees involving some of the highly positioned Managers at Sonae`s Group to ensure the overall alignment of the mid- and long-term strategy for Sonae`s campus.

7.3.10 Business Plan and feasibility study

Besides the contribution to achieve the environmental and social goals of Sonae's group, the PROBONO project will allow the companies that make part of the project to test and try new concepts and technologies that can later be integrated in their offering portfolio, including economic assessments.
Also, due to the geographical distribution of Sonae as a nationwide and international group, there can be possibilities of exploiting and testing the PROBONO's innovations in other sites.
The budget for the main items serving the Energy Tech-Hub scope through Sonae and Capwatt are detailed in Table 24.
Table 25 details the budget for the subcontracted tasks. Currently, the budget is aligned with the one calculated at the PROBONO proposal phase. In the next steps of the project these values will be further evaluated and detailed together with the feasibility studies. Also, effort will be made to promote synergies between the different technology tests to achieve possible cost savings.

Table 24 Energy Tech Hub budget

Energy Tech Hub elements	PROBONO budget for equipment and other goods and services (€)
Energy Community - smart metering equipment and dataloggers	31 500
Solar Power for Industry - CPC solar panels, thermal storage, the pipeline and control system	31 500

Energy Tech Hub elements	PROBONO budget for equipment and other goods and services (€)
Green H2 pilot project - electrolyser and equipment to connect to NG Pipeline	105 000
Control system, the storage 2nd life system, the EV charger and infrastructure	21 000
Phase Change Materials (PCM)	33 600
Smart EV Hub	100 000
TOTAL	**322 600**

Table 25 Subcontracting budget for the Porto LL

Subcontracted tasks	PROBONO subcontracting budget
Energy Community - Technical studies and algorithms creation for the CER and implementation of the software.	146 500
Solar Power for Industry - Development of the design of the systems by technical experts in CPC or Fresnel technology. (Please consider that this will be a demo unit, that will be installed in the tech hub, to develop our experience in the technology, for possible further replication)	16 115
Solar 2 Vehicle - Technical studies and development activities, to implement the Solar to vehicle integrated in the Campus	30 000

8 LL4 Aarhus Scoping and Implementation Plan

This chapter details the Scoping and Implementation Plan for the Aarhus LL. It begins with an overview of the Living Lab setup and continues with the as-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that cab be utilised in PROBONO are also described together with the first list of expected impacts and KPIs.
Next, the scenario considered for adoption (technologies, construction innovations and co-creation aspects) as well as the implementation plan are detailed along with the engineering activities necessary for the modification of the LL design according to local constraints like climatic, technical, economic, social and legal. Finally, current Business Plan details and feasibility study of design strategies are described.

8.1 Living Lab setup

8.1.1 Context – Local development plans – Key initiatives

One of the major challenges for the green transition in Aarhus is to translate sustainable ideas and research into concrete actions. Aarhus is a stronghold for innovation and architecture design industry. Connecting industry and research creates significant potential for a green transition with the focus on real and scalable actions.

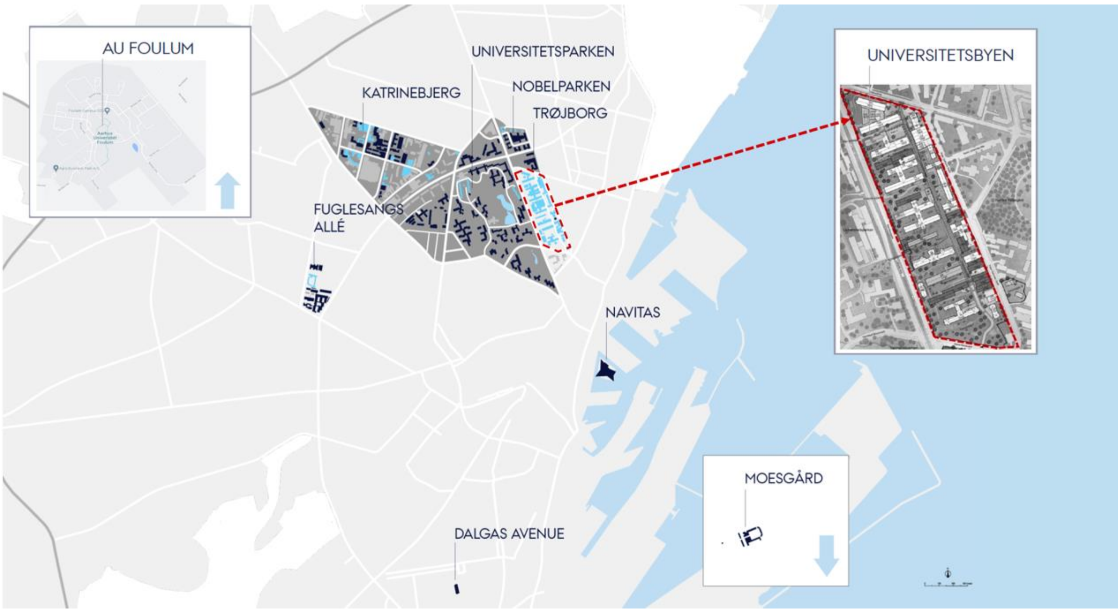


Figure 26 City-integrate Aarhus University

With a broad-based research and study environment, Aarhus University (AU) (Figure 26) is in a strong position when it comes to developing new sustainable solutions, and many AU students and employees are highly motivated to promote environmental sustainability, as attested by statements from the director Arnold Boon published in the Aarhus Municipality Green Transition Plan:
"We want to integrate sustainable development even more into our activities, and we want to think more about the university as a form of living lab, where we test sustainable ideas" - Arnold Boon, University Director, Aarhus University.[21]

Location and climate (coordinates, climate, HDD, CDD): The climate in Aarhus (56.1629° N, 10.2039° E) is mild, and generally warm and temperate. In Aarhus there is a lot of rain even in the driest month. The average annual temperature is 9.0 °C in Aarhus. About 703 mm of precipitation falls annually. The total CDD for the last 12 months in Denmark was 3.6 (baseline of 24 °C). The total HDD for the last 12 months was 3348.4 (baseline of 19 °C).

8.1.2 Vision and challenge to be addressed in PROBONO

The broader aim of the Aarhus LL is in providing data for supported decision-making in determining which design and renovation options are more sustainable, from a holistic perspective that puts environment, economic and social (occupant health, well-being, and architectural quality experience) as promoted by the DGNB[22] rating system.
AU has independently started working on a CO_2 benchmark for setting goals on energy reduction:
"The AU goal for 2025 is to reduce the university's CO2 emissions by 35% against a 2018 baseline"[23]
The first benchmark is based on operation use, and the PROBONO Aarhus LL aims in including the embedded energy so that refurbishment is increasingly more relevant.
The relevance lies in offering real data as well as actively supporting the industry in the most sustainable direction: to offer decision-makers end-user research-based collaboration (Co-Creation); implemented and adapted to the needs and limitations of the industry as well as with a holistic design perspective; and broad dissemination and education about results and evidence-based knowledge (Co-Learning).
Neighborhood approaches to be addressed by the PROBONO LL: The backbone of the Aarhus LL is that there is governance in place to use DGNB as the method to reach its sustainable goal. The "Gold goal" is based on a German certification product, that has been transformed and implemented for the Danish market for 10 years. The specific focus of the Aarhus LL is on optimising and achieving DGNB Gold Rating in two important, strategically located buildings:

- "The Kitchen 2.0": https://thekitchen.io/
- The AU BSS (AU School of Business and Social Sciences): https://bss.au.dk/en/

To achieve these goals, and to assess whether these targets are expected to be met, it will be necessary to develop new decision support tools, and develop innovative ways of conducting Life Cycle Assessment, particularly in terms of providing LCA information at the earlier stages of design and renovation, which we refer to as *Consequential LCA*. Developing such tools and pragmatic processes is also part of the Aarhus LL sustainability ambition.
The Aarhus LL will collect CO2 savings, commercialize research and develop evidenced based data and decision-making support, based on the Campus 2.0 guideline, FB23 national regulations, directives for universities on annual energy savings, and the AU Climate strategy.

8.1.3 Impacts and KPIs

The Aarhus LL aims to achieve a DGNB Gold Rating[24] for the two target projects (The Kitchen 2.0, and AU School of Business and Social Sciences) which include six buildings (referred to as buildings 23, 24, 1850, 1830, 1810, 1790 in the University City, detailed in Figure 28). The DGNB Gold Rating corresponds to a total performance index of 65% (point scoring system) and a minimum performance index of 50% across all six major quality categories[25] (environmental, economic, socio-cultural and functional, technical, process, and site). In addition, the Aarhus LL buildings must meet the upcoming Danish environmental impact FB23. The initiative will ensure the introduction of requirements for the calculation of the environmental impact in 2023 for all new construction and the introduction of a limit value of 12 kg CO_2 eq/m^2/yr (the combined

building material + the operation for 50 years measured in CO_2 equivalent) for new construction over 1000 m^2 from 2023 onwards.
The expected Aarhus LL impacts are summarised in Table 26. Energy savings will be estimated following IPMVP Option C (Whole Facilities). The LL is in the process of determining whether sufficient baseline energy data is available for the definition of the reference model.

Table 26 Aarhus LL impacts

Impact Category	Unit	LL Reference	LL Objective
I1. Primary energy savings	GWh/year	Flagship building energy demand: 2GWh/year	Flagship Building energy demand: 1.2 GWh/year Savings: 0.8 GWh/year GBN projection: 3 GWh/year FB23 Danish energy regulations: 12 kg CO2 /m2/yr build bigger than 1000m2 from 2023.
I2. Investments in sustainable energy	million €	-	40 million € invested
I3. Demonstration sites that go beyond NZEB performance	-	Flagship building specific heating and cooling demand: 1.2 kWh/m2/year	Flagship building specific heating and cooling demand: 0.7 kWh/m2/year Savings flagship building: 0.5 GWh/year GBN projection improvement 40%
I4. High energy performance	%	-	Achieve gold grade in the DGNB-DK certification system. Achieve Class 2 in the Danish voluntary energy regulation. DGNB Gold corresponds to total performance index of 65% (aggregate across all major categories) and minimum 50% for each category. FB23 corresponds to no more than 12 kg CO2 /m^2/yr build bigger than 1000m^2 from 2023.
I6. Reduction of the embodied energy in buildings	GJ or %	-	As above

8.2 PROBONO LL existing infrastructure

8.2.1 Building infrastructure

Aarhus University is an all-faculties university with 700.000 m^2, 38.000 students and 8000 staff. The Aarhus LL is centred on a site called the University City (Universitetsbyen). The University City site is an old hospital that is being refurbished, consisting of around 20 buildings that are critical in analysing the buildings in the context of a Green Building Neighbourhood, as illustrated in Figure 27 and Figure 28.

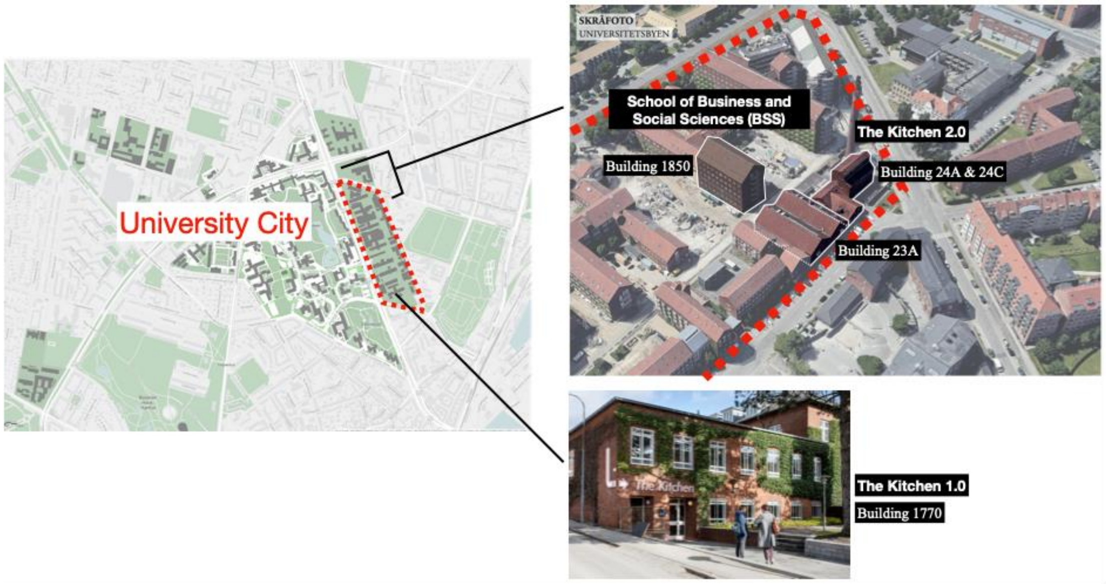


Figure 27 Location of University City (within the red dashed line), and three of buildings in the two Aarhus LL projects at the University City: The Kitchen 2.0 and BSS

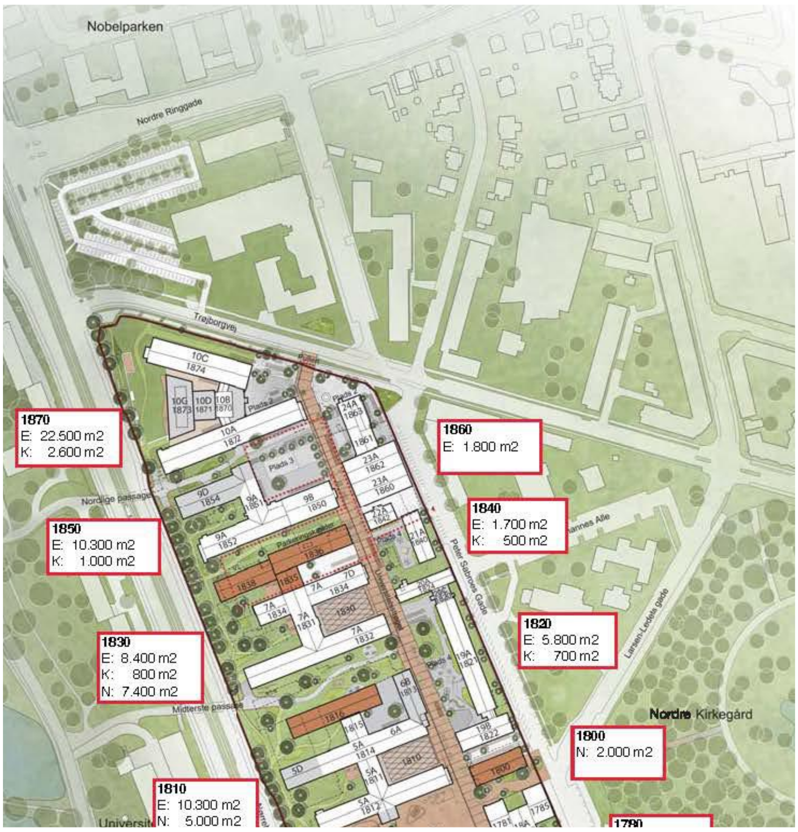


Figure 28 University City site where the two Aarhus LL projects are located: The Kitchen 2.0 (buildings 23, 24) and BSS (buildings 1850, 1830, 1810, 1790). E=existing buildings that are being kept (grey are the newer parts); K=basement area; N=new buildings.

The Kitchen 2.0 and the AU School of Business and Social Sciences (AU BSS) buildings have been selected due to their complementarity in terms of building phase, scale, and functionality (Table 27).

Table 27 Aarhus LL building attributes highlighting their complementarity

Building	Role as AU LL	Building Phase	Construction Period	Building function
The Kitchen 2.0 Buildings 23,24	Confirmatory checks based on sensor data	In-use, while in early sketches phase for subsequent deep refurbishment	2022-2024	Start-up hub (café, mixed-use spaces for work, meetings, networking, events)
AU BSS Buildings 1850, 1830, 1810, 1790	Refurbishment, renovation tasks	Tender phase, deep renovation designs	2021 - 2025	Academic activities (lectures, offices, student workspaces)

The current Kitchen building (referred to as The Kitchen 1.0) is acting as a trial run of the start-up hub concept that took advantage of an area of the University City that was not being utilized. It opened in 2019 and is set to be demolished in around 2024-2025. The next iteration, referred to as The Kitchen 2.0, will occupy a new building (buildings 23, 24), and is being designed and developed based on lessons learnt from The Kitchen 1.0. The newly renovated building is a boiler room and laundry facility for the former hospital.

The AU BSS is one of the largest schools of business and social sciences in Europe and will be relocated to the University City in 2025. This project is a 37.000m^2 deep refurbishment currently in the tender phase.

Figure 29 Visualisation of the BSS covered courtyard area (left) and an auditorium (right).

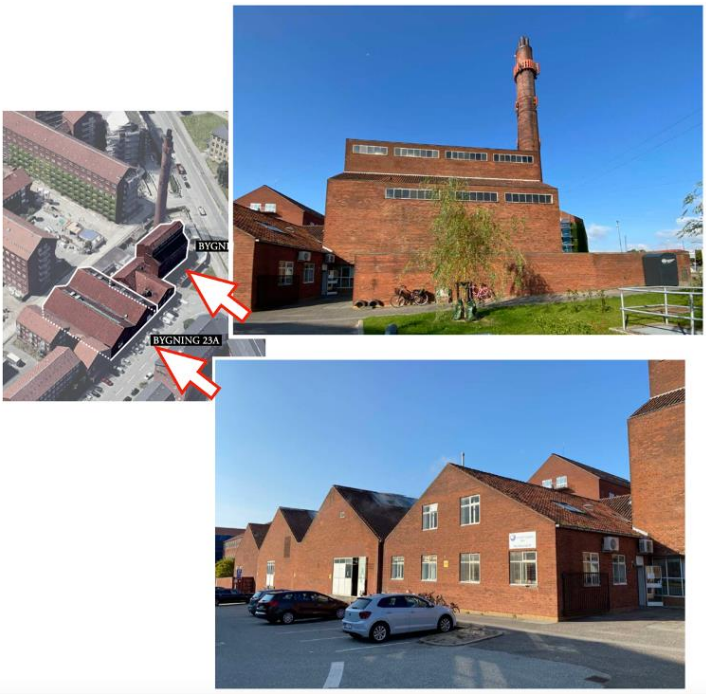


Figure 30 Photos of the exterior of building 24 on the University City site, which will become The Kitchen 2.0.

The characteristics of the two Aarhus LL buildings are summarized in Table 28.

Table 28 Aarhus LL building infrastructure

Building name	Building use	Year of construction	Net floor area (m2)	Occupant capacity	Renovation /construction method	Possibility for BIPV integration (Y/N)
The Kitchen 2.0: Buildings 23, 24	Innovation hub, incubator	late 1900, and 2025	3.877	~10 occupants during standard operation; up to 500 occupants during events (expecting a few such events per month)	New building but with the old brick deep refurbished (certified as a new building)	N
BSS: Building 1850	Offices,"Student Hub" lab spaces for university collaborators	late 1900, and 2025	37.000 (combined)	170 occupants (students, staff)	Deep refurbishment - brick building	N
BSS: Building 1830	Offices; study areas; cafes			400 occupants (students, staff)		
BSS: Building 1810	Offices; study areas; cafes			500 occupants (students, staff)		
BSS: Building 1790	Lecture theatre			800 seating capacity, 20 staff		

COVID plans*:* the primary impacts on the design of The Kitchen 2.0 and BSS in response to COVID is in social interaction and ventilation. Lecture theatres, pedestrian traffic corridors and other spaces where a large number of students congregate must now ensure appropriate distancing between occupants on-route or seated. Similarly, ventilation must minimise or eliminate transportation of airbourne contagions from and into densely populated areas at key times throughout the day. These additional criteria will be assessed and addressed in the design process through collaboration between ventilation and occupant simulations involving the PROBONO partner ITAINNOVA.

8.2.2 Energy infrastructure

Heating: AU buildings draw on the unique district heating system owned and operated by Aarhus Municipality (AffaldVarme Aarhus). The district heating system is fed by public and private sector heat producers, including Combined Heat and Power (CHP) plants that operate using waste-to-power (e.g. one plant in Waste Centre Lisbjerg), biomass (plants fueled by straw and woodchips), and seawater heat pumps.
Electricity: The district heating system described above supplies electricity to AU buildings. Natural gas is occasionally burnt to generate electricity on-site (at a location called Campus Viborg). In addition, AU buildings draw electricity from the national grid (which connects to the "Synchronous grid of Northern Europe"), where electricity is purchased through the European power exchange Nord Pool. Electricity generated in Denmark is primarily renewable (wind ~57%; biofuels and biodegradable waste ~20%; solar ~3%).

8.2.3 Monitoring infrastructure

AU has a facility management system (Dalux) and a digital team that are managing the electricity, heating, and water consumption of its existing buildings; Figure 32 presents an overview of the systems contributing to "AU Intelligent Buildings" and outputs of the activities of the current digital team. Figure 33 illustrates "use cases" of potential assessments that are currently being developed by the digital team. AU has data for all in-use buildings. The Aarhus LL can give external access to the Dalux system and to Power BI. AU has already started working on (Azure based) Digital Twins.

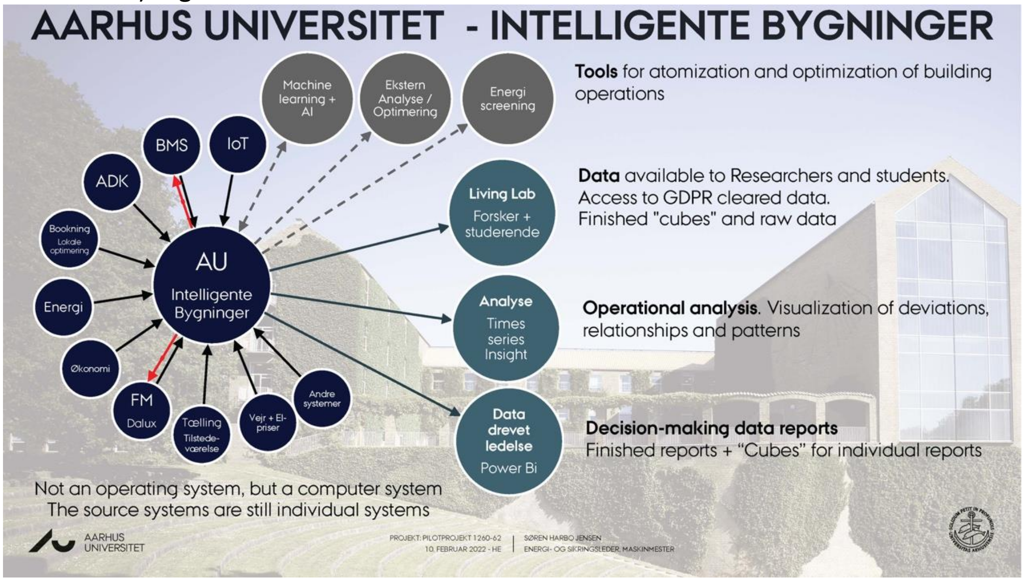
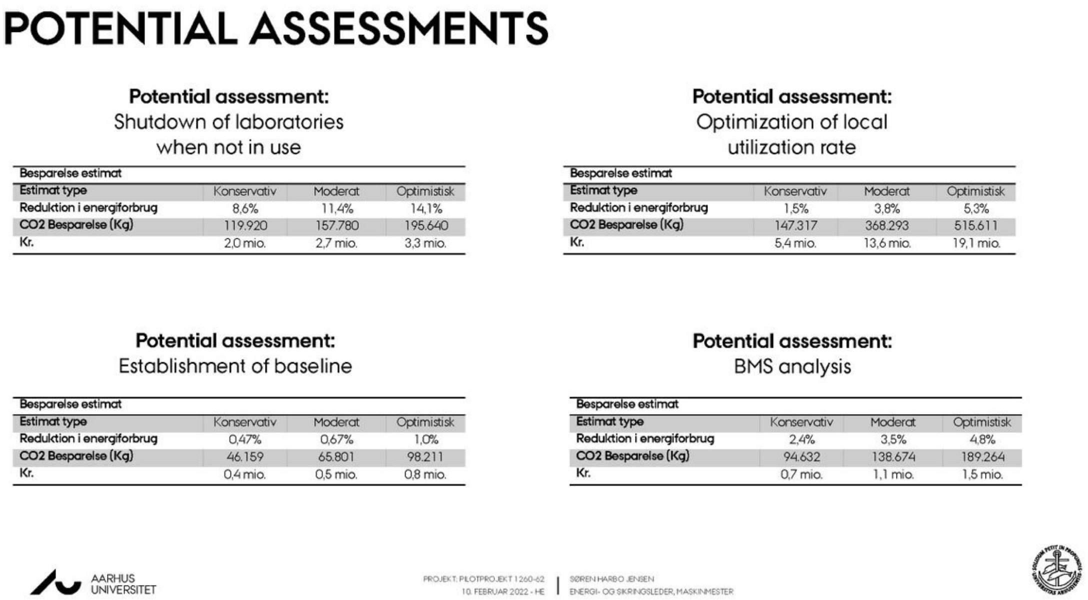


Figure 31 IoT, Intelligent Buildings overview



Potential assessment: Shutdown of laboratories when not in use

Besparelse estimat			
Estimat type	Konservativ	Moderat	Optimistisk
Reduktion i energiforbrug	8,6%	11,4%	14,1%
CO2 Besparelse (Kg)	119.920	157.780	195.640
Kr.	2,0 mio.	2,7 mio.	3,3 mio.

Potential assessment: Optimization of local utilization rate

Besparelse estimat			
Estimat type	Konservativ	Moderat	Optimistisk
Reduktion i energiforbrug	1,5%	3,8%	5,3%
CO2 Besparelse (Kg)	147.317	368.293	515.611
Kr.	5,4 mio.	13,6 mio.	19,1 mio.

Potential assessment: Establishment of baseline

Besparelse estimat			
Estimat type	Konservativ	Moderat	Optimistisk
Reduktion i energiforbrug	0,47%	0,67%	1,0%
CO2 Besparelse (Kg)	46.159	65.801	98.211
Kr.	0,4 mio.	0,5 mio.	0,8 mio.

Potential assessment: BMS analysis

Besparelse estimat			
Estimat type	Konservativ	Moderat	Optimistisk
Reduktion i energiforbrug	2,4%	3,5%	4,8%
CO2 Besparelse (Kg)	94.632	138.674	189.264
Kr.	0,7 mio.	1,1 mio.	1,5 mio.

Figure 32 Examples on assessments for energy saving

8.2.4 Non-energy infrastructure

Blue or green spaces: The University City is situated adjacent to the lush University Park, a public park that is lined with Aarhus University campus buildings around its perimeter (Figure 33). The park contains grassy open areas, oak trees, two artificial lakes, waterfowl, and other green and blue features. Pedestrian flow and visual access from The Kitchen 2.0 and the new BSS buildings are a focus point of the architects in the design team, and will be exploited to maximise health, well-being, and aesthetic appeal. The Bay of Aarhus is located south-east of the University City.

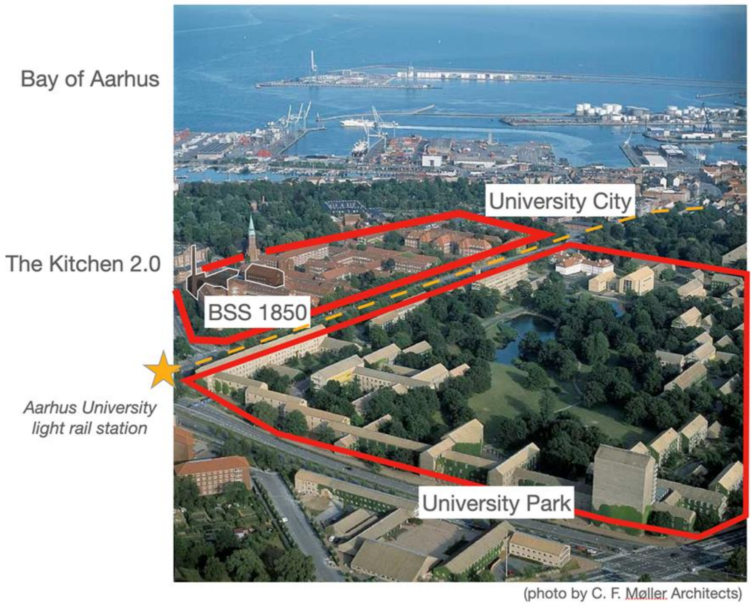


Figure 33 Illustrating the blue and green spaces in the vicinity of University City, University Park and Bay of Aarhus, and convenient access by light rail at "Aarhus University" station to other parts of Aarhus.

Other infrastructure: The Aarhus light rail (Letbahn) runs along the roadway in between the University City and University Park (Nørrebrogade) with a station (named Aarhus University) positioned directly on the corner of University City in close proximity to both The Kitchen 2.0 and BSS building 1850 (Figure 33). The light rail thus connects these buildings with both the Bay of Aarhus and Aarhus central station, significantly improving accessibility to and from the AU LL buildings, and connecting the buildings with amenities and blue spaces (the bay). The convenient access by light rail reduces the need for staff, students, visitors and other building occupants to reach the buildings by car.
There are no EV charging stations in the University City. The nearest EV charging station is a few blocks away from The Kitchen 2.0 (approximately 500m).

8.3 Existing models, data sets and tools

Models already in place: BIM models are already available (in Revit[26] and IFC format) for both The Kitchen 2.0 (buildings 23, 24) and the BSS (buildings 1850, 1830, 1810, 1790). The BIM models will evolve to be exploited in ITAINNOVA's ventilation simulation software. They will be augmented with human-centred objects (referred to in the research literature as spatial artefacts).
Digital Twin: DTs of both building projects (The Kitchen 2.0 and BSS) will be used once the buildings have been constructed and are in operation. The DTs will be used to assess specific human-centred criteria, which will be compared to the predictions made during the design phase.
Other IT tools: Standard architecture design software (Autodesk Revit) and geographic information systems (e.g. QGIS[27]) will be used.
The Renovation Domain Model (NovaDM) will be used to help stakeholders explore the design space of renovation options. This is developed in-house at AU.

The Model Identity Card (MIC) developed by SystemX, and the Functional Mockup Interface[28] (FMI 2.0) are expected to be used when integrating different simulations, primarily ventilation and occupant behaviour.
Available data sets: Select datasets for electricity, heating and water consumption of existing in-use buildings at AU can be made available, connected to the Dalux facility management system.
IT collaborative engagement tools and activities: Aarhus LL will use existing engagement platforms as appropriate that are available by the Aarhus municipality. For example, Aarhus municipality uses the Consul engagement platform, with a portal entitled “Together about Aarhus”, which includes tools[29] on legislation and participatory budgeting. The DT will be used to assist designers by comparing actual with predicted results of interventions. Facilities managers may use the DT to improve building performance, in association with the Building Management Systems, subject to final design of the DT. The DT may also offer data to building occupants, who could deliver feedback via a publicly accessible dashboard.

8.4 Implementation plan for adopted scenario

This section describes the singular scenario (technologies, construction innovations and co-creation aspects) for implementation and execution in the Aarhus LL.
There are different timelines and implementation plans for the different building-phases.

8.4.1 Selected technologies and planned interventions

Integrating Upcycling into “Consequential LCA” (COWI): The Aarhus LL will map how new and upcycled materials and methods can be categorized in Environmental Product Declarations (EPD) together with PROBONO partner COWI, e.g. reusing bricks and other materials from the former building in new ways.
The commonly used LCA calculation (attributable LCA) focuses on one building and not on the connected energy/CO_2/materials/buildings. COWI and AU are developing parallel calculations on what we are calling "consequential LCA" which also includes linked (scope 3) energy consumption on other grounds, transport, use of raw or reused materials etc. aggregated across multiple buildings. Thus, energy and CO_2 savings accrued in one building can be reasoned to "offset" other poorer performing buildings on-site for an overall higher-quality green neighbourhood, where increased energy usage may be used to enhance living quality, afford specialist scientific activities, and so on.
This will be undertaken in both The Kitchen 2.0 and BSS buildings.

Sustainable insulation (Soprema, Anerdgy): Aarhus LL is discussing with Soprema about what specific products would be most relevant for implementing in the early sketches The Kitchen 2.0 and BSS projects. For insulation the mineral fibre from Rockwool is the dominant product. In order to be relevant, the proposed products must live up to National regulations on performance, alongside with Rockwool. The interesting and possible increased market share in Denmark is the sustainability aspect, when the sustainability is scientifically calculated. The evidence-based calculations and test result, that can also help achieve DGNB points, can be shown in an EPD[30].
In addition to the production of raw material the use of upcycled products have several sustainable benefits and the intention of Aarhus LL is to translate the research into industry needs. For example, the Soprema product of using waste PIR (Polystyrene foam) as a part of (new) insolation panels would score well on attributional-LCA and initial guess is that they will perform very well on consequential-LCA.

The starting point for Soprema could be translating EPD to English (or Danish) with LCA calculations on the initially chosen products, showing the upcoming mandatory footprint of one project (attributable LCA). The parallel step would be to create, together with COWI, the first set of rules on how to calculate the Consequential LCA on the same products.

Advanced energy storage (Visblue): Together with Visblue, the Aarhus LL is implementing electricity storage in Flow-batteries. The batteries will be vanadium based redox flow batteries. In order to collect renewable energy, the first idea was ground based PV panels. The second idea is retrofit solar panels on the existing building roofs. In this specific case there are not many flat roofs so the development might indicate that creating a structure that can hold PV panels over the carpark might be the better solution. This will be undertaken in the rural Campus Viborg which is a part on the further development of the city campus.

Human-centred ventilation simulations (System X, ITAinnov, AU): In both The Kitchen 2.0 and BSS "virtual sensors" will be deployed into the as-designed BIM models of the projects, and simulations and static analyses to predict key performance indicator values will be performed. Once the buildings become operational, the predictions will be compared with reality, and the outcome of the comparison will be used to generate new knowledge for future designs and subsequent renovation and reconfiguration stages of The Kitchen 2.0 and BSS.
The collected data will primarily focus on occupant experience and behaviour, in combination with environmental (energy and CO_2, assess via currently in-use LCA tools) and cost criteria. That is, the aim is to assess whether the buildings are meeting the requirements of the building users, as intended by its design, and how design decisions make trade-offs between occupant experience, environmental impact, and financial cost.
Indoor air quality and thermal comfort will be the initial focus of ITAINNOVA's ventilation simulators. This is anticipated to require the integration of different kinds of simulations (airflow and occupant behaviour) into a single simulation run, thus requiring meta-model expertise from SystemX (Model Identify Check, MIC) and AU (co-simulation and evidence-based reasoning about human experience).

8.4.2 Stakeholders and their role

In the table below (Table 29) the various Aarhus LL internal and external stakeholders and their roles are further outlined, defined, described and categorized.

Table 29 Aarhus Living Lab stakeholders and roles

Stakeholder	Role	Internal (blank) /external ('X')
Users		
The Kitchen	Innovation and entrepreneurial hub at AU, with a broad network. Possible partner for commercialization of sustainable buildings, linking (and creating) external companies. Technology Transfer Office. Business Development.	
Providers		
FEAS *A. Enggaard*	Building owner UniversityCity– access to digital material and influence in the process. https://feas.dk/ Developer (Denmark's largest developer) https://www.enggaard.dk/	X
AARTart Architects	Architect for UniversityCity. Design and tender project, commissioned by FEAS.	X

Stakeholder	Role	Internal (blank) /external ('X')
COWI	Partner and also engineer firm for tenderproject "Incuba Next" Katrinebjerg tall, massive wood (CLT) building.	X
Influencers		
IClimate	"Emissions inventory for AU" baseline for CO2 already in progress, the next level is including buildings and also Scope 3. -to do: workshop on further involvement with the Aarhus LL. (Hans Sanderson)	
DK-GBC	NGO that provides and develops DGNB-DK	X
CAE Civil and Architectual Engineering department at AU	Influencers; "Danish universities" joint effort on creating master program in sustainable buildings. (Deputy head of Department, Kasper Lynge)	
Governance		
AU senior management	Local authority	
AU BYG (Estate department)	*The LL is aiming for developing into an international and cross sectional department*	
AU IoT project	In process and with access to all sensor data and combined with FM data. Collaboration on -what can the data be useful for? (Energy savings is on the operation, 25% of total, the Process energy (remaining 75%) is part of research and "not accessible" for energy savings. "Analysis for the procurement process" With the human focus (soft KPI) targeting is broader and with higher potential savings.	
Others*		
Grundfos, LEGO group, NREP, We build Denmark	Potential partners, https://nrep.com/	X
New Bauhaus initiative	AU are a part of the EC-initiative with base in Brussels.	X

Based on this list of stakeholders relevant for the Aarhus LL, they have been mapped according to the methodology described in Annex II. The output is displayed in Figure 34.

8.4.3 Design coordination

The role of the AU LL team during these on-going design phases, in collaboration with ITAINNOVA, is to provide input on achieving DGNB Gold and evaluating "soft" occupant experience criteria. ITAINNOVA will deploy virtual sensors into the as-designed BIM models of The Kitchen 2.0 and the BSS. The role of COWI in the AU LL is to develop upcycling opportunities in the design, and to develop and apply new LCA calculation tools ("Consequential LCA") that aggregate LCA across several buildings.

The Kitchen 2.0 is being designed by an architecture firm Transform, who are helping with the process of gathering user requirements. Subsequently the design will go through an architecture firm competition phase along with requirements, to compete to gain the contract (approximately early 2023). An agreement will be made between AU LL and the winning architecture firm that AU LL will assist in finding design solutions that ensure DGNB Gold will be achieved, by discovering and evaluating design alternatives.

In the case of BSS, the architecture firm AART Architects has already won the design competition and is proceeding with the detailed design. An agreement has thus already been made between the AU LL and AART Architects where the AU LL will provide support in achieving DGNB Gold by design alternative discovery and evaluation.

Therefore, the AU LL needs to coordinate carefully with AART Architects (in the case of BSS) and the winning architecture firm (in the case of The Kitchen 2.0), and will act as the main point of contact between these architecture firms and the other PROBONO partners (ITAINNOVA, COWI). In coordinating with these architecture firms, the AU LL will be taking an active role in providing AART Architects with design alternatives (rather than reacting to design options proposed by AART Architects); this is an innovative approach to co-creating that departs significantly from other design and construction projects being undertaken at AU. Thus, the AU LL will be also proactively requesting specific analyses from ITAINNOVA and COWI, and providing the necessary design inputs for these analyses.

8.4.4 Construction elements and connections

COWI will be supporting the AU LL in creating better reused materials in order to save on raw materials as part of improving the circular economy of the buildings. As the primary focus on the two building cases (The Kitchen 2.0 and BSS) is on interior and occupant experience, the design of the construction elements does not play any further role.

8.4.5 Tools for optimal component configuration and integration

Optimal component configuration in terms of “virtual” and actual sensor placement for accurate air quality analysis during the design and operational phases will be achieved in collaboration with ITAINNOVA. Upcycling and Consequential LCA analysis tools will be developed and used in collaboration with COWI. Integration with the Digital Twin will be achieved with support from the partners in WP5, primarily SystemX.

8.4.6 Timeplan

The timeplan for the Aarhus LL is detailed in Figure 35.

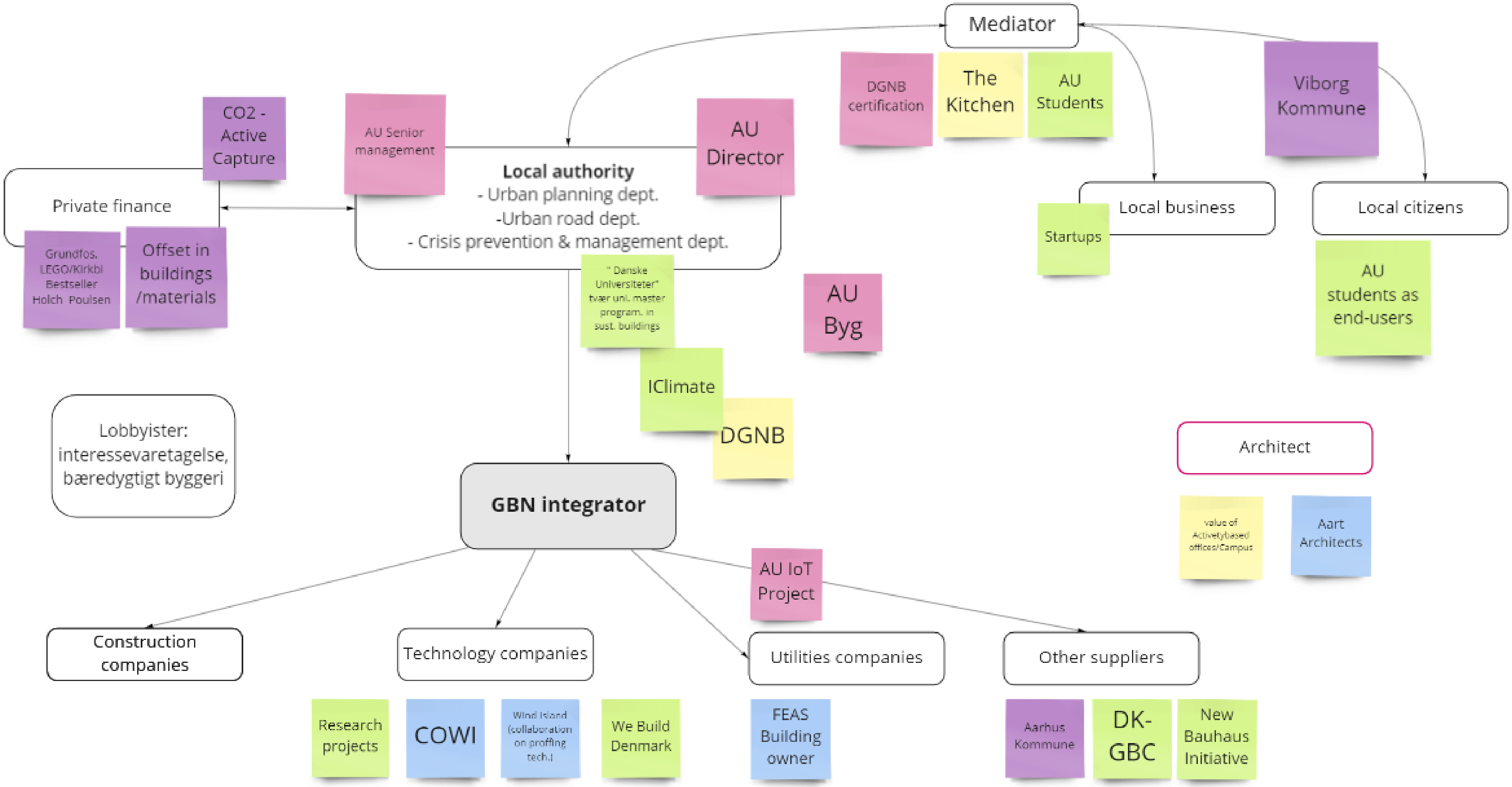


Figure 34 Stakeholder mapping for the Aarhus LL

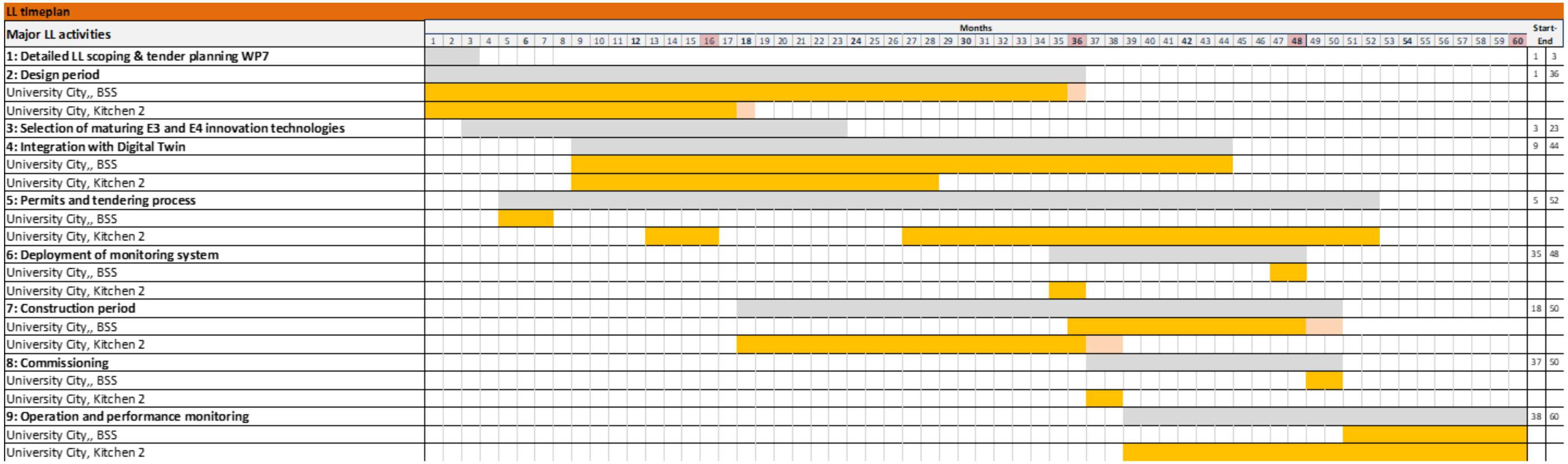


Figure 35 Aarhus LL timeplan

8.4.7 Risks and constraints

8.4.7.1 Risks

Potential risks and associated contingencies considered for the LL realisation are described in Table 30.

Table 30 Risks and associated contingencies for the Aarhus LL [P=Probability, I=Impact, L=Low, M=Medium, H=High]

#	Description of risk	P	I	Proposed risk-mitigation measures
During planning/design/technology development (incl. permits and tendering process)				
1	Predicted DGNB scores are not realised; poor prediction performance at design stage.	**L**	**M**	During development, the simulations and predictions will be made on smaller "test case" floorplans of existing buildings with known performance, to assess and calibrate the accuracy of the predictions being made.
2	Failure to perform sufficient analysis before the design phase completes.	**L**	**M**	We will undertake a tiered approach to providing analysis (informed by agile software development methods) where emphasis is on rapidly delivering iterative rounds of information on coarse design plans that target all areas of the facilities, and then subsequently delivering more fine-grained analysis in depth on particular zones in response to architect's feedback (in contrast to delivering a single comprehensive, detailed analysis near the end of the design period).
During construction/deployment/technology integration				
1	COWI upcycling plans are infeasible or too costly to implement.	L	M	Tight collaboration between COWI, the building owners, architects and contractors (coordinated by the AU LL) will support the alignment of construction plans and constraints, and will serve to identify problems in construction plans as early as possible.
During monitoring, evaluation and verification/technology optimisation				
1	Violation of GDPR occupant privacy regulations.	**L**	**H**	The following institutional resources at AU will be utilised to ensure compliance with relevant ethical and data protection procedures: (1) The AU Data Protection Officer (DPO) will be consulted to ensure the project handles personal information compliant to GDPR; (2) The AU central Ethical Committee will be consulted regarding ethical issues and relevant approval will be obtained; (3) Lawyers at the AU Technology Transfer Office will be consulted in legal matters, if necessary.
2	Failure to secure occupant permission to collect data.	**L**	**H**	Data is already being collected across numerous buildings at AU, and so we will work closely with the DPO and AU central Ethical Committee to maximise occupant engagement. Potential for value added in terms of reduced environmental impact, enhanced occupant experience, and being a part of generating new scientific knowledge on green buildings will be communicated to occupants to promote engagement, tying in with on-going Campus 2.0 communication initiatives.

8.4.7.2 Local constraints

Climatic: As the climate is generally warm and temperate there are no particular climate constraints to be considered.

Technical: Integration or at least compatibility with the existing Dalux facility management system (Dalux) should be reviewed when developing the digital twin infrastructure to ensure that there are no technical complications or barriers to deploying the digital twin system. The existing AU digital team who are managing the electricity, heating, and water consumption of currently operational buildings should be consulted to ensure that there are no unforeseen conflicts or barriers.

Economic: Time rather than financial cost is the primary business constraint (where the existing design and construction schedules must be adhered to), although certainly the plan to install sensors must fall within the allocated budget.
Social: The target green and socially beneficial impacts of the AU LL must be communicated effectively to all stakeholders (design teams, occupants, students, staff, AU management) in an evidence-based way, and importantly also data privacy aspects must be communicated where statements made about such sensitive aspects are able to be backed up with evidence when requested. The AU Data Protection Officer should therefore be consulted in good time for how to both ensure high standard of compliance with privacy and ethics regulations, and how this can be communicated to any concerned stakeholders.
Legal: GDPR policies need to be clarified and correct documentation set in order in good time to avoid delays or ethical issues. The upcoming Danish energy regulations FB23 will need to be carefully reviewed when proposing design alternatives.

8.4.8 Change management

An AU LL change management board has been set up where the AU LL leader is responsible for keeping track of encountered changes and any requested changes to the project plan and communicating these with the other AU LL PROBONO partners (AU, ITAINNOVA, SystemX, COWI, VisBlue, Soprema). The other AU PIs are responsible for reviewing reported changes and working together with the LL leader on adjusting the project plan accordingly, and in helping to communicate any important information back to the immediate AU LL partners (ITAINNOVA, SystemX, COWI, VisBlue, Soprema) and the PROBONO coordinators. This can include, for example, bringing new buildings into the AU LL, changes in the on-going design and construction schedules of the AU LL buildings, and proposals for changing the sensor installation plan.

8.4.9 Cost management

All AU LL budgeting is being monitored and controlled by the AU financial and legal support offices, with regular monthly reporting of financial expenditure, who are in close contact with the AU PIs. All expenditure will need to be reviewed and agreed upon beforehand by the assigned financial experts following university-wide standard practices.
Stakeholder engagement activities (workshops, interviews, surveys, experiments, etc.) will be carefully planned in advance, with the support of PROBONO partner GECO, and with local support from the AU Research Support Office to ensure that the appropriate scale and number of such activities is undertaken without risking going overbudget before collecting the necessary data.
Construction costs due to installation of sensors, installation of digital infrastructure and integration with existing digital systems will be carefully planned in collaboration with the building architecture teams (i.e. AART Architects), construction and commissioning contractors, and the existing AU digital team, mediated by AU LL lead. Reacting to unforeseen costs or unexpected (projected) cost overruns will be managed through the AU LL change management board process described in Section 8.4.8.

8.5 Business Plan and feasibility study

Owing to the large-scale construction programme being undertaken at AU (Campus 2.0), there is a high potential for replicability of the approach, thus multiplying economic gains across the university, Aarhus, and wider Denmark.

Economic viability and gains are part of the design analysis process that will be the core activities in the AU LL, i.e. predicting the short-, medium- and long-term benefits of discovered design alternatives, in order to incentivise upfront investment of greener products, construction processes (upcycling), advanced batteries, and the impact on occupant satisfaction. Thus, a detailed business plan will be developed during the collaborative design phase in order to justify any expenditure.

More accurate predictions, especially on social aspects, are of extremely high value, in particular in making the trade-off between criteria categories much more visible, namely occupant satisfaction, environmental impact, and financial cost. For example, within a design context, we are greatly concerned with identifying those decisions where a relatively small worsening in one KPI (such as energy usage, CO_2 emissions or financial) corresponds with a disproportionately drastic improvement in occupant experience. In the longer run such design alternatives are often far superior in terms of environmental impact, and are cheaper, as less day-to-day energy wasting interventions and expensive renovations are needed to rectify problems with occupant satisfaction, health and well-being. Quantifying these gains is part of the business modelling activities undertaken in assessing design alternatives.

Table 31 and

Table 32 provide information on the breakdown of the granted budget per item for the AU LL in PROBONO.

Table 31 Subcontracting (PROBONO budget)

Budget	**Description**
50,000	Installation of air quality sensors (and other sensors as determined during the design analysis phase) in AU LL buildings with support from ITAINNOVA. Integration of data collection and software infrastructure with a digital twin platform and existing Dalux system, if determined to be needed. Construction costs to implement COWI upcycling. Construction costs for installing VisBlue batteries, and green products (materials, insulation, etc.) as recommended by Soprema, if determined to be needed.
25,000	Social science expert partner that can collaborate with the AU LL in the processes and the methods for feedback collection and integration into the project (e.g. moderating focus group discussions, conducting interviews with various audiences, recruit participant panels and reporting) on the ground and in the local languages (Danish, English).

Table 32 Goods and Services/Equipment (PROBONO budget)

Budget	**Description**
198,000	Raw materials for RFB system construction, 80 kW/200 kWh: stacks for 80 kW, electrolyte for 200 kWh, tanks, electrical component, panel, connectors, control components, material for hydraulic system, metallic structures, Sensors, consumables for assembling, controller, pumps (186.000€). Equipment depreciation for containers housing the battery system (12.000€).
Amount to be determined	SOPREMA innovations cost of materials for implementation

9 LL5 Brussels Scoping and Implementation Plan

This chapter details the Scoping and Implementation Plan for the Brussels LL. It begins with an overview of the Living Lab setup and continues with the as-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that cab be utilised in PROBONO are also described together with the first list of expected impacts and KPIs.
Next, the scenario considered for adoption (technologies, construction innovations and co-creation aspects) as well as the implementation plan are detailed along with the engineering activities necessary for the modification of the LL design according to local constraints like climatic, technical, economic, social and legal. Finally, current Business Plan details and feasibility study of design strategies are described.

9.1 Living Lab setup

9.1.1 Context – Local development plans – Key initiatives

The Living Lab building is De l’Autre Côté de l’Ecole (ACE) school building (Figure 36), home to a private school. ACE will be renovating 2000 m² out of their total school facilities to bring the areas into use for the educational needs of the school and in line with the latest environmental and regulatory requirements of the European Green Deal. This renovation will also include transverse technical elements (roof, chassis, technical equipment, etc.).

Figure 36 Brussels LL. De l’Autre Côté de l’Ecole, Auderghem (in yellow, the area owned by ACE)

Participation in the PROBONO project is an opportunity to accomplish this transformation by meeting the highest standards of green innovation and the 2040 vision of the Brussels Government grouped in four major themes: Mobilise the region to build the framework for regional development and create new neighbourhoods; Mobilise the region to develop a pleasant, sustainable, and appealing living environment; Mobilise the region to develop its urban economy; Mobilise the region to promote multi-modal travel.

Location and climate: The Brussels Living Lab is located at Chaussee de Wavre 1789 (50.815770,4.429450) the Auderghem Commune, in the southeast corner of the Brussels-Capital Region, Belgium. The climate is sub-oceanic, humid and rainy and is influenced by the close proximity of the Atlantic Ocean, with decently warm summers and cold, close to freezing temperature, winters. The wind blows frequently, and can be rather intense, especially in wintertime. Brussels does not get an abundance of sun, especially in the winter months. On average, Brussels counts of around 1,600 sunshine hours annually and has an annual average of 2,096 HDDs and 60 CDDs.

Public/private business model and funding: ACE is a private school implementing the Feinet pedagogics. This being said, the Brussels Living Lab makes use of a combination of Public and Private funding in reaching the project targets. As an educator and a non-profit organisation, becoming sustainable and supporting others in the neighbourhood to do so too is a solid business, economic and educational decision. Willis Towers Watson, one of the largest insurance brokers worldwide, leading on PROBONO's ESG, finance and investment tasks primarily in WP1, will play a part in assessing, analysing the financing and access to funding needs and opportunities of the Brussels Living Lab to complement where needed the traditional funding sources used by ACE. Historically ACE has carried out works in the school building with financial support from one of the three constituent constitutional linguistic communities, the French Community of Belgium, Fédération Wallonie-Bruxelles.

9.1.2 Vision and challenge to be addressed in PROBONO

The Brussels LL will examine the business and socio-economic aspects of the Green Buildings and Neighbourhoods (GBN) transformation journey. Here, ACE will play an active role in showing the positive impact of data-driven knowledge on sustainability decision-making and how to maximise business and social innovation by influencing behaviour. This will be particularly so in the day-to-day management and operation of the school, in such areas as facilities, sustainable procurement, mobility and circular economy approaches as they relate to the educational and business needs of the school. This will make it possible to strengthen links with other local neighbourhood actors (companies, authority, commercial, mobility …) in order to move from a simple building renovation to a project that catalyses the dynamics of the neighbourhood around such initiatives as green energy and circular economy clustering. The pedagogy practiced in schools is a real opportunity to amplify social innovation (implementation of concrete projects as vectors of learning).

One of the principal mechanisms that the Brussels LL is exploring to underpin and provide a catalyst for the creation of a GBN is the use of a Renewable Energy Community (REC). In a similar fashion to how the Porto LL will use a REC on its sustainable campus at Sonae, so too will the Brussels LL as a means to bring together the disparate communities within the Auderghem Commune within a formally recognised sustainability structure.

As an integral part of the business-focused cluster of Living Labs (see section 3.2) the Brussels Living Lab aims to support evidence-based decisions as to the business, socio-economic and environmental value to benefit establishing a Green Neighbourhood from the clustering of diverse and standalone buildings. As an education provider in the heart of a vibrant commune the Brussels Living Lab will have a special focus on Citizen & Stakeholder Engagement and behaviours.

Details of the methodology to create mobility behaviour changes in the Brussels LL are found in Annex VI.

Energy efficiency standard: The Brussels LL aims to significantly reduce energy consumption and cut CO_2 emissions by over the course of a timeframe of 5 years, transitioning the Flagship building (Figure 37) into a near zero emission building enabling the creation of a green sustainable neighbourhood. In line with the Region's objectives the building in question should produce as much energy as it consumes over a certain period while energy production must be renewable.

It is important to mention that at European level the measures are currently not sufficient to be able to achieve the carbon reduction objectives set (-40% in 2030, -80 to -95% in 2050). To bridge the gap between targets and impact of the measures taken so far new legislation and support tools, such as the Pack Energie pour PME & non-marchand | Bruxe Energy Pack[31], as well as the creation of various financing tools have been introduced by the Brussels Capital Region.

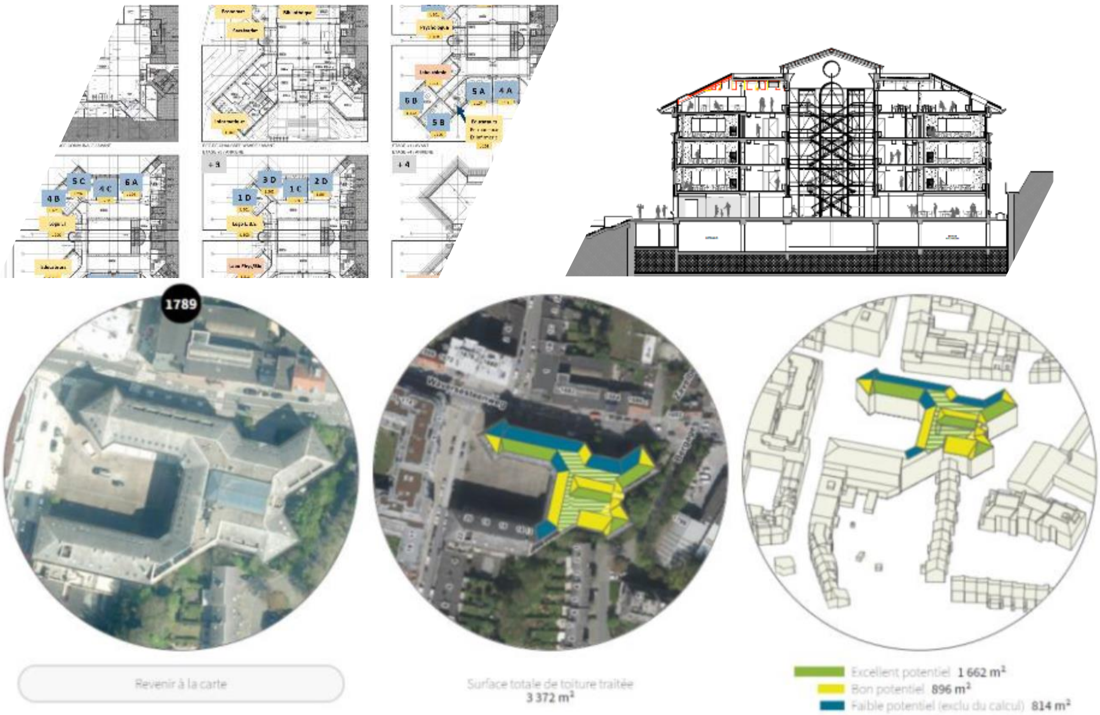


Figure 37 Flagship building – External view and characteristic floor plan(s)

Regulatory framework and technical codes: The Brussels Living Lab renovation will follow the latest environmental and regulatory requirements of the Green Deal and will be in line with the Brussels Regional Development Plan (PRDD), Auderghem Communal Mobility Plan (ACMP), Brussels Capital Region Circular Economy Strategy (BCRCES) and the Belgian Interfederal Energy Pact (BIEP), and compliant with the applicable legislation in the Brussels Capital Region and highest environmental standards.

'Arrêté Royal', covering outside fire resistance, and other regulatory constrains to carry out external and internal construction works are currently being assessed in the light of the technical plans described in this chapter and further developed moving forward.

9.1.3 Impacts and KPIs

The Brussels Living Lab is to renovate 2000 m², including ground floor office facilities and building roof, out of a total of approximately 7000 m² school area to bring the building up to the latest local and EU environmental and regulatory requirements. The specific KPIs and objectives for

the Brussels Living Lab are to be defined upon the outcome of a more detailed assessment of the baseline consumption with the installation of energy monitoring equipment by TPF (see section 9.4.1 for details). The KPIs, to be developed with WP6, will outline specific measurable targets not only for Energy Consumption, but also energy flexibility, Indoor Environmental Quality, biodiversity, Investment, circularity, inclusivity, climate resilience, mobility etc. The Brussels LL impacts defined to this point are summarised in Table 33.
Energy savings will be estimated following the IPMVP Option C (Whole Facilities). Baseline energy data for this purpose are available.

Table 33 Brussels LL impacts

Impact Category	Unit	LL Reference	LL Objective
I1. Primary energy savings	GWh/year	Energy demand: Gas consumption: 1.2 GWh/year (100% for heating purposes) Electricity consumption: 0.6 MWh/year (>50% lighting classrooms)	Savings: Flagship building: 0.65 GWh/year GBN projection: 3 GWh/year
I3. Demonstration sites that go beyond NZEB performance	-	Heating and cooling demand: 0.7 kWh/m2/year	Savings flagship building: 0.5 GWh/year Improvement related to NZEB: 40%

9.2 PROBONO LL existing infrastructure

9.2.1 Building infrastructure

ACE occupies and owns one end of a building (Figure 36, area marked in yellow). The building is characterized by a large atrium, surrounded by 4 floors rising up and surrounding the atrium (Figure 38). Most of the premises are classrooms, offices and relaxation areas used by the 540 of students and approximately 60 school staff. Two multipurpose spaces are located in the basement.

Figure 38 Atrium

The characteristics of the Brussels LL building are summarised in Table 34.

Table 34 Brussels LL building characteristics

Building name	Building use	Year of construction	Net floor area (m2)	Occupant capacity
De l’Autre Côté de l’Ecole	Education	1990	7 300	600

9.2.2 Energy infrastructure

The building relies on traditional energy sources and suppliers, such as electricity and gas. The current energy contract is with ENGIE[32], supplying ACE with green electricity. No renewable energy sources nor storage system are in place at ACE.

9.2.3 Monitoring infrastructure

Monitoring system/BEMS already in place: ACE has gradually introduced and implemented smart measuring devices for monitoring purposes in dedicated areas of the building (lighting and ventilation). Timers for heating, ventilation and lights have been installed.
Additional equipment/infrastructure needed for PROBONO: Sensors for consumption and demand measurement and response design management platform with meters for the monitoring and impact activities required.

9.2.4 Non-energy infrastructure

Blue or green spaces*:* ACE has limited green spaces on the school premises (Figure 39). The green space consists of a courtyard like back yard with incline of 50 x 50 meters, by greening a roof during previous construction works. The artificially created green space contains planted greenery, maintained by the students. The space is utilized by students during breaks for relaxation and leisure and can be turned into an amphitheatre for outdoor school events.

Figure 39 External spaces for improved microclimate and biodiversity support

Other existing infrastructure: The ACE building provides limited parking space for bikes surrounding the building envelope.
COVID plans: ACE followed the Belgian Government sanitary regulations[33] and recommendations applicable to schools in the Brussels Capital Region concerning hygiene, social distancing and telework.

9.3 Existing models, data sets and tools

Digital Twin: Social drivers are key to the purpose of the Brussels LL Digital Twin, stemming from the physical twin being a school with the mission to raise awareness of tomorrow's problems and equip the citizens of tomorrow. In line with the Green Deal and project objectives, the Brussels LL Digital Twin focuses on answering the following 2 high level needs:

1) enabling an energy community
2) prepare for a safer, cleaner and softer mobility that suits the needs of tomorrow.

Other IT tools: Objectives regarding the implementation and use of other IT tools yet to be defined in the co-creation process.

Available data sets: Consumption data on overall electricity and gas consumption available in monthly invoicing or audit reports since 2019.

Background info: An Energy QuickScan has been performed by an external evaluator in June 2021 (Table 35). Although the audit report does not address all the energy aspects in depth, it makes it possible to identify any main energy issues and give priority to those which require almost no investment and those which will reduce consumption considerably.

Table 35 Current performance of the Brussels LL building

Current performance of the building				
	bad	insufficient	sufficient	good
Facades	X			
Heating installation			X	
Sanitary hot water installation			X	
Ventilation installation			X	
Lighting		X		
Overheating	X			
Cold production		X		
Renewable energy		X		
Awareness-raising			X	

Given the size and complexity of the building envelope the energy loss of the building has not been calculated. It is to be assumed that besides the roof the building is non-insulated. On average, about 20-25% of heat loss goes through the walls, 25-30% through the roof, 10-15% through windows and doors, 10% through low floors, 10-15% through ventilation and around 5% via thermal bridges. The rest of the losses come from air renewal (ventilation) and the heating installation.

IT collaborative engagement tools and activities: Brussels municipality uses the faireBXLsamen Platform, which includes participatory processes.
https://brucity.monopinion.belgium.be/

The Brussels municipal website contains participation/ open data and other smart city resources.
https://www.brussels.be/participate
https://www.brussels.be/open-data
https://www.brussels.be/fab-lab

Stakeholder engagement in integration and cocreation: Pending completion of the stakeholder analysis (M12) and the engagement strategy (M18), it is currently possible to predict that several different engagement tools will be applied and tested, based on the scope and the goal of any specific engagement policy.

Digital Twin role in stakeholder interaction: User scenarios describing the actors, users, features of the Use Case and scope have been created within the context of D5.1.
Current stakeholder engagement: No formal stakeholder engagement has yet taken place. Informal discussions relating to aspects of the project such as establishing an energy community are ongoing.

9.4 Implementation plan for adopted scenario

The Brussels Living Lab retrofitting plans are built upon the functional construction and renovation requirements of ACE, as described earlier in 9.1. The intervention plans are the output of a co-creation process with technology providers, end-users and other direct stakeholders such as building managers, engineers, procurement professionals and architects. Upon further evaluation these plans are to be further defined, considering elements as the scope, time, impact and budget. The plans are draft plans and subject to change.

9.4.1 Selected technologies and planned interventions

The selected technologies described below are the initial selection based on draft plans, previous assessments and reports, such as the energy QuickScan audit report, and workshops with the technology providers as listed in Table 2

9.4.1.1 Energy and Water Monitoring. Provider: TPF

Based on the findings of an initial site visit conducted, and taking into account the structure of the school, the following actions form the basis for an energy monitoring plan for ACE:
Electricity: TPF is to install for each of the floors (-1 to 4) an electrical meter to create insight in the general use of electrical energy for the specific floor in concern. It is to be noted at this stage that for the level 0, since there will be a certain area that will be renewed, monitoring of electrical consumption for that area might be especially of interest. The renewal/redesign process and outcome will be monitored, with the aim to transform the area as "low emission", separately monitored. Plans to further evaluate the installation of additional electric meters to create awareness and insight for parts of the building (sport facilities, meeting rooms) from a functional point of view are at this stage still ongoing. Results of additional electric meters can be monitored and projected into the ACE entrance hall to create awareness for end users and data used as part of educational programs and support tasks in WP2.
Gas: Gas monitoring sensors will be installed to monitor general gas consumption and heat production systems. This allows to visualize future savings, and calculate real savings linked to specific investments in the heat production. The benefit of this is creating the possibility to monitor and measure the impact on gas consumption in case high efficiency heating systems would be installed at a later stage in the building lifecycle.
Water: Water monitoring sensors will be installed. Monitoring of a few strategically chosen meters supports detecting water loss and reduce water consumption (using the notifications messages form the monitoring software). Aquastop solutions to prevent leakage are currently being assessed.
Beyond monitoring: Monitoring is to be split into smaller areas by the use of zoning concepts. Other plans going beyond monitoring include:

- Install presence detectors to switch lighting on or off to reduce consumption
- Renew traditional lighting with LED to reduce consumption (impact visible on the monitoring system)
- Solar panels

- Impact campaigns with real data.

9.4.1.2 Roof solutions. Provider: Anerdgy and Soprema

The Brussels Living Lab has embarked on a journey with Anerdgy roof bot Service in M5, specialized in holistic roof concepts and planning to conduct a study on the most suitable roof solution for the Brussels Living Lab building to be implemented by Soprema, including but not limited to complete concept comparison, design and details planning through 3D CAD modelling, visualization and cost definition and forecast. The roof surface area of ACE is marked in yellow in Figure 36.

If flat roof structure accepts an additional static load of approx. 250 kg/m² it is to be considered for Soprema to install an innovative High Evaporative Green Roof solution that combines:

- New Wood Fiber insulation. Treated with biobased additives against fungi propagation.
- Partially biobased roofing membranes with root repellent additive.
- Smart & monitored irrigated green roof with the best plants cocktail for evapotranspiration.

With such roof solutions Soprema is to convert the Brussels Living Lab current flat roof into a 5th facade with improved impact on summer comfort below the flat roof, participation in heat urban island effect mitigation, lower carbon footprint for the flat roof and energy saving even in winter.

The first version of the Anerdgy roof analysis containing options, scenarios and impact assessments for the ACE roof renovation has been published and presented for validation in July 2022. The assessment is being currently being adapted based on the validation meeting feedback and is to be republished by September 2022.

9.4.1.3 Prefabricated Concrete. Provider: COWI

Further in second line, plans for the use and integration of renewable whole life cycle materials, such as sustainable prefabricated concrete by COWI, for the ACE planned staircase construction plans are still being assessed and evaluated.

9.4.1.4 Charging/battery solution. Provider: tbd

Upon the outcome of the roof analysis, and possible solar panel solutions, linked storage and charging options on individual or neighbourhood scale are to be further assessed and developed.

9.4.2 Stakeholders and their role

In the table below (Table 36) the various Brussels Living Lab internal and external stakeholders and their roles are further outlined, defined, described and categorized.

Table 36 Brussels Living Lab stakeholders and roles

Stakeholder	Role	Internal (blank)/ external ('x')
Users		
End users internal	Actively engage in the 1) co-creation 2) learning 3) stakeholder engagement and 4) disseminations of results	
End user external	Actively engage in the 1) co-creation 2) learning 3) stakeholder engagement and 4) dissemination and replication of results and findings	x
Finance sector	Actively engage in 1) access to finance and 2) policy recommendations 3) stakeholder engagement 4) dissemination and replication of results and findings	x

Stakeholder	**Role**	**Internal (blank)/ external ('x')**
Energy sector	Actively engage in 1) testing 2) monitoring 3) evaluation 4) dissemination and replication of results and findings	x
Mobility sector	Actively engage in 1) co-creation 2) implementation 3) evaluation 4) dissemination and replication of results and findings	x
Regulators	Actively engage in 1) transformation process 2) dissemination and replication of results and findings 3) policy recommendations	x
Providers		
Architect	Construction plans for retrofitting of the designated area	x
Contractor	Implementation of the construction plans for retrofitting of the designated area	x
Technology providers	Provide technology innovations and digital tools to reach KPIs and project objectives	
ESG	Provide expertise on insurance, access to sustainable finance and wide range of stakeholders for dissemination and replication purposes	
Influencers		
Community	Actively engage in the GBN co-creation process	x
School staff	Actively engage in the GBN co-creation process	
Students	Actively engage in the GBN co-creation process	
Governance		
School Association	Approval on budgetary decisions and project plans	x
Principle	Approval on budgetary decisions and project plans	
Funding Sources	Approval on budgetary decisions and project plans	x
Legal/regulatory framework	Approval project plans	x

Based on this list of stakeholders relevant to the Brussels LL, they have been mapped according to Annex II methodology. The output is displayed in Figure 40. In relation to the Brussels LL, it was agreed to split up the category of “Local business and citizens” as they will most likely play very different roles and be engaged accordingly.

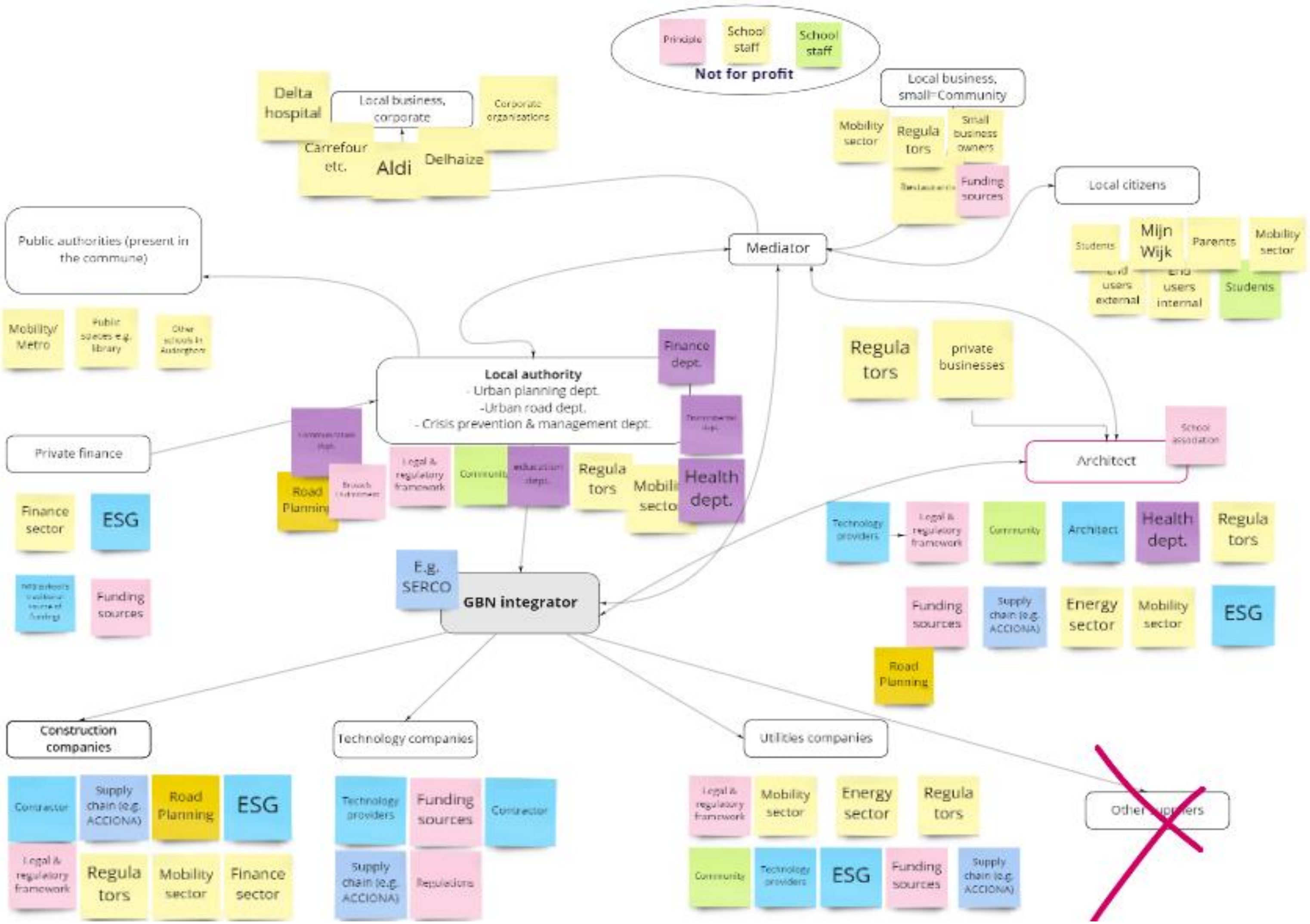


Figure 40 Stakeholder mapping for the Brussels LL

9.4.3 Design coordination

The design coordination regarding the proposed scope of work will be carried out in interaction with the contracting authority, the contractor and the Brussels LL team, including ACE (technical and functional design requirements), Anerdgy (roof planning concept) and Soprema (insulation and green roof with or without PV panels).

9.4.4 Construction elements and connections

The contracting authority, in collaboration with the contractor and the Brussels LL team, are to describe the requirements of the proposed construction elements, and connections thereof, including technical, functional, energy efficiency, regulatory and safety. The roof renovation and related energy improvements regarding the building and through the Renewable Energy Community on the neighbourhood, are the main priority of the Brussels LL construction work.

9.4.5 Tools for optimal component configuration and integration

The Brussels LL is exploring the benefits of installing monitoring equipment with TPF in the LL building for data driven decision making. The energy performance data from the sensors is to be utilised in the Digital Twin to enable a Renewable Energy Community in both energy production and consumption. Once an energy production system, such as PV panels, are in place and connected, the Brussels LL energy manager can have an operational dashboard to monitor energy performance. The Digital Twin is to serve as a One-stop Shop to help enable and build a local energy community, enable interconnection of various systems and provide information to the wider GBN through a single platform.

9.4.6 Timeplan

The works forecast and timeplan for major renovation activities for the Brussels LL are described in Figure 41 and Figure 42.

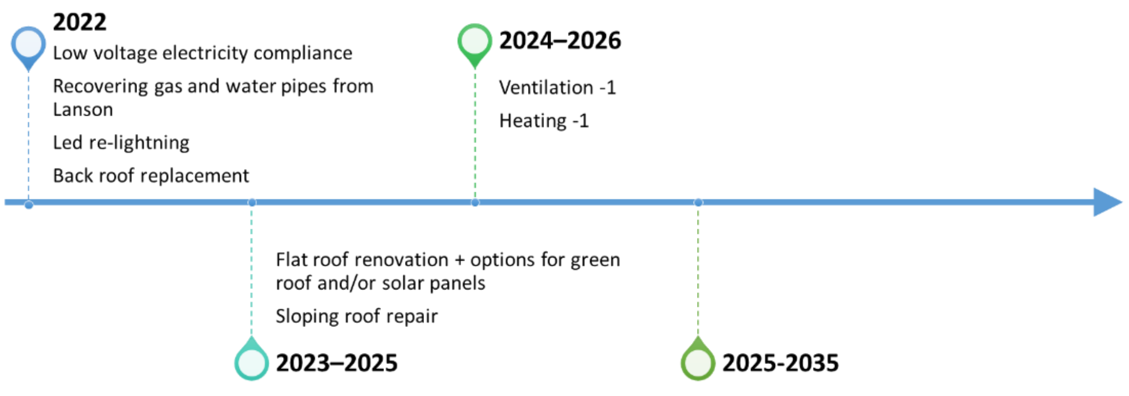


Figure 41 Works forecast

Figure 42 Timeplan for major construction/renovation activities in the Brussels LL

9.4.7 Risks and constraints

9.4.7.1 Risks

Potential risks and associated contingencies considered for the LL realisation are described in Table 37.

Table 37 Risks and associated contingencies for the Brussels LL [P=Probability, I=Impact, L=Low, M=Medium, H=High]

#	Description of risk	P	I	Proposed risk-mitigation measures
During planning/design/technology development (incl. permits and tendering process)				
1	Permit approval time for external interventions (roof)	H	H	SOPREMA experience on Belgium regulatory environment leveraged
2	Budgetary constrains	**H**	**H**	WTW engaged from early planning stage
3	Sufficient data for decision making	**L**	**M**	Sensors to be installed for rich data
4	Project scope and scale	**M**	**M**	Emphasis on stakeholder engagement
During construction/deployment/technology integration				
1	Tendering process time	M	M	ACE previous experience leveraged
2	Contractor to perform intervention using dedicated materials	**L**	**M**	SOPREMA experience with local contractors leveraged
3	Access to finance	**L**	**M**	WTW engaged from early planning stage
During monitoring, evaluation and verification/technology optimisation				
1	Sufficient data	**L**	**M**	Close collaboration with all partners for whole project life-cycle approach
2	Quality of data	**L**	**L**	Close collaboration with all partners for whole project life-cycle approach

9.4.7.2 Local constraints

Climatic: Impact of limited days of sunlight and heavy rainfall in the Belgian climate on the effectiveness of the High Evaporative Green Roof solutions and PV panels.
Technical: ACE roof and/ or access to roof to accommodate PV or Green Roof to be assessed.
Economic: ACE access to finance and budget for interventions to be established and confirmed.
Social: Business-socio-economic impacts dependent on effective engagement of stakeholders and neighborhood and communication across local language barriers.
Legal: Data protection and building regulations to be observed throughout.

9.4.8 Change management

Table 38 defines the possible changes, project stages where the change might occur, impact of the change, resources and actions regarding construction changes as considered for the Brussels LL to limit their impact on items such as costs, implementation delays, resources and KPIs.

Table 38 Brussels LL Change Management

Project stage	Change	Impact	Owner	Resources	Informed	Action
Specification	Change in construction plan	Need to change planning, design and implementation	ACE, LL leader	Technology providers, experts, relevant authorities, WP7 leader	WP and task leaders, stakeholders	Adapt planning, including timeline, budget and resources accordingly
Design	Design error	Need to redo/correct design and planning accordingly	ACE, LL Leader, architect, engineering consultant	Technology providers, experts, relevant authorities, WP7 leader	WP and task leaders, stakeholders	Involve design in the specification stage
Implementation	Unanticipated site conditions, regulatory constraints, budgetary constraints	Reassess design, redo related planning	ACE, LL Leader, subcontractors	Technology providers, experts, relevant authorities, WP7 leader	WP and task leaders, stakeholders	Quality control and governance to approve plans in the specification and design stage

The change management process model for the Brussels LL consists of the following 3 stages by Kurt Lewin [34]:

1. Identify the requirement for change (freeze)
2. Evaluate and propose the change: the evaluation considers all possible impacts that the identified change can have on other processes and resources, including of time and cost impacts (unfreeze).
3. Approve the change: Each identified change needs to go through a formal governance process (freeze).

Once the change has been approved it will be implemented as per the agreed planning. Following the implementation, the effectiveness of the change is analysed, drawing from the data collected during the change implementation.

9.4.9 Cost management

Cost management in the Brussels LL is managed by the contractors and overseen by ACE, with the support of the Brussels LL Leader (Serco). The contractors will be selected by ACE using a tendering process. Previous experience at ACE in carrying out construction work, supported by Serco's experience in running projects, will be utilised to avoid cost overruns. The Brussels LL cost management process aims to achieve the optimal cost-quality outcome for the project design, planning and implementation, including but not limited to:

1. Accurate resource planning determining resources, including manpower, materials, equipment to complete the project's activities.
2. Cost estimates for the resources needed to complete project activities associated with uncertainty.
3. Cost budgeting, including estimated cost for the project allocated separately to each of the activities.
4. Cost control identifying changes in the cost of the project, change management and evaluation of changes, desired costs, calculation of real costs, comparison of costs, evaluation of deviations in costs and recommendations for corrective action.

9.5 Business Plan and feasibility study

Table 39 provides information on the breakdown of the granted budget per item for the Brussels LL.

Table 39 Brussels LL Business Plan

Budget	Description
10,000	Hosting Services for platform components and their testing 5.000; Data collection devices (Smart Plugs, Meters and Sensors) for testing 5.000
25,000	Social science expert partner that can collaborate with SERCO in the processes and the methods for feedback collection and integration into the project (e.g. moderating focus group discussions, conducting interviews with various audiences, recruit participant panels and reporting) on the ground and in the local language.
5,013	Preparation of the construction activities in T7.5 (WP7), mainly for an architect to draw up the plans and the scope and for a contractor(s) to implement the works definition.

Besides the budget indicated above additional funding is explored, among others with Fédération Wallonie-Bruxelles, for the implementation of the construction works. Fédération Wallonie-Bruxelles is one of the three federal communities of Belgium with authority in the field of education.

10 LL6 Prague Scoping and Implementation Plan

This chapter details the Scoping and Implementation Plan for the Prague LL. It begins with an overview of the Living Lab setup and continues with the as-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure. Existing models, data sets and tools that cab be utilised in PROBONO are also described together with the first list of expected impacts and KPIs.
Next, the scenario considered for adoption (technologies, construction innovations and co-creation aspects) as well as the implementation plan are detailed along with the engineering activities necessary for the modification of the LL design according to local constraints like climatic, technical, economic, social and legal. Finally, current Business Plan details and feasibility study of design strategies are described.

10.1 Living Lab setup

10.1.1 Context – Local development plans – Key initiatives

The area of interest is located in the built-up part of the capital city of Prague, the local part of Dejvice. Dejvice is a North-West urban area of Prague built mainly in the first quarter of the 20th Century (Figure 43). Dejvice accommodates many embassies and the Czech Technical University in Prague (the oldest technical university in the Czech Republic) and University of Chemistry and Technology Prague. The Czech Technical University in Prague had 17 442 students in 2020.

Figure 43 Prague Dejvice (CTU campus) vs PROBONO LL

The CTU campus is urbanistically connected to the regulation of the newly built Dejvice district initiated at the beginning of the 1920s on the basis of a design by Antonín Engel. The object "Building B" is part of the campus of the CTU (Faculty of Civil Engineering; 3 314 students).
Location and climate: Prague (50.1035897° N, 14.3874175° E) has an oceanic climate with humid continental influences, defined as such by the 0 °C isotherm[35]. The summers are comfortable; the winters are very cold, snowy, and windy; and it is partly cloudy year-round. Over the course of the year, the temperature typically varies from -3°C to 25°C and is rarely below -12°C or above 31°C[36] (HDD 2842.60, CDD 61,9). Prevailing winds are from the West.

10.1.2 Vision and challenge to be addressed in PROBONO

Energy and resource efficient, seamless industrial construction/renovation workflows for the university campus with the use of BIM/DT/AR technologies will be implemented in the Prague LL. DTs will be utilised for the evaluation of the best solutions for energy and resource efficient building design.
Recycling/reuse of construction materials and reduction of the number of materials and components used will be sought, in order to reduce the embodied energy of buildings. The specific materials and components will be specified within the design stage with the support of Czech Technical University specialists.

Highly energy-efficient building designs adapted to local environments and climate conditions including mainly passive solutions for cooling systems (e.g. building orientation, solar shading, insulated building envelope and roof - reflects heat/lowers thermal emittance) will be applied. Sustainable, innovative zero-emission and more cost and energy efficient, renewable energy generation in the buildings combined with urban service facilities (e.g. charging facilities) and HVAC solutions will be implemented. Innovative waste heat recovery system from DHW and dual plumbing for grey and/or rainwater use is planned to be installed. Electricity generation and supply will be through small-scale PV system to partly cover electricity consumption of building. Green tariff (grid electricity from RES) supplied by utility providers will be explored.

The project will enhance comfort levels for users (students, teachers and staff). Low-energy transport promoting e-bikes, electric vehicles and scooters will be executed.

Significant energy cost savings are planned to be reached which can be an inspiration for further revitalization of campus buildings. It will serve as a replication template.

The Prague LL will focus mainly on the planning and Digital Twin development.

Neighborhood approaches to be addressed by the PROBONO LL: The Prague LL will explore solutions for further energy production and consumption reduction. Advanced traffic modelling and impact assessment will be sought and relevant policies to reduce emissions will be proposed. The resulting models will be integrated into the Digital Twin. The e-bike sharing hub powered by PVs will be built in front of the main entrance to the Faculty of Civil Engineering (Figure 44). The green areas South of Building B will be used for the Agrivoltaics living lab where students as people from the neighbourhood can see and explore what Agrivoltaics means as many do not this concept. At the North side of the Building B will be built e-cars charging station powered from the PVs.At the North side of the Building B will be built e-cars charging station powered from the PVs.
The concrete combined skeleton and wall system of the proposed building limits disposition (Figure 44). The North side is equipped with lecture rooms. The South facade hosts offices. The revitalization will be organized as Design&Build Public Procurement focusing on the following assignment:

- Lowering the energy demand to passive house U-values standards and as low as possible Embodied Energy.

- Optimization will be focused on securing high level of daylighting quality (including inner section), thermal comfort and fresh air with reasonable level of automatization (Smart Building).
- The South facade will form the major innovation sand-box. The expectations for the facade qualities involve:
    - Passive standard U-value
    - Shading the sun radiation when needed
    - Energy Production area
    - High architectural quality
- The most efficient HVAC and equipment will be chosen. Dynamic simulation of heating and cooling will be performed.
- The artificial lighting will be secured by Smart/Pro-cognitive LED lighting where suitable.
- The building will be designed as a living lab. The Digital Twin will be the virtual test bed.
- The complex quality of the design and the building itself will be secured by SBToolCZ[37] silver certification.

Scalable design of green, positive energy neighbourhoods, well embedded in the spatial, economic, technical, environmental, regulatory, and social context of the demonstration sites:

1) in line with spatial and regulatory requirements.
2) with ambition to deliver higher technical and environmental standards as required by national standards and regulations.

Energy efficiency standard: Prague LL aims to achieve better performance than the legislative requirements for nZEBs. Significant coverage of electricity consumption from locally produced renewable energy sources. Reduction of primary energy consumption by at least 30%.

Figure 44 Flagship building – External view and characteristic floor plan

Regulatory framework and technical codes:

- EU Energy Performance of Buildings Directive (2010/31/EU)
- EU Amending Energy Performance of Buildings Directive (2018/844/EU)
- EU Supplementing Regulation (EU) 2020/852
- CZ Act 406/2000

- Czech Technical Standards

10.1.3 Impacts and KPIs

The objectives of the retrofit are significant CO_2 emissions reduction, energy consumption reduction through interventions consist of installation of:

- energy efficient building envelope (passive house standards)
- ventilation system with heat/cold recovery and nanotechnology filtration
- LED pro-cognitive lighting with dimming based on outdoor light conditions
- Low energy consumption equipment
- Metering, building management system
- New efficient heating and cooling system
- Outside blinds on the South façade

and renewable energy production with Building Integrated Photovoltaics with battery storage supporting higher energy flexibility.
Other objectives are in achieving:

- Healthy Indoor comfort through:
  - ventilation system operated on CO_2 levels and temperature.
  - Pro-cognitive lighting enhancing the concentration and therefore improving learning efficiency.
- Biodiversity through
  - Green roof

The expected Prague LL impacts and KPIs will be determined once the selection of PROBONO innovations is more mature.
Energy savings will be estimated following the IPMVP Option C (Whole Facilities). The LL is in the process of determining the availability of baseline energy data for the definition of the reference model.

10.2 PROBONO LL existing infrastructure

10.2.1 Building infrastructure

The buildings of the Faculty of Civil Engineering are located at the end of the northwest axis (Figure 43). From the northeast side, the designed Building B is connected to the reconstructed building A. The land in the area under consideration slopes to the south and is bounded by existing streets (Figure 44). There is a grassed area to the south elevation. An entrance to the building is located on the west elevation.

Table 40 Prague LL building characteristics

Building name	Building use	Year of construction	Net floor area (m^2)	Heated floor area (m^2)	Fenestration area (m^2)	Occupant capacity	Renovation construction method	Possibility for BIPV integration (Y/N)
Building B	Education	1970s	25 752	26 810	2910	3500 students	prefabrication and standard renovation methods	Y

10.2.2 Energy infrastructure

Existing energy carriers, storage system and interaction with the grid: The building is connected to electricity and central heat supply system. The energy consumption is shared with other faculty buildings and is not sub-metered. The existing photovoltaic array is connected to the electrical grid for the sale of surplus production.

10.2.3 Monitoring infrastructure

Monitoring system/BEMS already in place: The very basic energy measurements are recorded, at quarter-hours max, including:

- Heat consumption
- Water consumption
- External Temperature, Relative Humidity (through local meteo station).

The Measuring and Regulation (Smart Building) after the revitalization will be supplied by information from many sensors monitoring the comfort of users and energy flows and will be an active control tool too.

10.2.4 Non-energy infrastructure

Blue or green spaces: There is a grassy area (park) at the southern facade, and the northern facade is separated from Kolejní Street by a grassy strip (Figure 45). There are no blue areas within the site.

Figure 45 External spaces for improved microclimate and biodiversity support

COVID plans: Social Distancing, remote learning.

10.3 Existing models, data sets and tools

Models already in place: CTU Campus - Faculty of Civil Engineering are using physical models of the campus that are used in their DT solutions with augmented reality. They have developed DTs for transportation to and from the faculty, monitoring energy efficiency and BIM model which will be updated directly by the future general contractor.
Digital Twin: The Prague LL will explore the solutions developed in Aarhus and will extend their DT models to cover the built infrastructure and energy flows. The Prague LL will focus mainly on the planning and Digital Twin development. Followed by the testing of the DT on the campus GBN. The plan is to verify the proposed technology and planning tools accuracy on one retrofit demonstrator.
Objectives regarding the Digital Twin technology were specified for two steps of the life cycle:

1. Planning process: optimization models to reach optimal quality of internal microclimate in the Building B while minimizing the energy consumption for various outdoor climate situations and identification of energy flows.
2. Operation time period/maintenance: real-time display of building mains and other elements while walking in the building in virtual reality goggles.

Available data sets:

- Energy data (electricity (1/4 hour max); heat (1 hour time step)) – no public access
- Weather data: weather station installed on-site – no public access
- Open data - https://opendata.praha.eu/
- Urban overheating data - https://adaptacepraha.cz/mapa-zranitelnosti-zastavek/

Background info:

- Occupancy information.
- Construction plans of the building

IT collaborative engagement tools and activities:
Part of the technical staff (faculty and rector's office) is directly involved in representing the University and the Faculty of Civil Engineering as contracting authority. The teachers as well as students will be involved in consultations.
The Digital Twin will be used as a visual tool to present the effects on microclimate and energy consumption of the Building B design.
Currently some staff from the Faculty of Civil Engineering, and rectorate and researchers from the CTU University Center for Energy Efficient Buildings (UCEEB) are already involved in the stakeholder engagement activites.
The Smart Prague website contains pages such as "I have an idea" (Mám nápad) and "I want to change that" (Chci to změnit) https://www.smartprague.eu/
Additionally, the Prague City Hall website has information on topics such as planning and territorial development, housing, education, safety, local agenda 21, business and innovation support, health and social: https://www.praha.eu/jnp/cz/index.html
Prague's geoportal website contains extensive geographical data:
https://www.geoportalpraha.cz/en
Prague's climate plan and sustainability portal: https://klima.praha.eu/en/
Prague's contact center:
https://www.praha.eu/jnp/en/about_prague/prague_contact_centre/index.html
info@praha.eu

10.4 Implementation plan for adopted scenario

This section describes the singular scenario (technologies, construction innovations and co-creation aspects) considered for implementation and execution in the Prague LL.

10.4.1 Selected technologies and planned interventions

The faculty of Civil Engineering building B will be deeply retrofitted. The load bearing structures, and some internal partition walls will stay. GBN related construction and lifecycle blueprints, processes, and controls from COWI together with recycled materials for insulation from CELSA as well as upcycling under new modern methods of construction from MM could be considered in this process. Furthermore, insulation products from SOPREMA and study of the integration of innovative roof planning concepts in the design from ANERDGY are also potential innovations.
The major part of the retrofit lays is the change of the suspended facade. The new suspended façade will be with integrated photovoltaics, quality triple-glazing and external roller blinds. The total U-value is expected to be below 0,56 W/m^{2}K. BIPV technology from Fraunhofer could be considered for the façade.
Good IEQ is one of the major goals of the retrofit. Pro-cognitive LED lighting will secure the visual comfort. The spatial acoustics will be part or the solution in the form of wall panels and thus reverberation time optimized. The quality and quantity of fresh air will be secured by a ventilation system with heat and humidity exchangers and with filtration nano-technology considering epidemiology risks.
The smartness of the building will be secured with automation of the systems based on occupancy and IEQ sensors (air temperature, relative humidity, levels of CO_2 and VOC). All variables will be monitored and recorded. A control centre with a demand response platform will be integrated. The demand response platform (predictive operation system) will be based on prediction of PV's production, energy consumption and instant capacity of the energy storage. Energy storage solutions from VISB and BEEP could be considered together with the GBN demand and response platform from TPF, STAM and TSRV.
Smart mobility will be represented by e-cars and e-bikes chargers. EV charging station and EV mobility system from BOVLABS could be considered.
An agrivoltaics living lab will contribute to electricity production from building integrated photovoltaics and to the education of visitors as teachers and students.

10.4.2 Stakeholders and their role

In the table below (Table 41) the various Prague Living Lab internal and external stakeholders and their roles are further outlined, defined, described and categorized.

Table 41 Prague Living Lab stakeholders and roles

Stakeholder	Role	Internal (blank) /external ('x')
Users		
Students	Discussion regarding solutions; users	x
Teachers	Discussion regarding solutions; users	x
Staff	Discussion regarding solutions; users	
Providers		

Stakeholder	Role	Internal (blank) /external ('x')
General Contractor	Tendering with competitive dialogue	x
Influencers		
CZGBC	www.czgbc.cz Czech Green Building Council	x
Governance		
The Czech Technical University – rector's office	Manage entire project	
The Czech Technical University – Faculty of Civil Engineering	Co-managing entire project	
The Czech Technical University- University Centre for Energy Efficient Buildings (UCEEB)	SBToolCZ management	
Technical and Testing Institute of Construction Praha (TZUS)	SBToolCZ Certification body	x

Based on this list of stakeholders relevant for the Prague LL, they have been mapped according to the methodology described in Annex II. The output is displayed in Figure 46 below. As for the neighbouring library, the residential buildings and small businesses it is still unclear how they will relate to the Prague LL. This will be clarified in the stakeholder analysis in relation to the greater vision for the Prague GBN.

10.4.3 Design coordination

The team of the Prague Living Lab will interact with contracting authority, technical supervisor and General Contractor and his design team to correctly size and prepare the installation of all the proposed scope of work.
Coordination of design with PROBONO technology providers: BIPV system (Fraunhofer Institute); insulation products (SOPREMA), roof planning concept (ANERGY), correctly size the second life batteries to meet the desired performance on the implementation scenario (BEEPLANET, VISB), demand response platform (TPF, STAM and TSRV), EV mobility system (BOVLABS).

10.4.4 Construction elements and connections

Works are intended to execute in the form of Design&Build therefore the contracting authority with the help of PROBONO team have to in-detail describe the requirements for the functionality of the building and the key parametres like energy efficiency and others.

10.4.5 Tools for optimal component configuration and integration

The existing tools, described under section 10.3, will be used in maximal manner. Tools which need to be developed are unknown at current stage of knowledge.

10.4.6 Timeplan

The timeplan for the Prague LL is detailed in Figure 47.

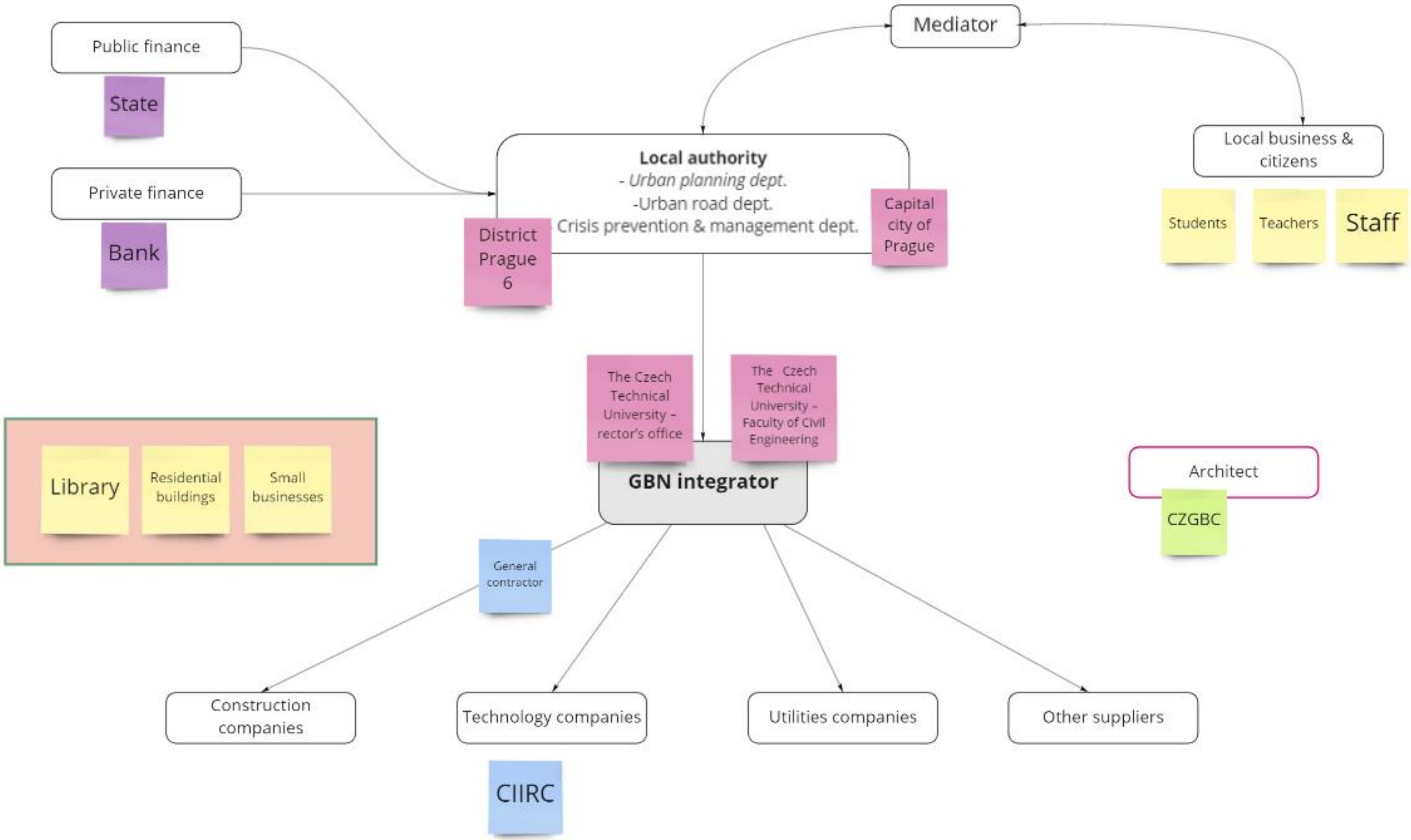


Figure 46 Stakeholder mapping for the Prague LL

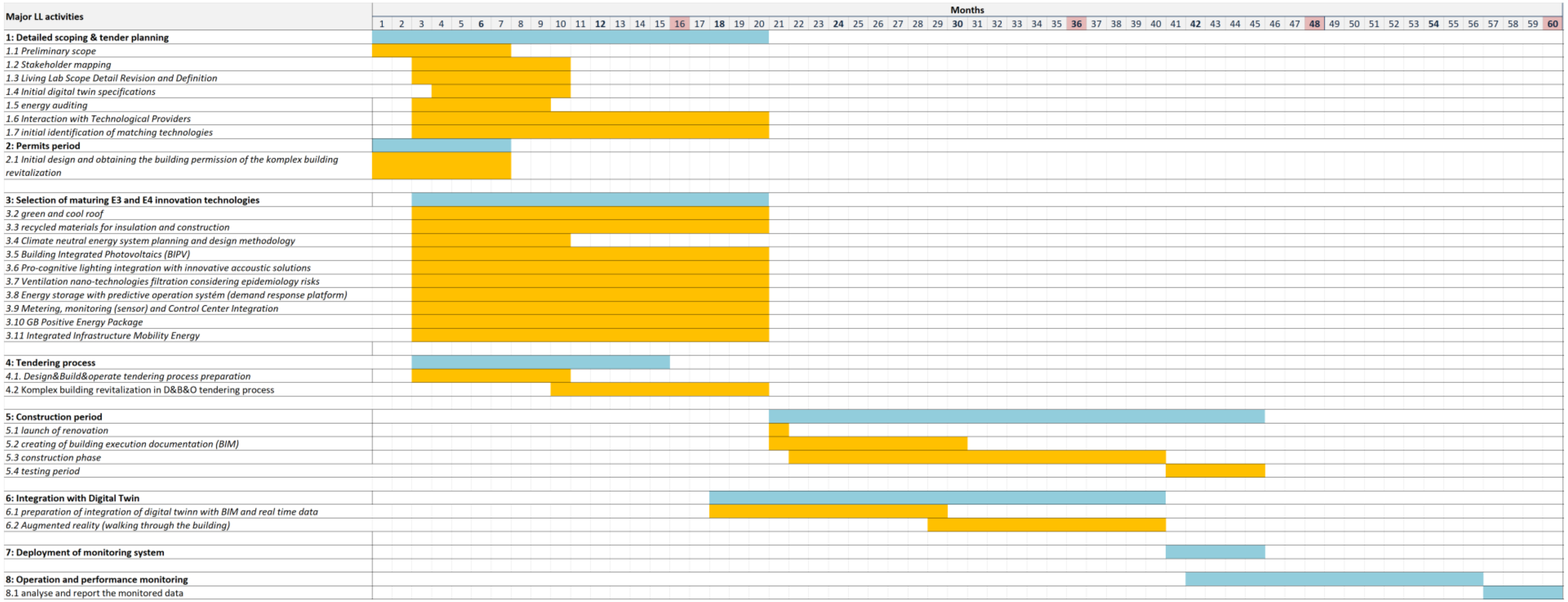


Figure 47 Prague LL timeplan

10.4.7 Risks and constraints

10.4.7.1 Risks

Potential risks and associated contingencies considered for the LL realisation are described in Table 42.

Table 42 Risks and associated contingencies for the Prague LL [P=Probability, I=Impact, L=Low, M=Medium, H=High]

#	Description of risk	P	I	Proposed risk-mitigation measures
During planning/design/technology development (incl. permits and tendering process)				
1	Permit approval time	H	H	The time reserve planning in a head
2	Fail to reach energy efficiency goals when the final project is prepared	**H**	**H**	Energy simulations and involvement of experts from the early design stages
3	Project scope and scale	**M**	**M**	Money reserve and stakeholder engagement
4	Closing the contract	**L**	**L**	Thorough discussion with all the applicants
During construction/deployment/technology integration				
1	Contractor to perform intervention using dedicated materials	M	L	Detailed technical description in the project assignment
2	Verification and technology optimisation	**M**	**M**	Technical teams involved to ensure the optimal implementation and deployment of innovations selected within Prague LL.
3	Availability of selected materials from project partners	**L**	**L**	Early assessment of technological availability and budgeting constraints
During monitoring, evaluation and verification/technology optimisation				
1	Sufficient data	**L**	**M**	Close collaboration with all partners for whole project life-cycle approach
2	Quality of data	**L**	**L**	Close collaboration with all partners for whole project life-cycle approach

10.4.7.2 Local constraints

Climatic: Cold Winters when the works cannot be executed. Insufficient solar radiation to easily fulfil the energy goals.
Technical: The construction has to be executed while the building is partly in-use.
Economic: Unforeseen changes in prices of construction components.
Social: Users complaints.
Legal: Obtaining use permission in time.

10.4.8 Change management

Changes identified as necessary by the PROBONO team will be discussed at the regular project meetings held monthly in person and bi-weekly online. Once a change has been identified, communication is made to the PROBONO project to request formal acknowledgement of the change, if necessary. The project risk register is updated to include any risk implications of the change. This risk assessment identifies any threat to deliverables, budget, timetabling, personnel, costs etc.
Once the change is identified, the Project Administrator will take responsibility for the change and tend to all relevant administration and management issues arising from the change.

10.4.9 Cost management

Costs for personnel are monitored through timekeeping logbooks by all PROBONO staff.

10.5 Business Plan and feasibility study

The revitalized Building B will have significantly lower energy consumption and at the same time providing high quality internal microclimate for users. The planned budget is 42 mil EUR and will be provided by the ministry of finance. The PROBONO budget only covers the soft cost of the preparatory activities (i.e. energy calculations, DT model) and development of the 3D virtual reality model. The outcomes form PROBONO project have to be implemented in the Contractor’s tendering assignment.

11 Conclusions

One of the primary goals of the PROBONO project is to turn six European district- and site-level areas into Green Building Neighborhoods (GBN), with positive energy balance and zero carbon emissions. Acting as Living Labs, two district level demonstrators, supported by local authorities, are located in Madrid and Dublin and four site level demonstrators, representing business/owner promoters of the green buildings and neighborhoods' transition, are located in Porto, Brussels, Aarhus and Prague.

All Living Labs will follow the common PROBONO implementation process, but each of them has a distinct ambition and scope on how to become a GBN.

A different mix of technologies, construction/renovation innovations and co-creation aspects have been developed under a single optimum adoption scenario for each Living Lab. Specific KPIs reflecting the impacts that each Living Lab envisions to achieve are currently being defined. This report provides the preliminary list of these KPIs and lists the technologies/measures of the optimum scenario that will be adopted for their achievement.

Dedicated timeplans along with the optimum implementation plans have also been developed and presented in this report. The implementation plans will continue to be updated as the planning and design work becomes more detailed.

As-is conditions for the building infrastructure, energy infrastructure, monitoring infrastructure as well as non-energy infrastructure together with information about existing models, data sets and tools and key stakeholders were collected through this report and formed input to the planning and design work of all PROBONO activities so far.

Work performed in conjunction with this report includes: the implementation aspects as they relate to GBN transition; the social dimension and the stakeholder engagements; planning and design for the GBN construction, renovation and green energy enablers; definition and development of the objectives regarding the DT technology and use cases; the LLs evaluation framework, including the list of KPIs and assessment methodologies for the impact assessment; architectural and energy audits; and, detailed design and construction plans. Dedicated reports with the outcomes of the work on each of these subjects will be produced in the following months from corresponding Work Packages.

Annex I – Common LL implementation process

1. Establish **GBN Stakeholders engagement** of key private actors (across the value chain) and public sector stakeholders and civil society to establish a Local Innovation Cluster and to assist/organize GBN co-delivery. Appoint the GBN Integrator by Month 4.
    a. Utilise WP2 outputs to guide co- design and co-creation local approach in each LL.
    b. Provide co-delivery plan and identify key co-design actions (local design workshops).
2. Prepare a long-term vision, mid-term strategic goals and targets and five-year (2023-2027) **GBN sustainability strategic plan** (Month 6)
    a. GBN sustainability strategic plan endorsed by the key stakeholders including definition of the list of the strategic lines (with projects examples) and actions according to renovation target established.
    b. Align GPN vision into municipal strategic plan.
    c. Identify sustainability and risk (urban resilience) metrics and provide Technical Report focused on ESG metrics with use of Pressure-State-Response model.
    d. Provide diagnosis detailed assessment and prioritization of main actions.
    e. Define standardization needs and local regulatory requirements utilising WP1 outputs and city masterplans available.
3. **Specify Renovation scenarios** and technical, economic, environmental implementation report of the interventions and associated timelines.
    a. Select Maturing Innovation Technologies E3 and E4 needed, utilising WP3 and WP4 outcomes (M6-15 phase 1) and the GBN DTs, Data Hub - Innovations Observatory.
    b. Organise development and deployment of Social Innovations (WP2).
    c. Specify Monitoring KPIs.
4. **Establish the GBN Design**
    a. Spatial data schema of GBN subsystems (Transportation, Buildings, Industries, Energy, Water, Waste, Land Use, Telecommunication, Healthcare, Education, Culture, Sports, Public Administration, Commerce, Social Care).
    b. Neighbourhood Sustainability Indicators Database
    c. Link with PROBONO Data Hub and Innovations Observatory
    d. Conduct Digital (Smart) Infrastructure Maturity Assessment across key infrastructure sectors and Natural Environment in the Neighbourhood.
    e. Produce detailed design of GBN using Smart Human-centred GBN Design Tools.
    f. Develop and operationalise the DT to support construction and operation.
    g. Submit designs for city/district information and approvals.
    h. **Specify Monitoring Framework**
5. **Implementation [Manufacture Construction and Operation] of the GBN LL supported by DT.**
    a. Validate the LL scenarios under at least 2 operational environments and European climates.
    b. To demonstrate the LL renovation scenarios
        i. Develop optimal implementation plan for scenarios adopted (technologies, innovations, co-creation aspects)
        ii. Define the integration needs for manufacture, construction, and operation processes.
        iii. Comply with existing National and European regulations.
        iv. Integrate the technologies and innovations under the LLs.

- v. Design the specific construction elements and connections.
- vi. Develop a tool for optimal configuration of all components.
- vii. Implement the monitoring system based on the definition set in T6.3.
- viii. Develop the executive plans following all previous constrains.

c. Identify the limitations for the technologies and innovations proposed and installed under the LL pilots to optimize their performance.
d. Validate the fulfilment of the objectives of the project.
e. Assess the performance of the integrated system.
f. Validate on-site cost advantages for LL scenarios and certificate the renovated scenarios.
g. Evaluate the GBN scenarios adopted from construction and operation point of view.
h. Provide Continuous Assessment

6. Establish sustainability and replicability and transferability actions.

a. Upskill relevant key stakeholders in the Neighbourhood on sustainability, urban resilience, smart infrastructure, and sustainability finance by a comprehensive Capacity Building Programme.
b. Prepare financing roadmaps to implement mid-term actions in the Plan.
c. Conduct Citizen satisfaction survey for project activities.
d. LL follow-up actions including local replication plans.
e. Transferability actions
f. Develop a Green Neighbourhood Sustainability Infrastructure Systems Plan (**"GNSISP"**) with vision by 2050, strategic goals by 2030 and 2040, targets by 2030, actions for 2023-2027.
    - i. District replication model analysis. Development of an implementation/replicability local plan. Replication of lessons learnt to Local Clusters and Followers.
    - ii. Transfer of LL results and knowledge to follower cluster. Technology and know-how transfer linked to the interventions developed and implemented.
    - iii. EU GBN LLs Networking.

Annex II – Stakeholder analysis methodology

The stakeholder analysis for each of the living labs in the present deliverable is based on the work done in the scope of T2.1 where a thorough analysis and mapping of the stakeholders and their role in relation to a GBN and the specific living labs are being developed. With an onset in the GBN Stakeholder map (Figure 48) the LL leaders are engaged to map out the situation in their specific LL.

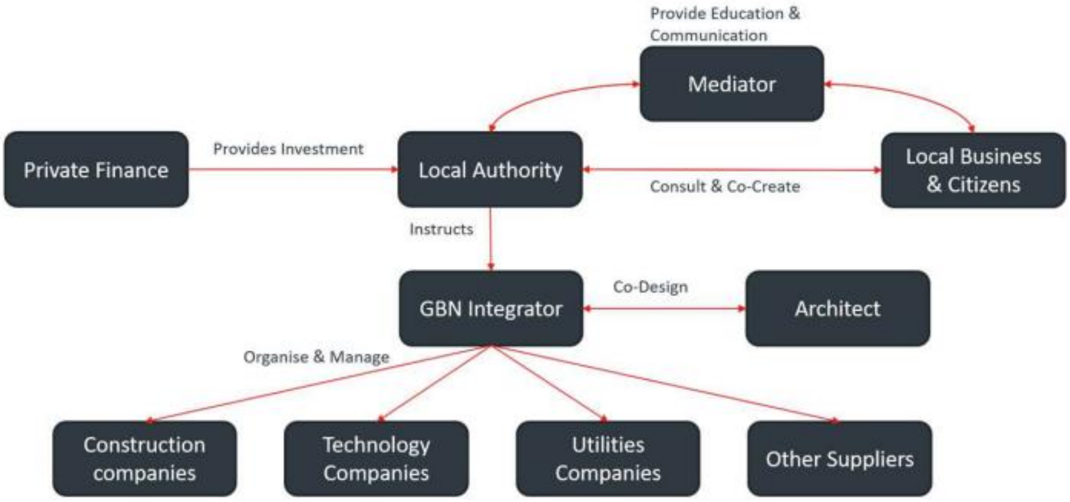


Figure 48 GBN Integrator and GBN stakeholder roles

Based on the UPIG model (Users, Providers, Influencers, Governance) LL leaders identified relevant stakeholders, either by the name of the person and organisation or if not possible, by category. The UPIG model was chosen as a tool as it invites LL leaders to think about LL stakeholders from 4 different perspectives and as such, not to oversee any. The next step was for the LL leader to place the stakeholders on the GBN stakeholder map using colour-coded sticky notes to represent the UPIG categories identified previously. These online sessions was facilitated using Miro boards (see example in Figure 49) and led by WP2 leader. During the sessions, the GBN stakeholder map was populated with the stakeholders relevant for the specific LL and in some cases, the arrows representing the influence and communication flows were re-drawn. The LL leaders were also invited to delete or add categories relevant for their LL. The output is a first assessment of the relevant stakeholders for each LL but it is worth stressing that moving on, this will be further detailed and possibly re-constructed. As such, the presentation of LL stakeholders in the present deliverable (sections 5.4.2, 6.4.2, 7.4.2, 8.4.2, 9.4.2, 10.4.2) should be considered a first assessment to be adapted throughout the duration of the project. This work will be continued in the scope of T2.1.

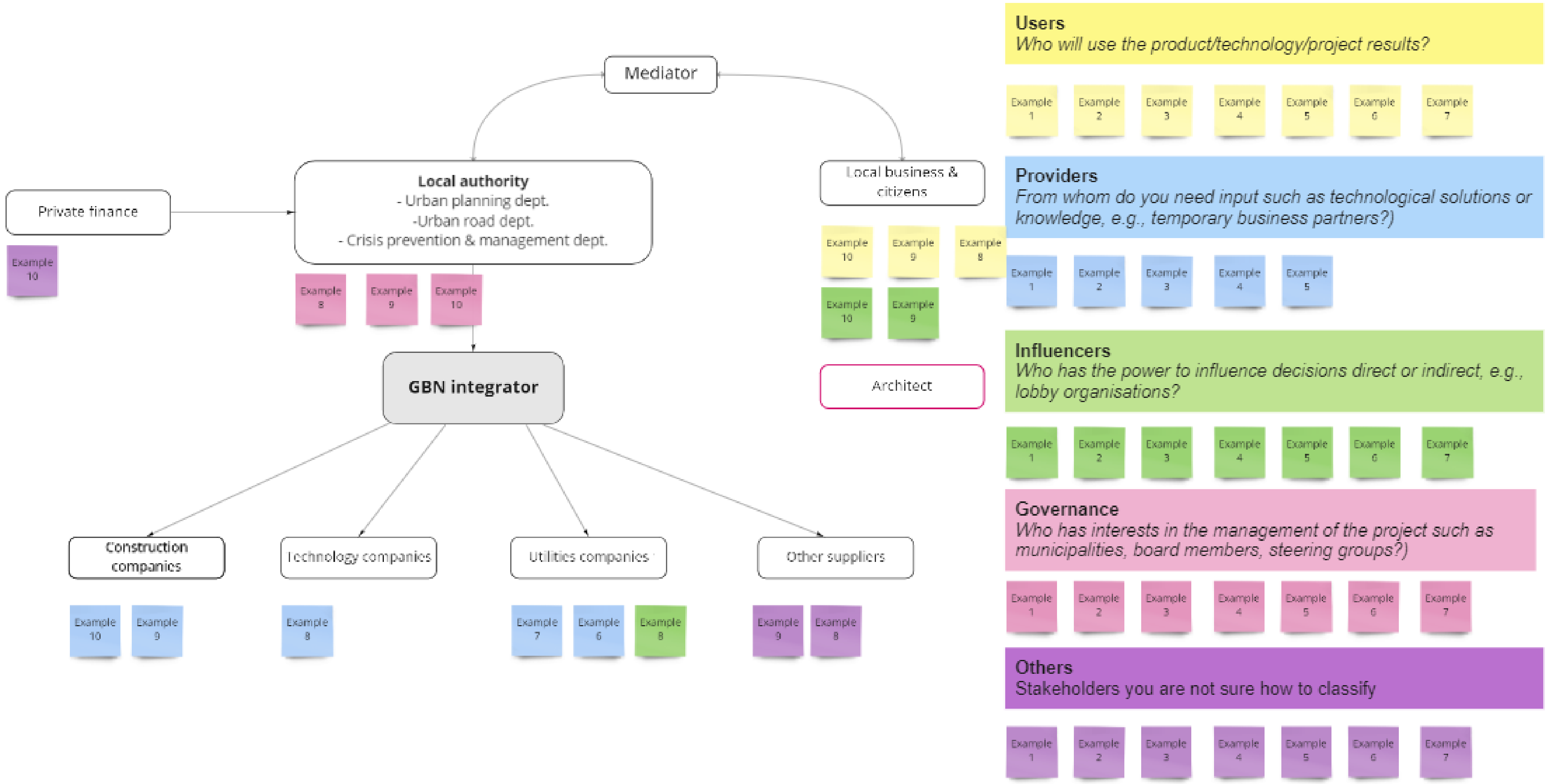


Figure 49 Miro board[38] template of the UPIB Model for the LL stakeholder analysis

Annex III – PROBONO workplan

	Workpackages and Tasks	Lead	Start (month)	End (month)
WP1	**Macro-Knowledge Base and GBN Framework**	**SERCO**	**1**	**48**
T1.1	GBN Analysis tools and decision support system	AU	1	30
T1.2	GBN Vision and KPI Formalisation	SERCO	3	32
T1.3	GBN Scenario Generation and Strategic Case Studies from LLs	SERCO	6	40
T1.4	GBN Transition Challenges, Enablers & Future Roadmap	RESAL	1	45
T1.5	GBN Integration Strategies, to manage and sustain GBN Transitions	SERCO	1	48
WP2	**Social and Behavioural Innovations**	**GECO**	**6**	**58**
T2.1	GBN and ProBono innovation value chain stakeholder mapping and analysis	GECO	6	12
T2.2	Behavioural analysis and operational best practices	EUR	6	12
T2.3	Social & behavioural innovations design and coordination	GECO	12	18
T2.4	IT Collaborative engagement tools for holistic and multi-stakeholder innovation	UCD	12	36
T2.5	Implementation of the social & behavioural innovation strategies	GECO	18	52
T2.6	Continuous calibration of the social and behavioural innovation activities	GECO	18	58
WP3	**PROBONO Smart Green Building Construction and Renovation**	**TUC**	**1**	**58**
T3.1	SOTA Reports and DT Models of Innovations for Smart Green Building Construction and Renovation	TUC	1	58
T3.2	GB Insulation and green and cool roof-centric innovations	SOP	1	52
T3.3	GBN related Construction and lifecycle blueprints, processes and controls including robots	COWI	1	52
T3.4	Building materials- upcycling	CELSA	1	52
T3.5	Social distancing (design for crowds, sensors) considering epidemiology risks	MM	1	52
T3.6	Systemic GBN Innovations multi-stakeholder	TUC	1	48
WP4	**Energy Monitoring and Clean Energy Production, Storage and Distribution**	**FRHF**	**1**	**54**
T4.1	Climate neutral energy system planning and design methodology	FRHF	1	48
T4.2	GBN demand and response platform	TPF	1	54
T4.3	Building Integrated Photovoltaics	FRHF	1	54
T4.4	PROBONO GB Positive Energy Package	ANE	1	54
T4.5	GBN Energy Storage	VISB	1	54
T4.6	Integrated Infrastructure Mobility Energy	BLABS	1	54
WP5	**Data driven human-centred GBN design and construction / renovation, operations optimisation**	**AKKA**	**1**	**54**
T5.1	GBN DT Requirements Specification and Architecture	AKKA	1	48
T5.2	GBN-DT Connectors, Common Data Space and Open Knowledge Base	KNT	3	54
T5.3	GBN-DT Global Decision Support and Optimization Platform	IRTSX	3	54
T5.4	GBN Digital Twin Deployment in LLs	AKKA	12	54
WP6	**Monitoring and evaluation of the project's Living Labs**	**CARTIF**	**1**	**60**
T6.1	Definition of the LLs Evaluation Framework	CARTIF	1	12
T6.2	Baseline calculation for the Living Labs	CARTIF	7	18
T6.3	Monitoring program definition and associated execution plan	CARTIF	12	24
T6.4	LLs impact assessment	CARTIF	12	60
WP7	**Living Labs GBN Implementation**	**INLE**	**1**	**60**
T7.1	Overall Living Labs implementation plan and Management	INLE	1	58
T7.2	Construction and Operation LL1 Dublin	UCD	4	58
T7.3	Construction and Operation LL2 Madrid	ACC	4	58
T7.4	Construction and Operation LL3 Porto	SONAE	4	58
T7.5	Construction and Operation LL4 Brussels	SERCO	4	58
T7.6	Construction and Operation LL5 Aarhus	AU	4	58
T7.7	Construction and Operation LL6 Prague	CTU	4	58
WP8	**Communication & Dissemination, Capacity Building, & Recommendations**	**SIN**	**1**	**60**
T8.1	Dissemination Strategy, Communication Plan and Activities	SIN	1	60
T8.2	PROBONO Alliance- Liaison and external cooperation	GECO	6	60
T8.3	Capacity building on project findings	UCD	12	60
T8.4	Governance and policy recommendations and drivers for GBN growth	SERCO	12	60
WP9	**Replicability, Exploitation & Commercialisation**	**PNO**	**1**	**60**
T9.1	PROBONO technologies: Market analysis	PNO	1	60
T9.2	PROBONO GBN Exploitation, Replication and Sustainability Strategy	PNO	1	60
T9.3	IP Management and IP Protection [Patent Filing]	INLE	1	60
T9.4	Standardization activities	DIN	1	60
WP10	**Project Management**	**ACC**	**1**	**60**
T10.1	Project Coordination	ACC	1	60
T10.2	Technical Management	INLE	1	60
T10.3	Quality Assurance	eBOS	1	60
T10.4	Data Management, GDPR and ethics policies	AKKA	1	60

*Legends : **MS** : Milestone, **D** : Contract Deliverable*

Annex IV – Template for LL timeplan

LL timeplan																																																												
Major LL activities	**Months**																																																										
	1	2	3	4	5	**6**	7	8	9	10	11	**12**	13	14	15	16	17	**18**	19	20	21	22	23	**24**	25	26	27	28	29	**30**	31	32	33	34	35	**36**	37	38	39	40	41	**42**	43	44	45	46	47	**48**	49	50	51	52	53	**54**	55	56	57	58	59	**60**
1: Detailed scoping & tender planning	*these are indicative. Please adapt to your schedule*																																																										
insert LL specific activity (description in this cell and duration on the right)																																																												
insert LL specific activity (description in this cell and duration on the right)																																																												
.....																																																												
e.g. Preliminary scope																																																												
e.g. Initial Digital Twin specifications																																																												
e.g. stakeholder mapping																																																												
e.g. enegy auditing																																																												
e.g. fabric testing																																																												
2: Design period																																																												
e.g. Initial designs																																																												
...																																																													
...																																																												
...																																																													
e.g Final designs																																																												
3: Selection of maturing E3 and E4 innovation technologies																																																												
e.g. initial identification of matching technologies																																																												
4: Integration with Digital Twin																																																												
5: Permits and tendering process																																																												
6: Deployment of monitoring system																																																												
7: Construction period																																																												
e.g. launch of construction/renovation																																																												
e.g. E3 technology implementation																																																												
e.g. E3 technology implementation																																																												
e.g. E4 technology implementation																																																												
e.g. E4 technology implementation																																																												
8: Commissioning																																																												
9: Operation and performance monitoring																																																												

Annex V – Expected contribution of the E3 and E4 technologies to the PROBONO Impacts

Table 43 Expected contribution of the E3 technologies to the PROBONO Impacts

PROBONO impacts	Unit	WP3 technical innovations "Construction and Renovation"									
		a) Insulation and green and cool roof solution				b) Construction and lifecycle processes				c) Building materials / Upcycliing	
		Integrated thermal & acoustic insulation	Wood fibre insulation	Cool roof membranes and bi-facial PV panels	Evaporative green roofs/walls	Modular construction	Climate change adaptation	Robots for consutruction inspection	Modular construtions workflow optimization	Recycled plastics as raw materials	Materials applied to pavements
1. Primary energy savings triggered by the project	GWh/year or %	High	High	None	None	None	None	Low	None	Low	Low
2. Investments in sustainable energy triggered by the project	million €	None	None	High	None	None	None	None	None	Low	Low
3. Demonstration sites that go beyond nearly-zero energy building performance	Not defined	High	High	None	Low	High	None	Medium	None	None	None
4. High energy performance	Not defined	High	High	None	Medium	None	None	Low	None	None	High
5. Reduction of GHG emissions for the total life-cycle	$tonCO_2$-eq/year or %	Medium	High	Medium	Medium	High	None	Medium	High	Medium	Medium
6. Reduction of the embodied energy in buildings	%	Medium	High	None	None	High	None	Medium	Medium	Low	Medium
7. Reduction of air pollutants for the total life-cycle	kg/year	None	None	None	None	Medium	Low	Low	Low	None	None
8. Potential for replicability using new or existing innovation clusters	Not defined	High	High	High	High	High	Low	High	Medium	High	Medium
9. Shortened construction/retrofitting time and cost	%	None	Medium	None	None	Medium	Medium	Medium	Medium	None	None
10. Improved indoor environmental quality (IEQ) and reduction of dust and noise	%	High	High	None	None	None	Medium	Low	None	None	None

Table 44 Expected contribution of the E4 technologies to the PROBONO Impacts

PROBONO impacts	Unit	WP4 technical innovations "Energy production, Storage and Distribution"								
		a) Climate neutral energy system		b) GBN demand and response platform	c) Buidling Integrated Photovoltaics (BIPV)		d) GB Positive Energy Package	e) Energy storage		f) Integrated Infrastructure Mobility
		Planning software for optimal energy system design	Planning guidelines	Energy system operation optimization platform	Coloured BIPV modules demonstrated	BIPV colour flexibility improved	Innovative roof planning method	Flow batteries	Second Life Batteries	V2G E-Mobility charging infrastructure with AI
1. Primary energy savings triggered by the project	GWh/year or %	High	High	High	Medium	None	Low	Medium	Medium	Medium
2. Investments in sustainable energy triggered by the project	million €	High	High	Medium	High	High	High	Medium	Medium	Medium
3. Demonstration sites that go beyond nearly-zero energy building performance	Not defined	None	None	None	None	None	None	None	None	None
4. High energy performance	Not defined	Medium	Medium	High	Medium	Medium	None	Medium	Medium	Medium
5. Reduction of GHG emissions for the total life-cycle	$tonCO_2$-eq/year or %	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low
6. Reduction of the embodied energy in buildings	%	None	None	None	None	None	None	None	Low	None
7. Reduction of air pollutants for the total life-cycle	kg/year	None	None	None	None	None	None	None	None	None
8. Potential for replicability using new or existing innovation clusters	Not defined	High	High	High	High	High	High	High	High	High
9. Shortened construction/retrofitting time and cost	%	None	None	None	None	None	None	None	None	None
10. Improved indoor environmental quality (IEQ) and reduction of dust and noise	%	None	None	None	None	None	None	None	None	None

Annex VI – Methodology for the creation of mobility behaviour changes in the Brussels LL

A change in behavior occur as a series of stages progressing reach the final stage – the new habit. Even subtle changes in attitudes and perceptions towards alternative transport modes have great potential to trigger long-term structural changes in the way we move. PROBONO aims at creating 3 major impacts in the mobility patterns in the neighborhood of the living lab, by triggering the change on 3 different community levels:

- DRIVE MODAL SHIFT - encourage people to change the transport modes they use to more sustainable ones, increase car occupancy & walkability, reduce the car dependency.
- SHIFT THE DEMAND – encourage people to travel outside of peak demand moments, distribute the demand more evenly throughout a day.
- REDUCE THE NUMBER OF TRIPS – limit the number of unnecessary trips.

Methodology to create the change

Within PROBONO the aim at triggering the behavior change is twofold: directly and indirectly (induced changed). The change is expected to occur on 3 community levels: students, employees of the school and parents of the students. The structure of expected outcome is presented below:

TRAVEL BEHAVIOR CHANGE

Direct impact:

- Students' travel behavior (with the perspective of long-term impact on their future transport choices)
- Travel behavior of school's employee

Induced impact:

- Travel behavior of parents and guardians dropping students

This approach allows to increase the magnitude of the impact. By triggering the behavior change in these 3-community level, PROBONO will be able to spread the positive effect across the entire community of Auderghem.

Assessment of the change in the Living Lab

Pre- and post-implementation mobility audit will be carried out to assess the impact achieved with the implementation of the project. Qualitative (interviews) and quantitative (surveys) data will be use for the final evaluation. To control for the possible external factors, a control school facility in a proximity of the living lab should be included with the same methodology and data collection periods.

Students, parents and school's employee will be subjected to data collection concerning their transport behavior (based on the proposed change structure above).

Changes in mobility extended to the neighborhood

PROBONO takes a holistic approach to changes it will induce by green transition of the neighborhood. Numerous KPIs are considered for the evaluation of the successful implementation of the project in the domain. Data from each level will be collected independently in two periods: reference period (before the implementation of PROBONO) and impact period (after the implementation) for comparison.

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