Deliverable D7.2 – Overall Implementation Plan and Management (II): Auditing and Monitoring Report

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DEFINITIONS

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.

Table of Contents

EXECUTIVE SUMMARY 11

1 INTRODUCTION 13

1.1 Mapping PROBONO Outputs 14

1.2 Structure of the deliverable and its relation with other work packages/deliverables 14

1.3 Relevance to the GBN concept 15

2 GBN FRAMEWORK 16

2.1 GBN Replicability, Sustainability and Transferability Strategy 17

2.1.1 Contribution of LLs to the GBN Replicability, Sustainability and Transferability Strategy 19

3 OVERALL MANAGEMENT AND MONITORING OF THE LLS AUDITING AND TRANSFERABILITY PLANS 20

3.1 LLs alignment towards a GBN sustainable plan 20

3.2 Determination of initial site conditions 21

3.2.1 Architectural audits 21

3.2.2 Energy audits 21

4 CONSOLIDATED VIEW OF LLS AUDITS AND PLANS FOR TRANSFERABILITY 22

5 DUBLIN LL AUDITS AND PLANS FOR TRANSFERABILITY 26

5.1 Dublin LL vision 26

5.2 LL transferability and contribution to the GBN concept 26

5.2.1 Dublin LL contribution to the GBN concept 26

5.2.2 Targeted impacts and KPIs 28

5.3 Prerequisites and preparatory work for implementation 29

5.3.1 Technology implementation preparation 29

5.3.2 Construction preparation 33

5.3.3 Permits acquisition 34

5.4 Initial site conditions 34

5.4.1 Results of architectural diagnosis 34

5.4.2 Results of energy audit 37

6 MADRID LL AUDITS AND PLANS FOR TRANSFERABILITY 38

6.1 LL vision 38

6.2 LL transferability and contribution to the GBN concept 38

6.2.1 Madrid LL contribution to the GBN concept 39
6.2.2 Targeted impacts and KPIs 40

6.3 Prerequisites and preparatory work for implementation 42
6.3.1 Technology implementation preparation 42
6.3.2 Construction preparation 51
6.3.3 Permits acquisition 51

6.4 Initial site conditions 52
6.4.1 Results of architectural diagnosis 52
6.4.2 Results of energy audit 54

7 PORTO LL AUDITS AND PLANS FOR TRANSFERABILITY 55

7.1 LL vision 55

7.2 LL transferability and contribution to the GBN concept 55
7.2.1 Porto LL contribution to the GBN concept 55
7.2.2 LL targeted impacts and KPIs 56

7.3 Prerequisites and preparatory work for implementation 57
7.3.1 Technology implementation preparation 58
7.3.2 Construction preparation 63
7.3.3 Permits acquisition 63

7.4 Initial site conditions 64
7.4.1 Results of architectural diagnosis 64
7.4.2 Results of energy audit 68

8 BRUSSELS LL AUDITS AND PLANS FOR TRANSFERABILITY 69

8.1 LL vision 69

8.2 LL transferability and contribution to the GBN concept 69
8.2.1 Brussels LL contribution to the GBN framework 70
8.2.2 Targeted impacts and KPIs 71

8.3 Prerequisites and preparatory work for implementation 72
8.3.1 Technology implementation preparation 72
8.3.2 Construction preparation 74
8.3.3 Permits acquisition 74

8.4 Initial site conditions 75
8.4.1 Results of architectural diagnosis 75
8.4.2 Results of energy audit 76

9 AARHUS LL AUDITS AND PLANS FOR TRANSFERABILITY 77

9.1 LL vision 77

9.2 LL transferability and contribution to the GBN concept 77
9.2.1 Aarhus LL contribution to the GBN concept 78
9.2.2 Targeted impacts and KPIs 79

9.3 Prerequisites and preparatory work for implementation 80
9.3.1 Technology implementation preparation 81
9.3.2 Construction preparation 82
9.3.3 Permits acquisition 83

9.4 Initial site conditions 83
9.4.1 Results of architectural diagnosis 83
9.4.2 Results of energy audit 86

10 PRAGUE LL AUDITS AND PLANS FOR TRANSFERABILITY 87

10.1 LL vision 87

10.2 LL transferability and contribution to the GBN concept 87
10.2.1 Prague LL contribution to GBN framework 88
10.2.2 Targeted impacts and KPIs 88

10.3 Prerequisites and preparatory work for implementation 88

10.4 Initial site conditions 89

11 CONCLUSIONS 91

REFERENCES 92

List of Figures

Figure 1: PROBONO Vision and GBN Transition Acceleration Enablers 13
Figure 2: WP1 Framework Lifecycle - D1.10 Positioning (source: D1.10) 17
Figure 3: Common LLs Implementation Process 20
Figure 4 implementation requirements for bi-directional charging in the Dublin LL 31
Figure 5: County Hall – BIPV Solar Panels 34
Figure 6: County Hall Basement - Battery Bank 35
Figure 7: County Hall Basement Mobility Hub – 2 Way EV Charging Infrastructure 35
Figure 8: Harbour Lodge Ceilings – Insulation 35
Figure 9: Harbour Square – Integration of BMS to Digital Twin 36
Figure 10: Lexicon - Integration of BMS to Digital Twin 36
Figure 11: Beaufort – Digital Twin, taking feed from existing API 37
Figure 12: Scheme of geothermal network 52
Figure 13: Location of Geothermal modules in the surrounding 52
Figure 14: Geothermal modules under the Cardenal Herrera Oria bridge 53
Figure 15: Plants of Geothermal modules housing 53
Figure 16: Section A-A' 53
Figure 17: Wells with geothermal and distribution pipes 54
Figure 18: Sonae Campus Smart Street 63
Figure 19: Maintenance building – accommodation of bi-facial PV cool roof technology 63
Figure 20: SONAE Campus and location of the Smart Street 64
Figure 21: Smart Street and the preliminary locations of some of the potential technologies to be implemented 64
Figure 22: Multi-project area 65
Figure 23: Area dedicated to mobility innovations 65

Figure 24: Logistics warehouse (Entreposto Sonae) 66
Figure 25: Multi-project area - floor –1 of the parking lot 66
Figure 26: Community garden 67
Figure 27: Houses of birds 67
Figure 28: Green wall 67
Figure 29: SONAE campus biodiversity projects 67
Figure 30: Typical ACE classroom considered for sensors installation 75
Figure 31: ACE school building roof 75
Figure 32: Green roof and solar green roof options for the school roof (roof renovation analysis by ANERDGY, Task 4.4) 76
Figure 33: Map of central Aarhus, with locations of The Kitchen 2.0, BSS, Katrinebjerg, and important surroundings 83
Figure 34: Examples of air quality simulation output and visualisations of The Kitchen 2.0 from ITA INNOVA. 84
Figure 35: Example of case model developed by COWI focusing on structural concrete analysis towards reducing embedded CO2 in the design of BSS. Documented in detail in deliverable D3.7. 84
Figure 36: Aerial view of Campus Viborg 85
Figure 37: Site layout of the Katrinebjerg project 86
Figure 38: South façade of Building B 89
Figure 39: Office plan 89
Figure 40: Basement 101 89
Figure 41: Basement 105 90

List of Tables

Table 1: Adherence to PROBONO's GA Deliverable & Task Description 14
Table 2: Summary of E3, E4 and E5 measures/technologies considered in each Living Lab 24
Table 3: Overview of Living Labs' implementation timeplan 25
Table 4: Dublin LL contribution to the GBN attributes 27
Table 5: Dublin LL targeted impacts and KPIs 29
Table 6: Selected E3, E4 and E5 technologies for the Dublin LL 29
Table 7: Dublin LL preconstruction check-list 34
Table 8: Madrid LL contribution to the GBN attributes 40
Table 9: Madrid LL targeted impacts and KPIs 41
Table 10: Public space preconstruction check list and status of activities 51
Table 11: List of permits for the District Heating and Cooling network project 51
Table 12: Porto LL contribution to the GBN attributes 56
Table 13: Porto LL targeted impacts and KPIs 57
Table 14: Selected E3, E4 and E5 technologies for the Porto LL 57
Table 15: Brussels LL contribution to the GBN attributes 71
Table 16: Brussels LL targeted impacts and KPIs 72
Table 17: implementation scenario for Brussels LL monitoring system 73
Table 18: Aarhus LL contribution to the GBN attributes 79
Table 19: Aarhus LL targeted impacts and KPIs 80
Table 20: Selected E3, E4 and E5 technologies for the Aarhus LL 80
Table 21: Preconstruction check-list for the Aarhus LL 83
Table 22: Contribution of Prague LL to the GBN concept 88

Abbreviations and Acronyms

Acronym	Description
AC	Alternating Current
ADR	Accord Dangereux Routier
API	Application Programming Interface
AR	Augmented Reality
BSS	School of Business and Social Sciences
BER	Building Energy Rating
BIM	Building Information Modelling
BIPV	Building Integrated Photovoltaics
BMS	Building Management System
BREEAM	Building Research Establishment Environmental Assessment
CAD	Computer-Aided Design
CERN	Conseil Européen pour la Recherche Nucléaire
CHP	Combined Heat and Power
DC	Direct Current
CDW	Construction and Demolition Waste
D	Deliverable
DG	Directorate General
DGEG	Direção-Geral de Energia e Geologia Portugal
DGNB	German Sustainable Building Council
DHC	District Heating and Cooling
DHN	District Heating Network
DK	Danish Krone
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
GHG	Green-House Gas
HVAC	Heating, Ventilation, and Air Conditioning
I	Impact
IEQ	Indoor Environmental Quality
IT	Information Technology
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LAN	Local Area Network
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LIDAR	Light Detection and Ranging

Acronym	Description
LL	Living Lab
M	Month
MNN	Madrid Nuevo Norte
M&V	Measurement & Verification
nb	Number
NGO	Non-Governmental Organisation
NZEB	Nearly Zero Energy Building
OCPP	Open Charge Point Protocol
P2P	Peer-to-peer
PCM	Phase Change Materials
PROBONO	The Integrator-centric approach for realising innovative energy efficient buildings in connected sustainable green neighbourhoods
PV	Photovoltaics
RA	Reclaimed Asphalt
RCA	Recycled Concrete Aggregate
REC	Renewable Energy Community
RES	Renewable Energy Systems
S2V	Solar-to-vehicle
s-LCA	social Life Cycle Assessment
SCM	Supplementary Cementitious Material
SEFA	Sustainable Energy Finance Association
SHIP	Solar Heat for Industrial Processes
ST	SubTask
T	Task
TBD	To Be Determined
TRL	Technology Readiness Level
V2G	Vehicle-to-grid
VR	Virtual Reality
WP	Work Package

Executive summary

Each of the PROBONO Living Labs has its own ambition and scope. Each of them 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.

The aim of the project is for all transferable outcomes to feed into a transferability and innovation replication framework that will enhance the transition capabilities of local communities. This framework is examined in WP1 and WP9. With regards to the Living Labs, transferability involves technology and know-how transfer linked to the interventions developed and implemented there. Transferable outcomes will be used to inform and inspire other green building neighbourhoods, stakeholders and follower clusters seeking to deploy similar solutions or interested in sustainable practices in general.

This report lays out the auditing activities carried out at pre-design phase in each of the six PROBONO Living Labs to help a) prepare the framework of indicators and criteria so as to establish sustainability and replicability and transferability actions in WP6 and WP9 and b) align Living Labs progress towards providing input for a GBN sustainable plan with actions for 2023-2027 reaching GBN long term goals for 2030 and 2040.

Living Lab specific information usable for the PROBONO GBN Exploitation, Replication and Sustainability Strategy resulting from this report are the following:

- Transferability plan for technologies and know-how
- LL contribution to the GBN concept
- Implemented measure(s)/ innovation(s) to achieve LL expect impacts in the duration of the project
- Implementation and assembly requirements
- Local constraints
- Data for future adaptation i.e. data that will be available after the implementation of the technology that will help adapt it and make it more transferable to other GBNs.
- Initial architectural diagnosis with identification of the most probable locations for the implementation of each of the technologies.

As demonstrated in this report, the Living Labs are at different maturity levels. At the moment, the list of selected technologies is considered final for Dublin, Madrid, Porto and Aarhus. By the end of 2023, as part of WP7, all Living Labs will have produced their Initial Design and Construction Plans which will also serve the refinement of decisions on technologies and the production of more detailed information about their implementation.

For efficiency purposes, all information required for the energy audit of the Living Labs was collected in the frame of Task 6.2 Baseline Evaluation. A template covering all the baseline requirements in terms of KPIs, Measurement & Verification (M&V) plans and lifecycle methods (LCA, LCC and s-LCA) from the Evaluation Framework defined in D6.1 was created with the contribution of all WP leaders. Depending on their context, each Living Lab collected the information from a different perspective (currently existing data, normative/code data, similar facilities data, etc.). In addition to this, the specific data collection about passive and active building elements and about the Life Cycle requirements depended on the specific impacts, scopes and data availability of each of the PROBONO Living Labs. The findings are reported in D6.2 Baseline Evaluation submitted on Month 16 of the project.

This deliverable is the successor of D7.1 (Overall LL Implementation Plan and Management (I): Detailed scoping and Implementation Plan) submitted on M9. The next version, D7.3, is due on M36 and will report on a) the implementation and deployment activities for the LLs monitoring system, (b) developed executive plans following all previous constrains (c) identification of

possible limitations of the technologies and innovations to optimize their performances, and (d) monitoring of compliance with existing National and European regulations and policies.

1 Introduction

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 (GBNs).
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 1).

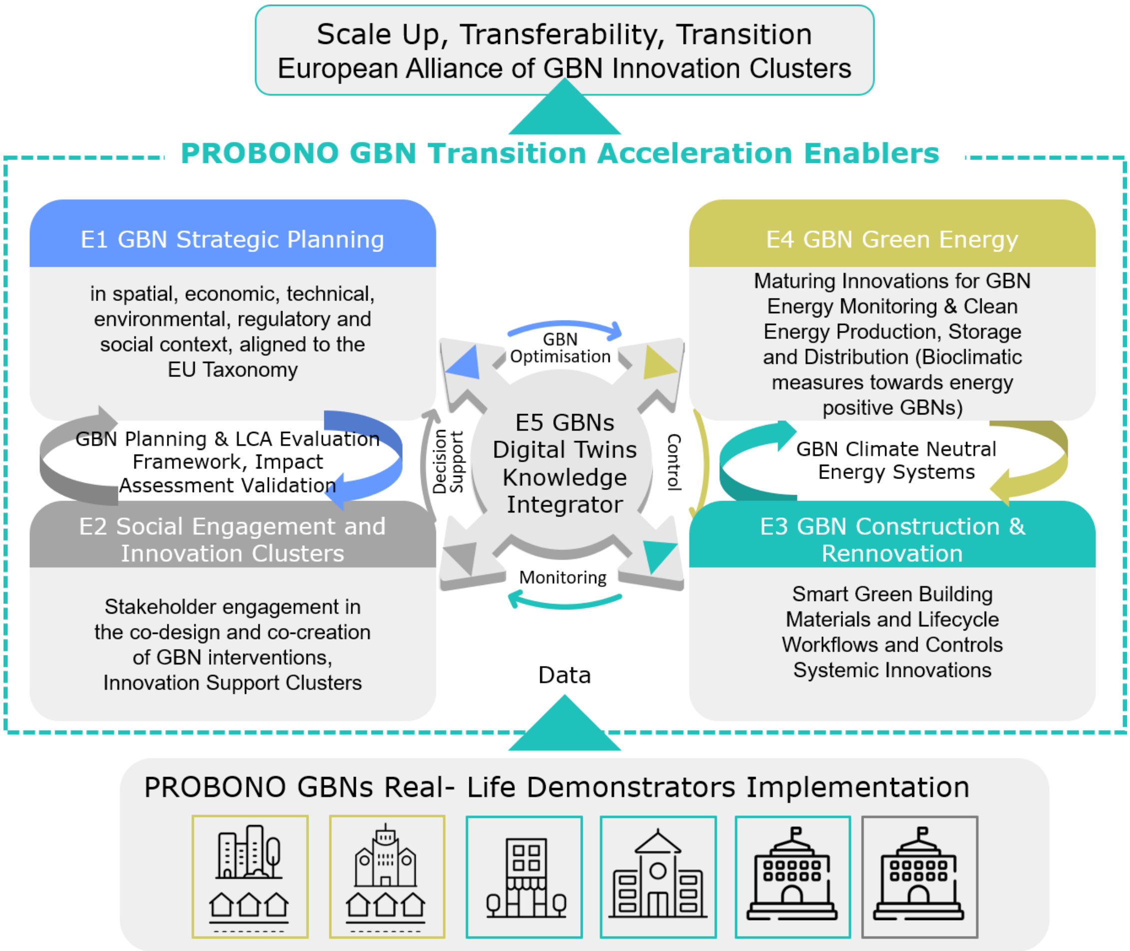


Figure 1: PROBONO Vision and GBN Transition Acceleration Enablers

The aim of this report is to help (a) Prepare a framework of indicators and criteria so to establish sustainability and replicability and transferability actions in WP6 and WP9, and (b) Align Living Labs progress towards providing input for a GBN sustainable plan with actions for 2023-2027 reaching GBN long term goals for 2030 and 2040.
It succeeds D7.1 (Overall LL Implementation Plan and Management (I): Detailed scoping and Implementation Plan) submitted on M9.

1.1 Mapping PROBONO Outputs

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

GA Component Title	GA Component Outline	Respective Document Chapter(s)	Justification
TASK			
SubTask 7.1.2 – Audits and Plan for Transferability	Prepare framework of indicators and criteria so to establish sustainability and replicability and transferability actions in WP6 and WP9.	5, 6, 7, 8, 9, 10	LL specific indicators and criteria for GBN sustainability and replicability and transferability actions.
	Align Living Labs progress towards providing input for a GBN sustainable plan with actions for 2023-2027 reaching GBN long term goals for 2030 and 2040.	5.2, 6.2, 7.2, 8.2, 9.2, 10.2	LL actions for the duration of the project (end date is Dec 2026) forming input for a GBN sustainable plan.
	Perform preparatory work for implementation, like the assembly of new technologies and/or corresponding equipment and data for future adaptations, depending on the needs of each demo-site.	5.3, 6.3, 7.3, 8.3, 9.3, 10.3	Overview of preparatory work for implementation for each LL.
	Perform a starting architectural and energy audit, in order to determine the initial site conditions.	5.4, 6.4, 7.4, 8.4, 9.4, 10.4	Results of starting architectural and energy audit for each LL.
	This pre-retrofit activity will serve to obtain the suitable information for elaborating the baseline energy consumption for the LL impact assessment activities (Task 6.4).	3.2	Overview of activities and tasks for the collection of the LLs baseline energy consumptions.
DELIVERABLE			
D7.2: Overall LL Implementation Plan and Management (II) This report formulates the findings of T7.1 and explores step/s B) Auditing & Monitoring Report.			

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

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: GBN framework.
- Chapter 3: Overall management and monitoring of the LLs auditing and transferability plans.
- Chapter 4: Consolidated view of LLs audits and plans for sustainability.
- Chapter 5 Dublin audits and plans for transferability.
- Chapter 6: Madrid audits and plans for transferability.
- Chapter 7: Porto audits and plans for transferability.
- Chapter 8: Brussels audits and plans for transferability.
- Chapter 9: Aarhus audits and plans for transferability.
- Chapter 10: Prague audits and plans for transferability.
- Chapter 11: Conclusions.

This deliverable receives input from multiple Work Packages. First of all, GBN integration strategies and transition models investigated in Task 1.5 are aimed at supporting the Living Labs to understand how their technology innovations support the journey of integration and transition towards a GBN, in advance of their testing and implementation within the LL. Concepts and assumptions outlined through T1.5, are iteratively tested and refined with the LLs during the course of the project and LL development. As part of T2.3 the LL visions and contributions to the technical, social, natural and physical attributes of a GBN are explored. The framework of IT collaboration tools described in T2.4 will also benefit all LL's and any organisation that would find collaboration tools useful, while the learnings and outcomes of the participatory mapping and planning workshop called Geodesign would benefit any organisation that would need a collaborative engagement process to solve their planning problems. In D7.2, a snapshot of how the LLs will explicitly contribute to the technical, social, natural and physical attributes of a GBN is provided.

The technology providers from WP3 and WP4 are in constant communication with the LL leaders for the selection, design and technology implementation preparation. The technology selection and implementation status on M18 of the project is summarised in this deliverable.

T6.1 has designed the PROBONO Evaluation Framework based on KPIs, M&V plans and Life Cycle methodologies, while by M16 of the project T6.2 has collected all the baseline information needed to calculate the baseline for each LL. All Work Packages, including ST7.1.2 have contributed to the template created for the collection of baseline information. Information related to energy audits is also summarised in this deliverable. The baseline information will be used in Task 6.4 (elaboration of baseline energy consumption for the LL impact assessment activities) and ST7.1.4 (performance assessment).

Finally, T9.2 developing the GBN Replicability, Sustainability and Transferability Strategy follows WP7 and supports the Living Labs to align their actions towards providing input for a GBN sustainable plan and prepare the framework of indicators and criteria so as to establish sustainability and replicability and transferability actions.

Subsequent deliverables to D7.2 include 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).

1.3 Relevance to the GBN concept

This deliverable offers a preliminary snapshot of how the LLs will explicitly contribute to the technical, social, natural and physical attributes of a GBN. This contribution will be further crystalised in the duration of the project. Furthermore, this subtask (ST7.1.2) contributes to the GBN Replicability, Sustainability and Transferability Strategy developed in Task 9.2. It describes actions until the end of the project and beyond that the LLs will be taking thus aligning with the GBN sustainable plan developed in T9.2.

2 GBN framework

A GBN is an ecosystem of different attributes, interacting within a wider System of Systems. A GBN aligns the human and natural world, reducing energy use through renewable, local sources and circular resources. A GBN aspires to a net positive impact on both humans and nature, operating in line with both the natural world and urban reality. It is an urban or rural ecosystem, that minimizes human impact on the natural world, balancing both development and Quality of Life. A GBN is a people-centered social, urban, and natural area, integrating natural and human infrastructures, through positive and sustainable collaboration.

In PROBONO, the GBN vision is realised through a set of multiple and variable indicators that will be further developed from those already set out in the PROBONO proposal, adaptable to desired use and maturity of location and context. The intent is to support the uptake and wider adoption of the PROBONO outputs and further the advancement of GBNs and their urban ecosystems in support of the Green Deal.

The different levels of a GBN are described through five principal constructs that contribute to the make-up of a GBN, that in any planned or transitioning GBN, depending upon a range of factors, may be focussed on:

1. applying **Technical** innovations to achieve its aims;
2. carrying out significant **Physical** construction works;
3. implementing a range of **Social** and people centric initiatives;
4. designing **Natural** and nature-based solutions, or;
5. including some or all of these in equal measures as a **Hybrid**.

Any innovations to be implemented, need to be considered within the framework of an overarching development and renovation plan.

The PROBONO LLs and the innovations under trial do not make GBNs in themselves. But they are an important contribution to them. These innovations and their role in the LL, in addition to having sustainability impacts, also need to be understood, planned and implemented with consideration to their wider role and contribution, both individually and collectively as part of the overarching development and renovation plan, towards achieving the *GBN Target Model* elaborated in T1.5. Such an understanding and implementation, requires a joined up and coherent view of how these and subsequent innovations, from any of the five GBN constructs are integrated into legacy and future developments.

The PROBONO Living Labs are specifically focussed on implementing and testing their chosen technology innovations to meet the project impacts and objectives, within their 'pre-PROBONO' renovation development plans. GBN integration strategies and transition models investigated in Task 1.5 are aimed at supporting the Living Labs to understand how their technology innovations support the journey of integration and transition towards a GBN, in advance of their testing and implementation within the LL. These strategies and models are, as expected, unsynchronised with the timings of the technology testing and implementation within the LLs and are therefore naturally restricted. However, concepts and assumptions outlined through T1.5, are iteratively tested and refined with the LLs during the course of the project and LL development.

D1.10 GBN Integration Strategies and Transition Models (I), the first deliverable output of T1.5 released on M12, provides the focus of Stakeholder Model with integrator role definition, sets the narrative for how it sits with the role and need for the GBN Integration Strategies and Transition Models as part of the wider WP1 Framework lifecycle (*Figure **2***).

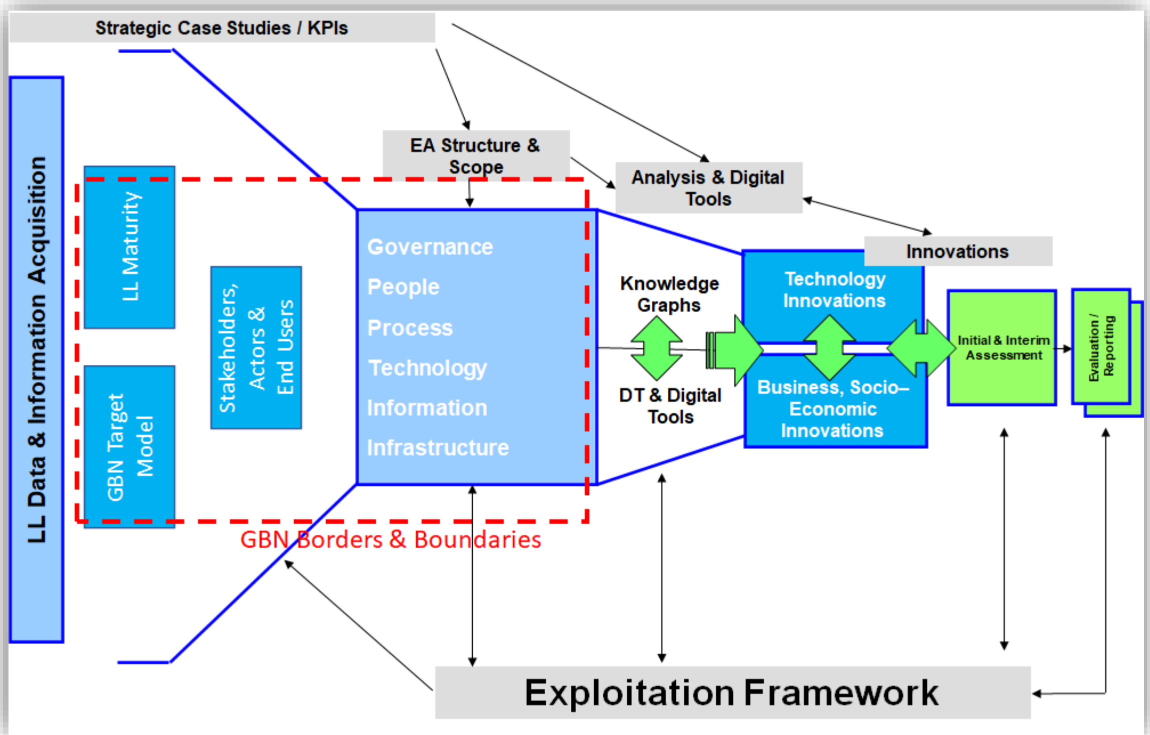


Figure 2: WP1 Framework Lifecycle - D1.10 Positioning (source: D1.10)

2.1 GBN Replicability, Sustainability and Transferability Strategy

PROBONO is generating multiple outputs that can contribute to the deployment of GBNs across Europe and globally. However, the concept and the vision of GBNs that are developed within WP1 (Macro-Knowledge Base and GBN Framework) and expanded in other parts of the project (WP2, WP8 and WP9) are the cornerstone for the future sustainability of GBNs and its transferability and replicability to other regional environments. This covers the following:

- The Green Building Neighbourhood concept – defining the baseline and the boundaries of sustainable neighbourhoods.
- The GBN Innovation Cluster – the multidisciplinary network of stakeholders at the local/regional level that will cooperate to achieve the GBN condition.
- The International GBN ecosystem – the international network of GBN Innovation Clusters facilitating the exchange of experiences and good practices on GBNs and local/regional environments which aim is to become a GBN.

These aspects have been considered at this stage in the first project exploitation assessment - publicly available deliverable D9.2 Exploitation, Replication and Sustainability (I). The proposed approach relies on using business modelling tools applied to the three elements listed above (GBN concept, GBN Innovation Cluster and the International GBN ecosystem). Considering the potential decision makers of GBNs (i.e. the urban planners in the local environments), preliminary sustainability plan focuses on developing a map of needs and the value proposition of the GBN as a concept, and the business case for the GBN Innovation Clusters in these local and regional environments.

As presented in D9.2, and aligned with other parts of the project, the core messages and the competitive advantage of PROBONO's GBN concept is:

- Reduced environmental impact of local and regional built environments, reverting into a more sustainable living based on circularity, reduced use of non-renewable sources and mainstreaming affordable renewable energy and better decision making.
- Enhanced quality of life of all stakeholders in a local or regional environment. On one hand, professional audiences and authorities, whose efforts and workloads will be streamlined in a long-term vision with clear ways to measure effectiveness of actions. On the other hand, citizens will live and make use of healthier spaces with higher value.
- Stakeholder engagement and involvement, taking part in all parts of the process based on their roles and competences; being aware of what is expected and what can be obtained, with the flexibility to be tailored to the particularities of local environments.

From here, multiple sustainability pathways can be defined and will be discussed during the project under WP9 (particularly under Task 9.2). The three pathways that are envisioned are:

- Enhancement of public knowledge.
- Standardisation.
- Development of new products and services.

As mentioned above, materialising the GBN concept requires a deeper analysis for decision making that facilitates the discussion with all the stakeholders that are part of the process of a neighbourhood to become a GBN. In this case, the Five Case Model[10] is used, since it provides a best practice guidance for the public sector to understand the viability of a project or a programme, that in the case of PROBONO refers to the deployment of the GBN and the establishment of the Innovation Clusters. These five cases cover strategic, commercial, economic, financial and managerial viability; and can be found in section 4.3.4 of D9.2.

Finally, one of the key aims of PROBONO is the creation of an international ecosystem of GBNs and lead the promotion of cohesion across multiple global initiatives with similar decarbonisation objectives of local and regional environments. By setting up and promoting the ecosystem, PROBONO will:

- Progress towards convergence and standardisation of methods and concepts for achieving climate neutrality at local and regional level, contributing significantly to national and European sustainability.
- Ensure cohesion and consistency on the messages shared towards relevant stakeholders in order to create awareness and spread the word on the GBN concept, GBN Innovation Clusters and overall sustainability lifestyles and built environment.
- Optimised efforts to reach out the targeted audience at all levels, will facilitate awareness creation and engagement.

Cooperation by now focuses on liaison activities and potential joint actions are already being discussed and planned under Task 8.2 both with: i) the 'sister projects' and; ii) other projects with thematic overlapping through the Green Deal projects call. Sustainability pathways for the liaison activities and the international ecosystem of GBNs, will be explored (as presented in D9.2). A realistic scenario would mean that:

- Sister projects are capable of coordinating their efforts and exchange best practices; ensuring cohesion and joint standardisation actions.
- Involvement of additional projects to be integrated in the loop of GBN innovation. Including other areas beyond the built environment, such as food systems or mobility and transportation.

Next steps under Task 9.2 for assessing replicability, sustainability and transferability for the LLs and the GBN concept will follow a mixed exploitation assessment of:

- PROBONO's project results, which includes all the outputs generated, in order to identify the most innovative and commercially viable ones and develop a strategy for maximising its usage during and after the project.
- Exploring ways to showcase, attract and finance the transition for the LLs and other future GBNs through the proposed models and network.

It is expected that this will allow to identify, attract and achieve KPIs on additional follower LLs and large-scale GBNs across Europe. This work to attract and engage other follower LLs and GBNs will take advantage of the work developed by the whole consortium under WP8 (Communication & Dissemination, Capacity Building, & Recommendations), following the guidelines established by D8.1 and the subsequent updates on the document D8.2, D8.3 and D8.4.

2.1.1 Contribution of LLs to the GBN Replicability, Sustainability and Transferability Strategy

This document brings together key findings generated across the PROBONO project and how this is integrated and implemented in the project LLs. Similarly, the LLs will also contribute to the future of the GBN concept, as presented below:

- GBN sustainability: as explored in D9.2, and introduced in this document, the sustainability of the GBNs will rely on the competitive advantage of the concept for all the targeted audiences, that are all stakeholders that are part of the local and/or regional communities considered.
  The implementation plan of the LLs will then provide clear pathways on how these improvements and the value proposition of the GBN will be delivered to the stakeholders, allowing to identify and iterate on the assumptions and the conclusions on all the dimensions of the GBN.
- GBN replicability and transferability: is considered to be a consequent step on ensuring the sustainability and future usage of the GBN concept. On this regard, the contribution of the findings of the living labs to standards, will ease the process of promoting success cases and accelerating innovation development and deployment in real conditions across Europe.

All these measures, will significantly contribute to facilitating interaction with future follower scenarios (at both the wider local level -like in the case of Madrid- or beyond the PROBONO project) and supporting the achievement of the ambitious expected impacts of the project.

3 Overall management and monitoring of the LLs auditing and transferability plans

The PROBONO Living Labs, although having a unique scope of activities, will use the common toolset/asset of enablers (Figure 1) and follow a common implementation approach (Figure 3). The common LL implementation process, elaborating the steps in Figure 3, is summarised in D7.1. This report is an output of the third step of the implementation process **C. Specify Renovation scenarios**.

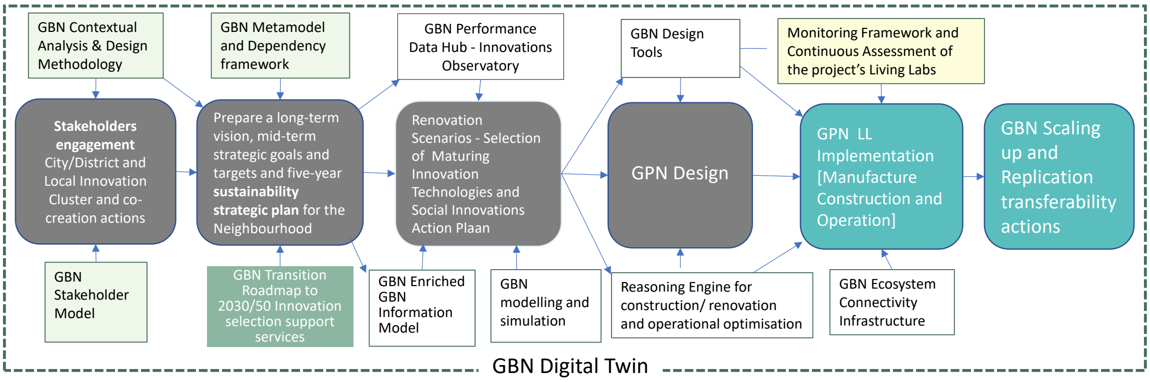


Figure 3: Common LLs Implementation Process

This chapter describes the procedures followed for the management and monitoring of the LLs auditing and transferability plans.

3.1 LLs alignment towards a GBN sustainable plan

The GBNC (Green Building Neighbourhood Committee) is a small transverse group of project partners driving the ambition of driving transformation and change in GBNs using its activities in the LLs. The GBNC meets regularly to:

- Define and promote /operationalize a unifying, simple GBN vision/ narrative for everyone.
- Share practically what GBNs are and track progress on GBN transformation.
- Acknowledge and reconcile the duality of the project scales (space and time), between the LLs approach and the GBN ambition.
- Make sure the development of the GBN concept and the PROBONO work lives on after the project ends.

The GBNC, together with WP1 and WP2, organised a GBN workshop (*Green Building Neighbourhood: What is it, how do we get there and why should we?)* with all project participants as part of the General Assembly meeting in Chania (February 2023). The objective of this workshop was to create internal alignment and disseminate the concept and approach of GBN. At the end of the GBN workshop, LLs were asked to reflect on the workshop's learnings and adapt their LL vision and how it links to a GBN as well as how their LL's overall and individual innovations contribute to a GBN. These reflections are detailed in D2.3 (Social and behavioural innovations design) and summarised in chapters 5-10 below for each LL.

Following the in-person GBN workshop in Chania a series of communications was performed between the WP1 and WP2 leaders and the LL leaders in order to provide two-way feedback on the GBN concept and how that applies to the different LLs.

In the WP7 monthly meeting of May 2023, the WP1 leader and GBNC presented to the LLs and associated PROBONO stakeholders (WP leaders, technology providers) the updates on the work of the GBN definition and explained what the expectations are from them (inputs: what/when) regarding the GBN definition in the months to come.
Finally, a workshop is organised by WP1 with LL stakeholders in September to help identify, consolidate and validate data and toolsets for Living Labs resulting from WP1.

3.2 Determination of initial site conditions

Architectural and energy audits were performed, in order to determine the initial site conditions in each LL. This pre-design activity served to obtain suitable information for elaborating the baseline energy consumption for the LL impact assessment activities (Task 6.4).

3.2.1 Architectural audits

Through Task 7.1 and this deliverable, the LLs were asked to specify the potential locations for the considered PROBONO technologies e.g. the roof, wall, basement, surroundings etc. For each case a photo and/or floor plan and or aerial view etc has been provided.

3.2.2 Energy audits

The energy audits for the Living Labs were primarily performed through Task 6.2 and are reported in detail in **D6.2 Baseline Evaluation**. The preparation of a template for the collection of feedback and requirements from all Work Packages was led by CARTIF. All Work Packages, including ST7.1.2 contributed to the preparation of this baseline data collection template. The baseline template covered all the baseline requirements in terms of KPIs, M&V plans and life-cycle methods (LCA, LCC and s-LCA) from the Evaluation Framework defined in D6.1 and will be used to create the reference scenario for each site. It is composed of 4 different sections:

1. Building info: General information for each of the buildings composing the Living Lab.
2. Envelope/ Passive building elements: Information needed for the definition of the passive elements of each building (walls, roof, floor, windows, etc.).
3. Active elements: Information on the energy active elements of the specific building (heating systems, cooling systems, ventilation systems, etc.), the energy fluxes (energy consumption from the different fuels, energy production from renewable energy sources (RES), etc.), available monitoring systems, maintenance procedures, Building Energy Rating (BER) and e-mobility aspects.
4. Life cycle assessment: Data needed for the definition of the reference conditions before applying the life cycle assessment methods.

This information was collected considering each of the LLs current conditions and data availability as well as final end-use.
The baseline information will be used in Task 6.4 (elaboration of baseline energy consumption for the LL impact assessment activities) and ST7.1.4 (performance assessment).

4 Consolidated view of LLs audits and plans for transferability

Under the shared objective of transforming into Green Building Neighbourhoods, each of the PROBONO Living Labs has its own ambition and scope. Each of them will provide both an experimentation and innovation environment and testbed for GBN innovative solutions. A different mix of technologies, design, construction/renovation innovations and co-creation aspects are being developed under a single optimum adoption scenario for each Living Lab.

All transferable outcomes of the project will feed into a transferability and innovation replication framework that will enhance the transition capabilities of local communities. With regards to the Living Labs, transferability involves technology and know-how transfer linked to the interventions developed and implemented there. Currently, the transferability plans in individual Living Labs are as follows:

- Other local authorities will benefit from the results achieved by partner DLR in the **Dublin LL** in retrofitting their current infrastructure in order to enable a GBN. They will identify the unique challenges that local authorities face in attempting to transition from fossil fuels to sustainable energy. Local authorities, as well as private property owners, who are working with protected buildings face an even greater challenge in retrofitting their buildings and achieving an energy transition. The outcomes of DLR's achievements will benefit a range of public and private entities from local authorities, to energy service providers, to construction companies in understanding what a GBN can be from a retrofitting perspective.
- The **Madrid LL** aims to develop the legal, technical, and financial framework for Madrid large scale development. A PROBONO Green Paper will analyse the misalignment between developers/investors needs in terms of meeting green financing/ESG commitments and those of the policy/legislation is in the context of new developments and/or large corporations, since the current Spanish law proposal is only targeting SMEs and renovation.

  Moreover, a Geodesign (see D2.3 for details) and a citizen survey is to be conducted in collaboration with Madrid City Council; these activities are expected to present socio-economic and legal results to be integrated in a transferability action plan promoting co-creation and design/engagement actions with potential end-users. Innovation clusters such as Madrid Subterra, ADHAC or EE platform will be utilized for support.

  If results are favourable, the large scale of the project may catalyse a private investment 45 times larger than the initial public investment in this pilot project, only in MNN.

  The business model for MNN large scale development is a public concession.
- The renewable energy community (collective auto consumption) implemented within the **Porto LL** can serve as a real test project for collaborative energy management, effective governance mechanisms, stakeholders engagement strategies, and innovative energy-sharing mechanisms, very important to the governance model inside the REC. Lessons learned and best practices can inspire other communities interested in creating their own renewable energy communities or collective auto consumption, and can better prepare other locations against the main challenges within the process of developing and implementing a REC. Collaboration with the Brussels Living Lab further enhances knowledge sharing and the potential for impactful and sustainable solutions.
- The **Brussels LL** will be the only LL in which PROBONO will be able to participate and support both the procurement process of the architect as well as the green finance fund raising process. The outcomes of both will provide rich material for knowledge and understanding in the process of sustainable renovation and GBN development. Findings and process on Finance and Investment Analysis in the context of GBNs and

sustainability renovations will be used in terms of transferability for the other LLs, in particular in Madrid, where an investors workshop is to be held to address green financing and ESG issues in relation to policy and legislation. The Brussels LL outputs in this context will also be transferred into a WP8 Green Paper on ESG and green financing.
The PROBONO project support to the procurement process of the architect will also provide valuable learning to the development of GBNs and renovation of buildings that will be included into transferability outputs.
From the energy data derived from the Sensors Monitoring and Behaviours study, energy efficiency can be understood through building use and behaviours. This study, in collaboration with technical partners in WP3 and WP4, as well as social sciences in WP2, will provide significant outputs for transfer both across PROBONO itself, as well as externally.

- A large focus point in the **Aarhus LL** is to ensure that the experience and knowledge generated through the project will be operable. This will be done through the Living Lab´s focus on development and testing in actual buildings while keeping functional architecture intact and striving towards net zero environmental sustainability. This approach encourages the translation of research into building industry-relevant products, and prototyping green deal transitional examples. One of these intended products is the delivery of an enhanced decision-support tool, directed towards the architect and engineering team in order to make better decisions earlier in the process. This will be a step towards making social sustainability (and its related values) quantifiable and showing the effect on a full university, by making it possible to embed more architectural qualities in the early phases.
The AU LL encompasses a number of buildings at various stages of renovation, that are serving as cases for "lessons learnt" as to when and how technologies can be pitched and incorporated into a running construction project.
A key indicator is the grade achieved in the green certification system DGNB-DK which is used in Denmark and Germany (in a modified form). Demonstrating that a building meets social criteria in DGNB is of particular interest, where numerous social criteria are under-specified in the certification system and thus it is not clear how a building should achieve a particular "point" nor whether this promotes more (socially) sustainable buildings.
- Sustainable renovation and GBN development are the central focal points of the refurbishment of the Building B of the Faculty of Civil Engineering at CTU in the **Prague LL**. They will serve as an exemplar and living lab for students, professionals and the general public. Transferability will lie in the adoption of complex solutions by other buildings and neighbourhoods.
An important transferable output is the White Paper on "Green Neighbourhood Sustainability Planning and Construction" which will be based on SBToolCZ methodology and is the most important part in public procurement. According to the FIDIC yellow book terminology this will be related to 'Employer's Requirements', i.e. definition of complex quality and sustainability.
The innovative application and supporting hardware of the VR application that will be developed as a digital twin allowing maintenance personnel to orientate where particular mains are located (i.e. to see them in VR while walking in the building) are ready for transfer to other buildings to complement the BIM for facility management.

The PROBONO Living Labs although having a unique scope of activities, use a common toolset/asset of enablers and follow a common implementation approach. A key output from the LLs will be an open directory of more than 40 validated maturing GBN innovations. These

have been selected to highlight the transferability nature of all innovations and benefits achieved, refined, and configured with local parameters and data sets.
The current list of maturing innovations selected by the LLs is summarised in Table 2.
The final list of selected technologies, expected to be delivered before the end of 2023, will be mapped against the pairs of sustainability indicators prescribed in ISO 37101[11], and demonstrate that PROBONO actions have a holistic GBN impact.

Living Lab	Considered measures/technologies
1 - Dublin	• Coloured façade BIPV (FRHF) • Battery bank (BEEP) • 2-way EV charging infrastructure (BLABS and CIDAUT) • Integration of BMS to Digital Twin (AKKA and DLR) • Cellulose ceiling insulation (SOP) • Green roof (SOP)
2 - Madrid	• 2nd life batteries (BEEP) • White steel slag (CELSA) • Low carbon concrete and sustainable road pavement (ACCIONA I+D) • Integrated mobility infrastructure (CIDAUT) • Recycled materials for foams and profiles (CIDAUT) • Geothermal pumps (ECOFOREST) • Preliminary Design, Detailed Design and BIM Model (IDOM)
3 - Porto	• Phase Change Materials - PCM • Smart EV Hub • Green Hydrogen production • Solar Heat for Industrial Processes - SHIP • 2nd life batteries • BIPV • Bi-facial PV • Cool roof (SOP) • Vehicle to Grid • Solar to Vehicle • Renewable energy community
4 - Brussels	• Energy and IEQ monitoring (TPF, STAM, TSRV) • Sustainable roof solutions (SOP)
5 - Aarhus	• Advanced energy storage with flow-batteries (VISB) • Sustainable insulation (SOP) • LCA calculation methods development (COWI) • Human-centred decision support tools with a focus on air quality (AU and ITA)
6 - Prague	• Digital model for ventilation assessment (ITA) • Development of human-machine interface for DT (CTU)

Table 2: Summary of E3, E4 and E5 measures/technologies considered in each Living Lab

An overview of the E3 and E4 technology implementation timeplan for each Living Lab is provided in Table 3.

DUBLIN	2022	2023				2024				2025				2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
BIPV implementation																	
Insulation implementation																	
MIcro grid implementation																	

MADRID	2022	2023				2024				2025				2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Mobilization and Preliminary works																	
Construction of District Network and urbanization (Only District Network included in PROBONO budget)																	
Commercial (offices) building construction (not included in PROBONO budget)																till	end of 2(
Residential building contruction (not included in PROBONO budget)																till	end of 2(
E3 technology implementation																starting mid 2	
E4 technology implementation																starting mid 2	

PORTO	2022	2023				2024				2025				2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.1 Renewable Energy Community Tools																	
1.2 Metering and Control Center Integration																	
2.1 Solar Heat for Industry (SHIP)																	
2.2 Green H2 Pilot																	
2.3 Solar 2V																	
2.3 2nd Life Storage																	
2.4 V2G																	
2.5 Smart EV Hub																	
2.6 PCMs																	
2.7 BIPV																	
2.8 Cool roof testing																	
3.1 Community Garden																	
3.2 House of Birds																	
3.3 Green Wall																	

BRUSSELS	2022	2023				2024				2025				2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Installation of monitoring system																	
Solar green roof installation																	

AARHUS	2022	2023				2024				2025				2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Installing VisBlue flow batteries (BSS and Viborg Campus)																	
Soprema support structure and solar panels (BSS)																	

Table 3: Overview of Living Labs' implementation timeplan

Information required for the energy audit of the Living Labs was conducted in the frame of Task 6.2 Baseline Evaluation. Depending on their context, each Living Lab collected the information from a different perspective (currently existing data, normative/code data, similar facilities data, etc.). In addition to this, the specific data collection about passive and active building elements and about the Life Cycle requirements depended on the specific impacts, scopes and data availability of each of the Living Labs within the PROBONO project. The findings are reported in D6.2 Baseline Evaluation submitted on Month 16 of the project.

5 Dublin LL audits and plans for transferability

5.1 Dublin LL vision

Imagine a neighbourhood that not only enjoys stunning views of the Dublin Bay and the Dublin Mountains but also boasts a cutting-edge energy and climate resilience system. That's the vision of the Dún-Laoghaire-Rathdown Green Building Neighbourhood.

Through a process of stakeholder and citizen engagement, combined with technological and social research, the Living Lab aims to find and implement a solution that addresses the complex challenges of energy and climate resilience in the Green Building Neighbourhood. The Living Lab's goal is to arrive at a solution that can be validated through the development of a digital twin and proven through scenario testing in a physical twin, the Harbour Lodge building.

The Mobility Hub, located in the basement of County Hall, will be the 'Energy Core' of the Green Building Neighbourhood, from where the physical infrastructure of the network will radiate outwards to the wider town and community. The roofs of County Hall and its 'mini-me' Harbour Lodge will generate energy to feed batteries in the basement that will trade energy with the e-cars and e-bikes of the Mobility Hub, as well as with the building, the national grid, and the local network of green buildings in the neighbourhood.

Moreover, a single 'Dual Distributed Network' cable system will be installed to provide power and communications interconnectivity for the neighbourhood, allowing for the expansion of the GBN network in the future.

In four years' time, visitors to Dún Laoghaire's Terrace Café on the roof of County Hall will be treated to stunning views of the water sports taking place in the harbour, Irelands National Watersports Campus, while enjoying the shade provided by a canopy of photovoltaic panels. Citizens will also have the convenience of monitoring the energy produced, stored, and used in the neighbourhood through the dlrZero app on their phones, and they will be incentivized to opt for green choices in local energy and connectivity use.

The PROBONO lead Living Lab in Dún-Laoghaire-Rathdown is an ambitious and inspiring project that offers a glimpse into a sustainable and resilient future for communities. The Living Lab's solutions can serve as a blueprint for other neighbourhoods and cities looking to enhance their energy and climate resilience while embracing a sustainable lifestyle.

5.2 LL transferability and contribution to the GBN concept

Other local authorities will benefit from the results achieved by DLR in retrofitting their current infrastructure in order to enable a GBN. They will identify with the unique challenges that local authorities face in attempting to transition from fossil fuels to sustainable energy. Local authorities, as well as private property owners, who are working with protected buildings face an even greater challenge in retrofitting their buildings and achieving an energy transition. The outcomes of DLR's achievements will benefit a range of public and private entities from local authorities, to energy service providers, to construction companies in understanding what a GBN can be from a retrofitting perspective.

The benefits to the GBN as well as the criteria for contributing to the GBN framework from the implemented innovations in the Dublin LL is further described in the next section.

5.2.1 Dublin LL contribution to the GBN concept

PROBONO is not just a single and only project at DLR in the field of green initiative, but a key component of a broader initiative that aims to create a sustainable and innovative urban environment. By integrating green technologies, smart solutions and social engagement, the LL contributes to the vision of a DLR and GBN that can serve as a model for future developments.

The DLR is also committed to sharing its knowledge and experience with other stakeholders and partners who are interested in advancing the field of green building.
The Dublin(DLR) LL will contribute to the attributes of a GBN as described in Table 4. The table also details how the implemented PROBONO innovations will contribute to the GBN framework and under what criteria.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met in order for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Technical			
Green Building Digital Twin	Software development by PROBONO partner	Open City Data. Sensors deployed.	Number of implemented DT solutions. And number of users.
Smart EV charging - Vehicle to grid integration (V2G)	Setup and installation of EV chargers capable of V2G	Space provided. Location study (where should EV point be installed).	Number of installed EV chargers. Charger use over time. Amount of energy provided back to grid.
Physical			
Building Integrated Photovoltaics (BIPV)	Setup and installation of PV on assigned buildings	Installation sites identified considering heritage protection and efficiency.	Installed PV capacity. Energy produced.
Energy insulation of Harbour Lodge building	Setup and installation of insulation layers	Project plan, thermal measurements	Cost of energy for heating and cooling.
Coloured façade BIPV	Setup and installation of coloured PV on assigned buildings	Installation sites identified considering heritage protection and efficiency.	Installed PV capacity. Energy produced.
Social			
Geodesign workshop	Workshops designed and led by UCD in collaboration with PROBONO partners (eg. DLR)	Consultation process with UCD in order to determine suitability for their goals.	Post workshop evaluation process in order to determine its success.
IT Collaborative engagement tools for holistic and multi-stakeholder innovation	List of current IT collaborative engagement tools.	List of current IT tools in use. UCD to determine suitability of tools for LL.	D2.4 has been submitted which contains this information and is available to other LL's.
Coloured façade BIPV	Tenants of Ferry Terminal building to be consulted and brought on board. Installation of BIPV on the building and measured outcomes.	DLR to provide Fraunhofer with information for Energy Planning Model.	Citizen opinion on installed BIPV (survey)
Tenant engagement strategy for retrofitting	DLR to provide a suitable retrofitting scheme for surveying. UCD to help design survey and consultation process for pre- and post-retrofit follow up.	A suitable retrofit scheme to be identified and made available by DLR. UCD to provide expertise in consultation and survey design.	Development of an engagement strategy for retrofitting social housing.

Table 4: Dublin LL contribution to the GBN attributes

5.2.2 Targeted impacts and KPIs

In the course of the project the LL impacts and KPIs will be achieved through the implemented innovations further described in chapter 5.3.

Table 5 lists the LL targeted impacts, as described in the PROBONO Evaluation Framework (D6.1), draws links and causal relationships with the integrated technologies (last column), and the retrofitted demo sites (LL objective) for each situation prior to retrofitting (LL baseline).

Impacts	Unit	Pillar	LL objective	Implemented measure(s)/ innovation(s) to achieve impact
Primary energy savings	GWh/year	Energy	Flagship Building energy demand 1.2 GWh/yr Flagship Building savings 0.8 GWh/yr	Solar PV on roof, battery bank in basement, DDN network.
Investments in sustainable energy	million €	Economic	40 million € invested	Investment via various projects and EPC's
Demonstration sites that go beyond NZEB performance	Not defined	Energy	Flagship Building specific heating and cooling demand: 40- 45 kWh/m2/year (nZEB standard for office buildings); Flagship building savings: 0.5 GWh/year Flagship building Improvement related to nZEB 40% Retrofit buildings in Ireland need to achieve a BER of B2 to achieve nZEB status. An analysis of the Harbour Lodge revealed this is possible. The aim is to achieve nZEB status for all buildings. It is expected that the Lexicon Library will be energy positive.	Various improvements made to buildings to bring them up to BER B2 status.
High energy performance	%	Energy	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%	Retrofitting scheme for social housing and improvements made to energy sources for flagship building.
Reduction of GHG emissions for the total life-cycle	tCO2-eq/year or %	Envir.	Flagship Building GHG emissions (cradle to cradle): 167 tCO2-eq/year Improvement: 60%	Shift from gas boilers to renewable energy.
Reduction of the embodied energy in buildings	GJ or %	Energy	Improvement: 20% *The embodied energy of the building will not be reduced (already constructed), the embodied energy of the retrofit will be reduced	Using sustainable materials such as recycled batteries and cellulose insulation made from recycled materials

Reduction of air pollutants for the total life-cycle	Not defined	Envir.	Not defined *Air quality will be monitored in the flagship building and inform about improvements.	Air quality monitoring
Shortened construction/retrofitting time/cost	%	Economic	Not defined *Time/cost shortening period not specified so far. Optimization of the retrofit process will enable significant time and cost reductions.	Optimizing retrofit process
Improved indoor environmental quality (IEQ)	%	Social	IAQ Improvement 30% Dust and noise issues will be reduced (Not quantified)	Improvements made through continued monitoring

Table 5: Dublin LL targeted impacts and KPIs

5.3 Prerequisites and preparatory work for implementation

The PROBONO technologies selected for implementation by the Dublin LL are summarized in Table 6. Further information about the potential locations for implementation are provided in section 5.4.
The timeplan for implementation of the different PROBONO innovations in the Dublin LL is shown in Table 3.

Technology / provider	Location
1. Coloured PV Solar Panels (external provider for PV panels, FRHF for coloured design)	Ferry Terminal facade
2. Battery Bank (BEEP)	Country Hall Basement
3. Two-Way EV Charging Infrastructure (BOVLABS and CIDAUT)	County Hall Basement Mobility Hub
4. Integration of BMS to Digital Twin (STAM, UCD)	Lexicon Library, County Hall
5. Cellulose Ceiling Insulation (SOPREMA)	Harbour Lodge Ceilings
6. Green Roof (SOPREMA)	County Hall Roof

Table 6: Selected E3, E4 and E5 technologies for the Dublin LL

Details about the implementation requirements, assembly requirements, local constraints and data for future adaptations are provided in the following sections.

5.3.1 Technology implementation preparation

5.3.1.1 <u>Coloured PV Solar Panels (MEGASOL for PV panels, FRHF for coloured design)</u>

- **<u>Implementation requirements</u>**

Technical: A survey of the southern façade of county hall will be completed by August 2023.
Consultation Process: Local authorities do not require planning permission to carry out works on its own property in Ireland. However, a public consultation process is typically required.

- **<u>Assembly requirements</u>**:

As this is a relatively new technology, we will need to ensure that a contractor capable of installing these panels are acquired.

- **<u>Local constraints</u>**:

Due to the buildings protected status, the old rooftop cannot be used for Solar PV. Only the rooftop of the newer extension.

- **Data for future adaptations**:

This will demonstrate what building Integrated solar panels can look like, particularly on a local authority building next to protected historic structures. It is hoped the coloured design will negate the often-negative feedback on Solar PV aesthetics.

5.3.1.2 Battery Bank (BEEP)

- **Implementation requirements:**

Transport and handling:

- Ensure access with a truck with more than 3500 kg and platform.
- Ensure unloading of equipment close to its location.
- Facilitate the handling of equipment from unloading to final position with the use of a pallet truck, without slope, without steps and with a sliding floor or, failing that, an overhead crane.
- Guarantee access: with doors more than 1 m wide and 2 m high.

Room conditions:

- Floor levelled and slidable with pallet truck.
- Mandatory ventilation. Minimum air exchange with the outside must be guaranteed.
- Recommended air conditioning. Suitable operating temperature for battery cells is between 10 and 30 ºC.
- Fire detection/extinguishing recommended.
- Location away from hazardous equipment or flammable products.
- Location away from water pipes, wet environments or other conduits.
- Clearance around the coil: 1.2 m in front and 30 cm on the sides. Minimum internal height of 2.2 m.

Inverter on grid batteries:

- Maximum distance between inverter and batteries 5 m linear.
- Inverter side distances 0.6 m.
- Maximum inverter height 1.5 m from the ground.
- DLR to purchase its own inverter.

Communications:

- Access to local network that allows internet access and remote access from the outside.

Electrical installation:

- Distance between current transformers and wattmeter maximum 2 m.
- Current transformers at the grid connection point supplied by the customer.

- **Assembly requirements:**

Access to the County Hall basement and EV charging infrastructure.

BEEP Scope of Work:

- Design, supply, assembly and commissioning of the battery storage system.
- Assembly and installation of battery racks.
- Supply of communications switch.
- Supply and installation of communications wiring and DC power between batteries and inverter.
- Obtaining data, performance reports, reliability, etc.

- ADR transportation.
- Unloading of equipment/Supervision of equipment unloading.

- **Local constraints:**

There are no local constraints at this present time. The location is suitable to meet the requirements of the technology.

- **Data for future adaptations:**

Data can be used to integrate with the Digital Twin.

5.3.1.3 Two Way EV Charging Infrastructure (BOVLABS and CIDAUT)

- **Implementation requirements:**

Broadly speaking, implementing bi-directional charging requires the following:

- A survey of the current EV charging infrastructure (it has been completed).
- An analysis of certain aspects (e.g. compatibility of car models currently in DLR).
- Access to internet (cloud infrastructure) and P2P blockchain to enable the energy trading between vehicles and the battery bank.

At regulatory level, a summary is given below (*Figure* ***4***):

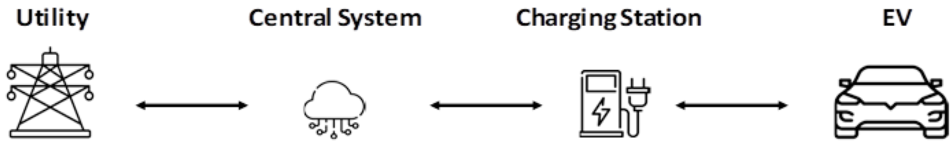


Figure 4 implementation requirements for bi-directional charging in the Dublin LL

Utility:

- IEEE 1547 – Standard for Interconnection and Interoperability of Distributed Energy Resources with associated Electric Power Systems Interfaces.
- EN 50549 – Requirements for generating plants to be connected in parallel with distribution network.

Central System:

- IEC 61850 – Communication Networks and Systems in Substations.
- IEEE 2030.5 – Standard for Smart Energy Profile Application Protocol.

Charging Station:

- OCPP2.0.1 – Communication protocol between central system and Charging Station (with this protocol it is possible to connect any central system with any charge point, regardless of the vendor).

EV:

- CHAdeMO – DC Charging Standard
- ISO 15118-20 – Road vehicles. Vehicle to grid communication interface (this protocol specifies the communication between the EV and the electric supply equipment).

- Finally, implementing V2G requires the following components:
  - Utility/ ISO control signal.
  - Utility/ ISO communication network.
  - Utility/ ISO back end billing system as CIS integration.

- EV/ data systems.
- Premise-based net metering.
- Grid-tie inverter.
- Local electromagnetic system.

- **Assembly requirements:**

– The technology must be located in the basement of County Hall where the current infrastructure is located along with the planned battery bank.
– On the other hand, bidirectional charging requires the setting up of dedicated lines which link the vehicles to the power grid.
– The electric utility must agree in implementing new technologies and business models
– EVs with V2G capabilities.

- **Local constraints:**

Bidirectional charging uses the charge stored in the vehicles to supply power during peaks. If the number of V2G compatible vehicles is low, this may lead to complete or partial discharge of a vehicle under certain conditions. One possible solution would be to develop micro grids, which allow for control of supply and demand of power.

- **Data for future adaptations:**

– Integration with Digital Twin which will display charging information on a dashboard for the users in DLR.
– Interoperability requirements.
– Cost to install. V2G is still at an early stage of development, so installation costs are high.

- **Other preparatory work needed for implementation:**

Considering the current total number of EVs with V2G capabilities, a study on stored energy that can be given it back to the grid during off-duty times.

5.3.1.4 Integration of BMS to Digital Twin (AKKA and DLR)

- **Implementation requirements:**

Access:

– Access to BMS API will be provided by DLR.
– Access to infrastructure to enable Digital Twin will be provided.

- **Assembly requirements:**

Access to building BMS.

- **Local constraints:**

Working with systems already in place in the Dublin LL.

- **Data for future adaptations:**

Demonstrates the adaptability of a Digital Twin.

5.3.1.5 Cellulose Ceiling Insulation (SOP)

- **Implementation requirements**:

Optimal Location and Access
- Access to the ceiling space required.
- Identifying optimal locations to close thermal bridges.
- Survey and photos to be provided to Soprema by DLR.
- Identification of contractors capable of working with this material.

- **Assembly requirements**:

Access to the ceiling space and the use of contractors capable of working with the material.

- **Local constraints**:

Ensuring the damp local climate does not affect the material and working with a protected heritage building.

- **Data for future adaptations**:

There are many protected heritage buildings in Ireland and across the EU that would benefit from results of this.

5.3.1.6 Technology 6: Green Roof (SOPREMA)

- **Implementation requirements:**

Refurbishment of roof membrane and greening.
- Survey
    - A survey of the current state of the County Hall roof infrastructure has been completed by DLR. The roof is load bearing but needs work in refurbishment and water proofing.
    - Further analysis of the roof to be carried out with Soprema.
    - DLR will provide more details on the roof area.
- Consultation Process
    - Local authorities do not require planning permission to carry out works on its own property in Ireland. However, a public consultation process is typically required.

- **Assembly requirements**:

Access to the roof will be provided.

- **Local constraints**:

Due to the buildings protected status and difference in design, the old rooftop cannot be used. Only the rooftop of the newer extension.

- **Data for future adaptations**:

Refurbishing the waterproof membrane and greening the roof should provide long term protection.

5.3.2 Construction preparation

The preconstruction check-list for the Dublin LL and status of each of the activities on the list is provided in Table 7.

Preconstruction Check List	Status
Site analysis	On going
Time plan	On going
Retrofit approval	On going
Finalised design documents	On going
Contractors Identified	Not started
Review of Design Document	Not started
Begin Retrofitting Activities	Not started

Table 7: Dublin LL preconstruction check-list

5.3.3 Permits acquisition

Local authorities do not require planning permission to carry out works on its own property in Ireland. However, a public consultation process is typically required.

5.4 Initial site conditions

In order to determine the initial site conditions the LL has performed a starting architectural and an energy audit. The main findings are reported below.

5.4.1 Results of architectural diagnosis

The initial architectural audit arrived to the potential locations for the considered PROBONO technologies as listed below (Figure 5 - Figure 11).

Figure 5: County Hall – BIPV Solar Panels

Figure 6: County Hall Basement - Battery Bank

Figure 7: County Hall Basement Mobility Hub – 2 Way EV Charging Infrastructure

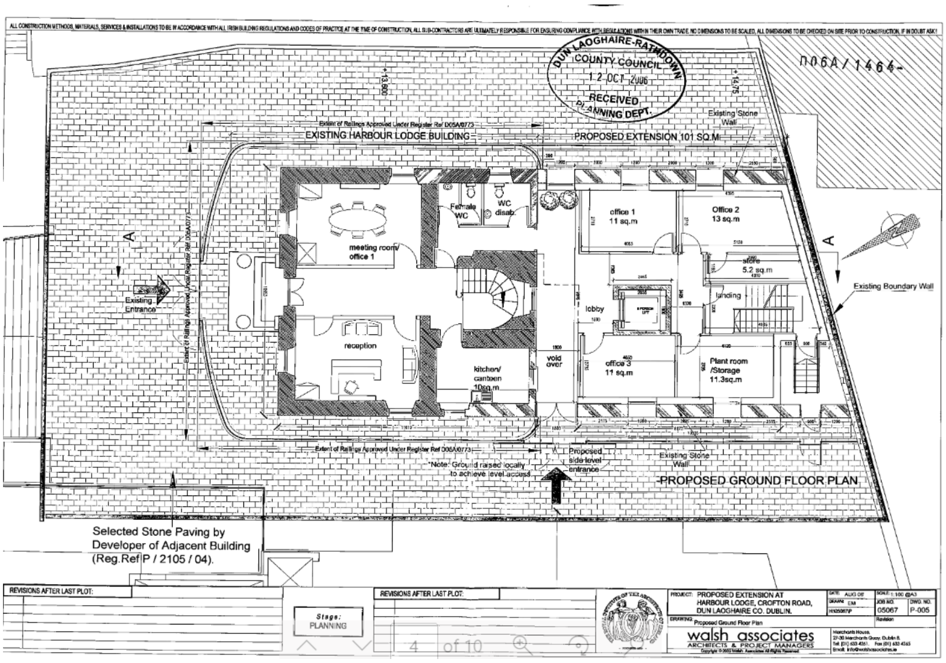


Figure 8: Harbour Lodge Ceilings – Insulation

Figure 9: Harbour Square – Integration of BMS to Digital Twin

Figure 10: Lexicon - Integration of BMS to Digital Twin

Figure 11: Beaufort – Digital Twin, taking feed from existing API

5.4.2 Results of energy audit

The scope of the Dublin LL is renovation of existing buildings that maintain their same use post-renovation. As such, the baseline definition is based on the LLs current status (pre-intervention status). The collected baseline data are reported in detail in D6.2 Baseline Evaluation, submitted on M16.

6 Madrid LL audits and plans for transferability

6.1 LL vision

The Madrid Living Lab Living Lab is set to showcase a geothermal energy model which stands as a benchmark for sustainable urban design, planning, and rehabilitation in Europe. Our model aligns perfectly with the goals of the European Green Deal, aiming to contribute to sustainability standards and design scalable solutions for urban regeneration, all based on renewable energy.
At Madrid Living Lab, our objective goes beyond achieving zero CO_2 emissions. Madrid Living Lab strives to establish a positive energy balance and create green districts that promote a brighter future for our cities. Through innovative methodologies, we empower the implementation of feasible solutions for individual buildings while also considering the broader context of green districts.
In terms of our contribution to the Green Building Neighbourhood (GBN), Madrid Living Lab excels in various aspects. From a technical standpoint, we conduct a comprehensive assessment of the GBN's current state, identifying opportunities, needs, and challenges. Our aim is to minimize environmental impacts, support preventive management, and facilitate decision-making by tailoring solutions for specific profiles. Socially, the Living Lab promotes long-term vision and resilience in the face of future regulations. It also encourages collective interests over individual ones, reduces human impacts, fosters behavioural change, decentralizes aspects of the GBN, improves quality of life, and contributes to climate energy crisis resilience while reducing fossil fuel consumption. Lastly, from a natural perspective, the Living Lab reduces material usage by implementing circularity in building materials.
Looking ahead, the Madrid Living Lab project is progressing smoothly according to our planned timeline and deliverables. We have several exciting actions underway, including the construction of a geothermal network, two buildings (a commercial building and a residential building), and urbanization projects. The thermoactivation of the buildings connected to the geothermal network is a key aspect of our vision.

6.2 LL transferability and contribution to the GBN concept

The pilot project aims to develop the legal, technical, and financial framework for Madrid large scale development. In Madrid the 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. A PROBONO Green Paper from subtask 8.4.3, will analyse the misalignment between developers/investors needs in terms of meeting green financing/ESG commitments and those of the policy/legislation is in the context of new developments and/or large corporations, since the current law proposal is only targeting SMEs and renovation.
Moreover, a Geodesign and a citizen survey is to be conducted in collaboration with Madrid City Council:

- Geodesign workshop targeting the neighbouring community of the two PROBONO buildings, including citizens, NGOs, local retailers and potential users of the office building. This workshop will focus on developing a list of requirements for the design of the buildings and their immediate surroundings. The list of requirements will be part of the procurement process for the designer.
- Citizen survey is focusing in MNN neighborhood, and the results from this assessment will be used to inform communication activities and behavioural change interventions (linking possibly to the BREEAM activities).

These activities are expected to present socio – economic and legal results to be integrated in a transferability actions plan promoting co-creation and design/engagement actions with potential end-users. Innovation clusters such as Madrid Subterra, ADHAC or EE platform will be utilized for support.
The pilot project aims to assess the viability of the project in 0,03 million of square meters but with the focus of MNN large scale development of about 3 million square meters. Thereby, if results are favourable, the large scale of the project may catalyse a private investment 45 times larger than the initial public investment in this pilot project, only in MNN.
The business model for MNN large scale development is a public concession.
The benefits to the GBN as well as the criteria for contributing to the GBN framework from the implemented innovations in the Dublin LL is further described in the next section.

6.2.1 Madrid LL contribution to the GBN concept

The Madrid LL will contribute to the attributes of a GBN as described in Table 8. The table also details how the implemented PROBONO innovations will contribute to the GBN framework and under what criteria.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met in order for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Technical			
Energy community	Green energy sources and social engagement. Green Paper	Legal barriers to be overtaken, to implement energy community	Inclusion of energy communities in municipal strategic plan with implementation in MNN.
GBN related construction and lifecycle blueprints, processes and controls	Technology providers, COWI to develop technically	Implementation of E3 and E4 innovation technologies in the MNN design	Define standardization needs and local regulatory requirements based on WP1 outputs
Physical			
Geothermal District Heating Network and Heat pumps (100kw) integration	Design and BIM model	Regulation gap for geothermal energy in DHN	Standardization of the necessary elements of Geothermal DHN. Simulation with a positive result in relation to energy baseline.
Low carbon concrete and reclaimed asphalt implementation	Processes, lab tests and monitoring by CELSA and ACCIONA I+D for substitution of DHC concrete for a low carbon concrete mixture and use of White steel slag in concrete and asphalt. The use of non-primary available resources.	The recycled aggregates should meet the technical requirements established in the Spanish standards, availability of steel slag in the local area, the lower quality of CDW recycled than natural aggregate and consequently of recycled than conventional concrete, especially with regards to durability.	Standardization of processes and requirements for recycled aggregates
Social			
Geodesign workshop	Workshop designed by SIN and UCD targeting the neighbouring community of the two PROBONO buildings	Co creation with DCN and Madrid City Council of the workshop, to achieve common view	Citizens' active participation, list of measures to be applicable in building design

Survey focused to MNN neighborhood	Survey designed by SIN and supported by Madrid City Council	Explore citizens' opinion on MNN sustainability implementation	The results from this assessment will be used to inform communication activities and behavioural change interventions (linking possibly to the BREEAM activities).
Natural			
Low carbon concrete and reclaimed asphalt implementation	Some lab testing should be performed to fully characterise the recycled and secondary materials (i.e RA, recycled aggregates, slags), as well as the novel asphalt and concrete mixes to make sure that all the technical requirements established in the National Legislation are fulfilled.	Meet requirements for use of steel in concrete and asphalt. Regulation restrictions on recycled aggregates	Positive results of lab tests for implementing of recycled aggregates to concrete.
Second life batteries	Engineering project, legalization, management and adaptation of land for the installation.	Security requirements do not allow for the batteries to be in the same room as the geothermal equipment	Adequate and proper room to place batteries
Hybrid			
GBN Energy infrastructure for mobility	Commercial bi-directional chargers suitable to be installed in the places and conditions defined within the LL	Placement of the solutions is a key element to consider (e.g on the street, in a garage, outside but in a private-access place), and the characteristics of the electric network that would feed the bi-directional chargers	Specific places identified in the urbanization project

Table 8: Madrid LL contribution to the GBN attributes

6.2.2 Targeted impacts and KPIs

In the course of the project the LL impacts and KPIs will be achieved through the implemented innovations further described in chapter 6.3.

Table ***9*** lists the LL targeted impacts, as described in the PROBONO Evaluation Framework (D6.1), and draws links and causal relationships with the integrated technologies (last column), and the retrofitted demo sites (LL objective) for each situation referring to the national regulation requirements established in the CTE, Código Técnico de la Edificación (LL baseline).

Impacts	Unit	Pillar	LL objective	Implemented measure(s)/ innovation(s) to achieve impact
Primary energy savings	GWh/year	Energy	Flagship building energy demand: 2.76 GWh/year Flagship building savings: 6.04 GWh/year	District network design.

Investments in sustainable energy	million €	Economic	Flagship building + network + thermal station 4.2 million €	Thermal station + network 2 M€. Already designed
Demonstration sites that go beyond NZEB performance. High energy performance	Not defined	Energy	Flagship Building specific heating and cooling demand: 49 kWh/m2/year Flagship Building improvement related to NZEB: 65% At least nZEB status will be achieved for all buildings (commercial and residential). The aim is to achieve Energy Positive building status for residential building.	Roof planning assessment Geothermal pumps
Reduction of GHG emissions for the total life-cycle	tCO_2-eq/year or %	Envir.	Flagship Building GHG emissions (cradle to cradle): 913.5 tCO_2-eq/year Flagship Building Improvement: 69%	Integrated mobility infrastructure White steel slag Low carbon concrete and sustainable road pavement Recycled materials for foam and profiles
Reduction of the embodied energy in buildings	GJ or %	Energy	Embodied energy in LL buildings: 500-900 GJ Improvement: 10-50% *depends on the % of components integrated	2nd life batteries module
Reduction of air pollutants for the total life-cycle	Not defined	Envir.	Not defined *Measurement will allow the measures definition and final improvement establishment	Digital twin for the construction phase. On progress
Shortened construction/retrofitting time/cost	%	Economic	Improvement in time/cost expected: 40-50%	White steel slag Low carbon concrete and sustainable road pavement Recycled materials for foam and profiles
Improved indoor environmental quality (IEQ) Reduction of dust and noise during retrofitting	%	Social	Improvement IEQ: 30-40% Improvement Dust and noise during retrofitting: 30%	Digital twin for the construction phase. in progress

Table 9: Madrid LL targeted impacts and KPIs

6.3 Prerequisites and preparatory work for implementation

The PROBONO technologies selected according to the overall development plan of Las Tablas are implemented in the following areas:

- Geothermal District Heating Network:
  - Preliminary Design, Detailed Design and BIM Model (IDOM)
  - Geothermal pumps (ECOFOREST)
- Urbanization project
  - White steel slag (CELSA)
  - Low carbon concrete and sustainable road pavement (ACCIONA I+D)
  - Integrated mobility infrastructure study (CIDAUT)
  - DT for demolition and construction phase (USC)
- Residential and office Buildings:
  - Second Life batteries (BEEP)
  - Roof planning assessment (ANERDGY)
  - Recycled materials for foams and profiles (CIDAUT)

Further information about the implementation areas for the DHN and urbanization project is provided in section 6.4.

The timeplan for implementation of the different PROBONO innovations in the Madrid LL is shown in Table 3. It is important to mention that the construction project designs are currently being carried out (2022-2023), the tendering process will be carried out between 2023-2024, the construction of the district heating and cooling network will be carried out between 2025-2026 and finally the building will be thermoactivated outside of the duration of the project. Contingencies for the delays in the thermoactivation are currently being considered. The updated plan will be decided and integrated in the Madrid LL activities before the end of 2023.

In terms of legislative framework, it is worth mentioning that the law related to the geothermal network, was established in 1973 (Ley 22/1973, 21 de Julio, de Minas), and the geothermal authorization procedure would take 2 years, by following this regulation. For this reason, the Madrid LL partners (DCN, ACCIONA, Municipality of Madrid) are working on justifying how to avoid this obsolete regulation in order to speed up its implementation.

Details about the implementation requirements, assembly requirements, local constraints and data for future adaptations are provided in the following sections.

6.3.1 Technology implementation preparation

6.3.1.1 Preliminary Design, Detailed Design and BIM Model of geothermal District Heating Network (IDOM)

- **Implementation requirements**:

National regulation does not provide any support for the geothermal energy in District Heating and Cooling Network. So the challenge is to prepare a design that can be approved by the local City Council. Moreover, from the point of view of costs, the project aims to develop a minimum number of boreholes in public spaces and the rest of the boreholes will be executed and invested by the private developer of each building.

- **Assembly requirements**:

Preliminary and Detailed Design
Energy recovery with direct connection of different heat pumps
Distributed geothermal exchangers, using public land.

Direct connection to buildings that use low temperature systems like TABS or underfloor heating/cooling systems.
Organic growth of the network in mini loops connected two by two.

- **Local constraints**:

As the geothermal network is going to be implemented in public space, agreement with the local authorities is fundamental. The solution has been co-design with Madrid city council.
Delay for the permit for execution the geothermal boreholes: Crea Madrid Nuevo Norte is exploring a potential exception of the mining law.

- **Data for future adaptations**:

Technical and costs information that can support in filling the gap in national regulation on geothermal energy for District Heating and Cooling Network.

- **Other preparatory work needed for implementation**:

Coordination with the other new development projects (i.e. Herrera Oria bridge, network of different building services, etc) is needed as the geothermal module and network must be fully integrated into its urban context.

6.3.1.2 DT for demolition and construction phase (USC)

- **Implementation requirements:**

This work doesn't deal with personal information or other data that would require specific legal requirements. In the event that such information is utilized, we are committed to strictly follow standard procedures and best practices for data handling, privacy and compliance. As no sensitive or regulated information will be used, no legal requirements have been identified. In case any of the inputs to our system are protected by legal requirements, we will fully comply with existing regulations and obligations.
From the technical perspective, our system requires access to environmental data from satellites, models and in-situ observations. A first prototype has been implemented aimed to provide data capture and processing, product distribution and user-friendly visualization in an interoperable and dynamic environment.
The costs associated to our development are due to the initial software engineering processes. The developing environment relies on open-source tools and the datasets we currently use are available free of charge. In addition to personnel resource allocation, future costs might include expenses related to accessing specific datasets, procuring hardware or implementing a cloud-based solution.

- **Assembly requirements:**

Data Collection and Aggregation: The system routinely will collect information from satellite and weather prediction centers. It currently, and for testing purposes, ingests wind data from GFS. USC plans to incorporate additional datasets, including in-situ monitoring stations managed by local and regional authorities.
Data Distribution: There is interoperable middleware for data distribution in multiple formats (e.g. netCDF, Mat, csv).
Visualization platform: Using Leaflet Javascript library, there is an online viewer where users can interact dynamically with the mapping platform, manage layers and visualize time-series.
Security: The system must ensure data integrity and implement strict access control policies, and, if needed, compliance with data protection regulations.

Integration with external systems: The interoperable framework provides web services and a REST API to provide functionalities and resources to external systems. For example, within WP5, this system can feed ML models.

- **Local constraints:**

The monitoring of the atmospheric constituents using LIDAR would require renting the unit for several weeks. The system would be managed by ACC and the collected data will be processed and analysed by USC. The renting process requires to know some months in advance the exact dates the demolition activities will take place. The allocated funds for purchasing a LIDAR unit are insufficient and the alternative solution we propose is renting it during the demolition tasks. We are working on designing the in-situ component of the data collection system. For completing this task, we need to interact with local and regional authorities managing the observations network.

- **Data for future adaptations:**

We are implementing routines that ensure long-term data collection capabilities and easy adaptation to changes.
We need to discuss with stakeholders' other data repositories that might require special usage rights and/or commercial licenses.

6.3.1.3 Roof-planning assessment (ANERDGY)

- **Implementation requirements:**

Assessment of building typologies and energy efficiency to provide information to the Tender of the design of the buildings.

- **Local constraints:**

CTE_HE: National regulation for renewable energy production from municipality.

- **Data for future adaptations:**

Criteria for leveraging roof design in the energy production and buildings' energy demand, such as average of green roof needed to optimize buildings' energy demand.

- **Other preparatory work needed for implementation:**

Definition of building design freedom.

6.3.1.4 2nd life batteries module (BEEP)

- **Implementation requirements:**

Transport and handling:

- Ensure access with a truck with more than 3500 kg and platform.
- Ensure unloading of equipment close to its location.
- Facilitate the handling of equipment from unloading to final position with the use of a pallet truck, without slope, without steps and with a sliding floor or, failing that, an overhead crane.
- Guarantee access: with doors more than 1 m wide and 2 m high.

Room conditions:

- Floor leveled and slidable with pallet truck.

- Mandatory ventilation. Minimum air exchange with the outside must be guaranteed.
- Recommended air conditioning. Suitable operating temperature for battery cells is between 10 and 30 ºC.
- Fire detection/extinguishing recommended.
- Location away from hazardous equipment or flammable products.
- Location away from water pipes, wet environments or other conduits.
- Clearance around the coil: 1.2 m in front and 30 cm on the sides. Minimum internal height of 2.2 m.

Inverter on grid batteries:
- Maximum distance between inverter and batteries 5 m linear.
- Inverter side distances 0.6 m.
- Maximum inverter height 1.5 m from the ground.

Communications:
- Access to local network that allows internet access and remote access from the outside.

Electrical installation:
- Distance between current transformers and wattmeter maximum 2 m.
- Current transformers at the grid connection point supplied by the customer.

- **Assembly requirements:**

Integration with the building design.
BEEP Scope of Work:
- Design, supply, assembly and commissioning of the battery storage system.
- Assembly and installation of battery racks.
- Delivery, installation and commissioning of the power inverter.
- Supply of communications switch.
- Supply and installation of communications wiring and DC power between batteries and inverter.
- Obtaining data, performance reports, reliability, etc.
- ADR transportation.
- Unloading of equipment/Supervision of equipment unloading.

- **Local constraints:**

Not compatible to be in the same room with geothermal equipment due to security requirements.

- **Data for future adaptations:**

Requirements on the compatibility with other equipment.
Requirements on electrical connection with panels and on connectivity to the internet.
Evaluation of the 2nd life batteries performance.

- **Other preparatory work needed for implementation**:

PROMOTER SCOPE preliminary to work
- Engineering project, legalization, management and adaptation of land for the installation.
- Electrical installation from the connection point of the plant to the inverter. An electrical installer able to manage electric panels is required.
- Ensure access to installation grounding.
- Internet access of the installation.
- Ethernet communication cabling between equipment. Battery energy management with the rest of the system.

- Labor Risk Prevention documentation.

6.3.1.5 White steel slag (CELSA)

- **Implementation requirements**:

The use of steel slags in construction may require compliance with local regulations and standards for the use of industrial byproducts in construction materials. Technical requirements may include testing of the steel slag to ensure that it meets the required specifications for use in concrete and asphalt. Cost considerations may include the transportation and processing of the steel slag, as well as any additional testing or quality control measures.

- **Assembly requirements:**

Assembly of the road pavement using steel slags will require the inclusion of steel slag as a partial replacement for natural aggregates in the asphalt mixtures. The steel slag will need to be properly processed to meet the required specifications and then mixed with the other materials to produce the asphalt mixtures.

- **Local constraints:**

Local constraints could include the availability of steel slag in the local area or the cost of transporting it from other locations. There may also be concerns around the environmental impact of using steel slag in construction, such as the potential leaching of heavy metals.

- **Data for future adaptations:**

Data collected during the construction process and subsequent monitoring of the road pavement will be useful for evaluating the performance and durability of the steel slag-based asphalt mixtures. This data could include information on the strength, stiffness, and resistance to fatigue and rutting.

- **Other preparatory work needed for implementation**:

Other preparatory work may include identifying suitable sources of steel slag, testing the steel slag to ensure it meets the required specifications, and developing protocols for processing and incorporating the steel slag into the asphalt mixtures. Additionally, the use of steel slag in construction may require additional training and safety protocols for workers involved in handling and processing the material.

6.3.1.6 Low carbon concrete and sustainable road pavement (ACCIONA I+D)

The potential technologies from ACCIONA I+D to be applied in the LL Madrid are the low carbon concrete and sustainable road pavement. The use of non-primary available resources is a competitive advantage to reduce the carbon footprint of construction materials and to target to a more circular model.

The low carbon concrete mixes will be developed using lower carbon cement with supplementary cementitious materials (SCMs) and secondary materials (recycled aggregates from construction and demolition waste (CDW) and slags from steel production) to partially replace natural aggregates.

The sustainable asphalt pavements will also include the use of slags and recycled aggregates from C&DW apart from reclaimed asphalt (RA) from old pavements to maximise the environmental profile of the asphalt mixtures.

- **Implementation requirements**

Substitution of DHC concrete for a low carbon concrete mixture. The adequacy of secondary materials both, technically and environmentally, shall be evaluated to be used in asphalt mixtures and concrete mixes. Additional testing may be required to guarantee that the use of these materials for the development of new mixtures does not impact negatively in their final properties and fulfills the requirements of the Spanish national legislations ((Spanish Structural Code (RD 470/2021) and the Spanish Specifications for Road and Bridge Construction (PG-3 and PG4)).

The recycled aggregates should meet the technical requirements established in the Spanish standards UNE-EN 12620:2002+A1:2008 Aggregates for concrete and UNE-EN 13043:2003 aggregates for bituminous mixtures.

In the case of concrete mixtures, the Spanish Structural Code (RD 470/2021) limits the content of coarse recycled aggregate up to 20% by weight out of the total weight of coarse aggregate for structural concrete. Recycled aggregate may be used for mass concrete and reinforced concrete with characteristic strength no greater than 40 N/mm2 while its use in prestressed concrete is excluded. In the case of the manufacture of non-structural concrete, up to 100% of recycled coarse aggregate may be used. With this limitation, the final properties of recycled concrete are hardly affected compared to results obtained for conventional concrete. For higher percentages, special studies and complementary experiments are required for each application. For non-structural concrete, up to 100% of recycled coarse aggregate may be used.

In relation to the steel slags for concrete, in addition to complying with the provisions for natural aggregates, the Spanish Structural Code (RD 470/2021) states that it will be previously verified that they are stable, that is, that they do not contain unstable silicates or unstable ferrous compounds.

On the other side, the inclusion of artificial and recycled aggregates, such as slags, and recycled aggregates, in new asphalt mixtures is permitted by the Spanish specifications (PG-3), but to at a limited extent or with some considerations, mainly from a technical point of view. In particular, the percentage of slags and recycled aggregates from C&Ws is not restricted as long as the minimum values required by Spanish specifications (articles 542, 543 and 544 for the different asphalt mixtures) are met. For the use of RA there is a regulation (Orden Circular 2/2023 about the reuse of surface layers and bituminous pavements) recently published with the aim to promote the use of RA for the development of new asphalt mixtures as an alternative of conventional materials. This regulation limits the levels of RAP, mainly depending on the asphalt mixtures type accommodating the RA and the facilities of the asphalt plant to produce these mixtures. Generally, levels up to 20% of RA can be incorporated into new asphalt mixtures with any modification in the asphalt plant. Higher levels than 20% can be only achieved by asphalt mixing plants provided with special installations (such as parallel drums) to heat the RA separately.

With regards the use of slags the technical note 03/2020 (NT 03/2020 about the use of steel slags in road pavements) is an excellent guide which includes technical recommendations for the implementation with success of slags in asphalt mixtures. This note states the importance to consider the difference in density between slags and natural aggregates, especially for a precise mixture design which must be done volumetrically.

The higher density of slags also impacts the cost being the transport costs higher. However, it should be noted that the price of slags is usually lower than natural aggregates, which potentially could compensate the excess costs in transport.

Other secondary materials to be used in the low carbon concrete and asphalt mixtures, such as recycled aggregates from CDW can potentially be more expensive than their conventional alternatives.

- **Assembly requirements:**

Specific assembly requirements are likely not foreseen for the implementation of the low carbon and sustainable asphalt mixes and neither is major capital expenditure for asphalt or concrete plants required.

- **Local constraints:**

Maximum use of recycle aggregates in concrete. It would be recommended that asphalt and concrete providers has some previous experience with the use of secondary materials as aggregates.

The main obstacle of implementing low carbon concrete is the lower quality of CDW recycled than natural aggregate and consequently of recycled than conventional concrete, especially with regards to durability. So, depending on the quality of the recycled aggregates, the replacement of natural aggregates with recycled aggregates can be total (100%) or partial (<100%), although most of the current national legislations do not allow or recommend such high replacement ratio. On the other hand, the use of fine RCA below 2 mm is uncommon because of the high-water demand of fine material smaller than 150 µm, which lowers the strength and increases the concrete shrinkage significantly. This high-water absorption and high cohesion of fine RCA also makes the concrete quality control very difficult. In fact, as mentioned earlier, the Spanish Structural Code (RD 470/2021) limits the content of coarse recycled aggregate up to 20% by weight out of the total weight of coarse aggregate for structural concrete and do not specifically mention the use of fine recycled aggregates.

No major obstacles are identified for implementing the new asphalt mixtures with sustainability credentials, provided that their performance is at least comparable to that of their conventional alternative. The production, paving and compaction process of asphalt mixtures is similar to the standard procedure; just mixing times and temperatures should be adjusted according to the laboratory studies during the production phase of the asphalt mixtures.

- **Data for future adaptations:**

Quantity of recycled aggregates (total i.e. 100% or partial i.e. <100%) as per quality of recycled aggregates.

Data collected during the construction and monitoring phase regarding quality of CDW recycled can affect durability.

- **Other preparatory work needed for implementation:**

Some lab testing should be performed to fully characterise the recycled and secondary materials (i.e RA, recycled aggregates, slags), as well as the novel asphalt and concrete mixes to make sure that all the technical requirements established in the National Legislation are fulfilled.

The secondary and recycled materials have some characteristics that may make their use difficult, as for example heterogeneous constitution with fractions of several size gradings, high water absorption or levels of hazard that should be looked at before the implementation to evaluate their technical end environmental feasibility. This is why some lab testing should be performed to first fully characterise the recycled and secondary materials (i.e RA, recycled aggregates, slags), and second characterize the developed low carbon and sustainable asphalt mixtures with the incorporation of the secondary materials.

6.3.1.7 Integrated mobility infrastructure (CIDAUT)

- **Implementation requirements:**

Consultancy services aiming at implementing an integrated charging infrastructure for EVs in the LL.

Legal/cost requirements are mainly related with:

1. safety of each of its components (bi-directional chargers, second-life battery packs) alone and as a whole assembly, both considering the infrastructure itself and also people nearby;
2. availability of the required electric network to support this implementation; and
3. development of a business model attractive to all stakeholders directly or indirectly involved in the implementation.

Technical requirements are mainly related to:

1. existence of commercial bi-directional chargers suitable to be installed in the places and conditions defined within the LL (e.g. estimated EV fleet to cover per charger, accessibility to the charging point);
2. interoperability of the implemented solutions with current and future EV models and communication protocols;
3. scalability of the solution, assuming a steady growth in the EV deployment during this decade; and
4. existence of a flexible and scalable communication layer that supports high-bandwidth and high-reliability transmitting links.

- **Assembly requirements:**

Full specifications of all the elements of the integrated mobility infrastructure solution should be known to ensure smooth implementation and operation of the system (at hardware and software levels).

- **Local constraints:**

Assuming that this kind of solutions will be implemented in non-industrial building environments (either public or private), a key element to consider is the placement of the solutions (e.g on the street, in a garage, outside but in a private-access place), and the characteristics of the electric network that would feed the bi-directional chargers.

- **Data for future adaptations:**

Compatibility of the implemented system with EV models and communication protocols.
Data collected during implementation phase, such as peak hours or average of renewable energy, related to district heating and electric infrastructure, that can affect the service provided to citizens.

- **Other preparatory work needed for implementation:**

Benchmarking and selection of best candidates for the bi-directional charger considering a techno-economical approach to the problem: cost of implementation, interoperability of the product, hardware and software interfaces with other elements of the network, etc.

6.3.1.8 Recycled materials for foam and profiles (CIDAUT)

- **Implementation requirements**:

Consultancy services aiming at assessing the feasibility of introducing recycled and highly recyclable materials in existing or novel buildings. Legal/cost requirements are bound to existing regulations, as well as any further requirements that may be imposed by the geothermal network for its proper operation throughout the year.
Technical issues are two-fold:

1. for the case of the recycled insulation materials, the requirements to be met are related to the energy consumed in the procurement process, and also to the geometry, size and specific material properties needed to achieve the desired performance. Also, the available space and environment in which it is to be used (inside or outside buildings) for thermal insulation of products such as pipes or wall boards; or acoustic insulation under floor tiles.
2. for the case of the recycled structural materials, the requirements to be met are thoroughly defined in Spanish regulations, but also its integration with other conventional materials and construction-related processes has to be considered.

- **Assembly requirements**:

1) thermal, acoustic insulation requirements and dimensions of foams for applications such as pipes protection, walls or floor tiles.
2) expected dimensions of the recycled profiles, mechanical requirements and environmental conditions to which it is to be subjected.

- **Local constraints**:

Assuming that both solutions will be implemented in a building, relevant constraints are related to the immediate environment in which the solutions will be implemented, as may condition future dismantling and recycling strategies (e.g pipes, walls or floor tiles)

- **Data for future adaptations**:

Criteria for designing pipes insulation according to performance needed, geometry and size, optimizing energy consumed in the fabrication process.
Requirements for integrating recycled structural materials with conventional materials.

- **Other preparatory work needed for implementation**:

Assessment of the scalability of the solutions developed (feasibility of producing enough amounts of the materials while at the same time ensuring sufficient flows of recycled material in the longer term).

6.3.1.9 Geothermal pumps (ECOFOREST)

- **Implementation requirements:**

Cost included in PROBONO. Five geothermal pumps are to be implemented within the geothermal module. Equipment with R410a refrigerant, three-phase supply, with energy label A^{+++++}.

- **Assembly requirements:**

DHC module. Qualified installer specialising in this kind of unit, no frigorist's licence is required, since the refrigerant is enclosed in the internal circuit of the heat pump; IDOM, as qualified engineering company, is carrying out of the project; specific equipment will be used in the execution, for the collection related to the perforation.

- **Local constraints:**

Permits of the DHC. The main constraints could be related to permits (including drilling), dimensions of the technical room, noise levels in the area, total distance between collection and emission.

- **Data for future adaptations:**

Technical data regarding geothermal pumps' power, temperature required and users' demand vs geothermal pumps performance that can support in filling the national regulation for geothermal energy in District Heating and Cooling Network.

- **Other preparatory work needed for implementation:**

The ecoGEO HP heat pumps are designed for indoor installation, so it will be necessary to design a structure that ensures NO water penetration or humidity. Also, in this case, when installing 5 units in a cascade, it is important to take into account the space to be left between them, as well as from the wall. The same applies to the wells that will need to be drilled.

6.3.2 Construction preparation

The preconstruction checklist for the Madrid LL and status of each of the activities on the list is provided in Table 10.

Preconstruction activities	Status
Site analysis	Closed
Time plan	Closed
Identifying the necessary permits	Closed
Transfer of lands	On going
Acquiring the necessary permits	On going
Construction approval	On going
Finalize design documents	On going
Finalizing material take off	On going
Bidding process	Not started
Contract award	Not started
Review of Design Document	Not started
Begin of site construction	Not started

Table 10: Public space preconstruction check list and status of activities

Public space site preparation process for construction will be integrated in the urbanization project (to be developed).
Building space preconstruction and site preparation will start on 2026.

6.3.3 Permits acquisition

The permits needed for the Madrid LL and the status of their obtainment are summarised in Table 11.

Permits	Status	Constraints	Actions
Enabling title for the execution of the pipe network and geothermal module	Not requested	To be requested at the same time than urbanization project	Integration in the urbanization project
Authorizing title for the use of the subsoil	Not requested	To be requested at the same time than urbanization project	Integration in the urbanization project
Exploitation of geothermal pipes	Not requested	It applies Minery law (1972)	Meetings with the regional authority

Table 11: List of permits for the District Heating and Cooling network project

6.4 Initial site conditions

In order to determine the initial site conditions the LL has performed a starting architectural and an energy audit. The main findings are reported below.

6.4.1 Results of architectural diagnosis

6.4.1.1 <u>District Heating and Cooling in the public space</u>

The location of the design of the District Heating and Cooling network was evaluated and compared for different locations in the public space. The agreement with the city council was to locate the module underground above Cardenal Herrera Oria bridge (Figure 12 - *Figure* ***16***).
The design is being integrated with the public space. However, the surroundings of the public space have not been designed yet.

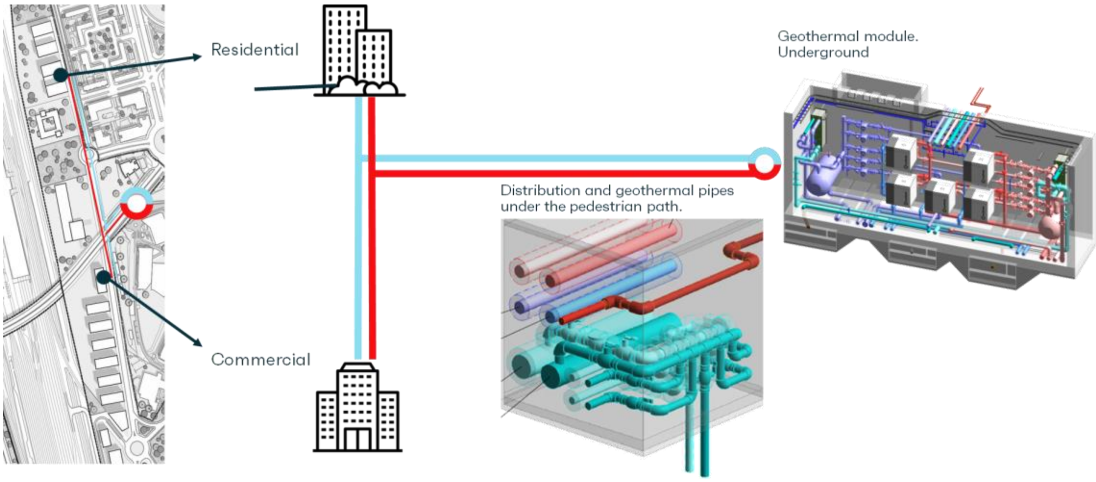


Figure 12: Scheme of geothermal network

Figure 13: Location of Geothermal modules in the surrounding

Figure 14: Geothermal modules under the Cardenal Herrera Oria bridge

Figure 15: Plants of Geothermal modules housing

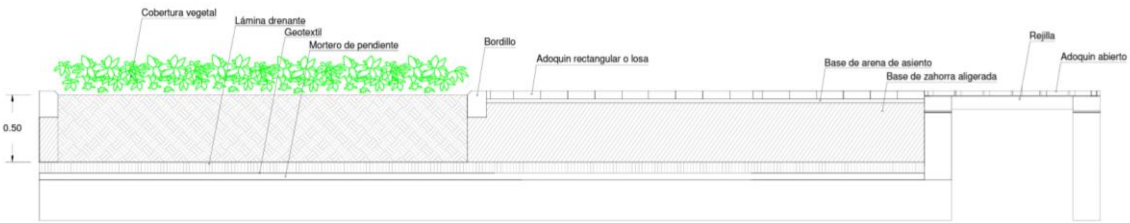


Figure 16: Section A-A'

To decrease fire prevention requirements of the module, it was decided that the second life batteries (BEEP) will be in the private buildings instead of the public infrastructure.
To reduce easements within the distribution network, the geothermal pipes will be located under the distribution pipes (*Figure **17***).

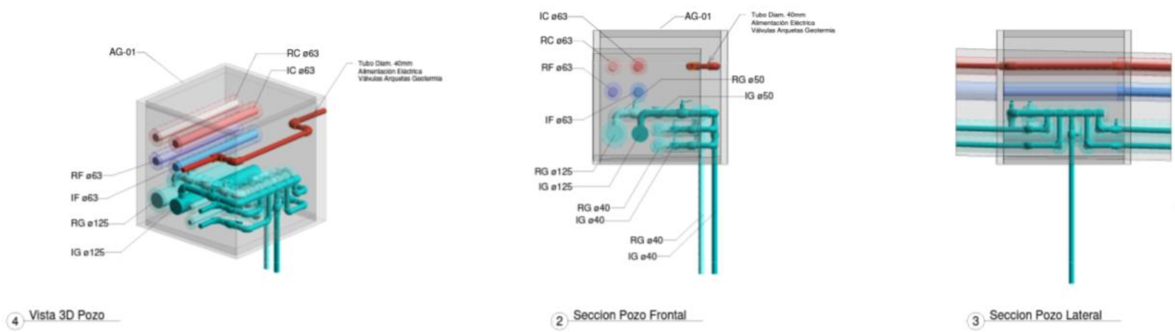


Figure 17: Wells with geothermal and distribution pipes

6.4.1.2 Design of the residential and office building

New construction. Design not developed yet.
Main intention is to incorporate as many PROBONO technologies as possible in the buildings, in order to minimize building's energy demand and maximize the energy performance of the installation.

6.4.2 Results of energy audit

The scope of the Madrid LL is to construct new buildings (one residential and one tertiary office building). As such no baseline data is available so the followed approach will be based on normative/legislation at country/local level. The baseline data considered for the Madrid LL are reported in detail in D6.2 Baseline Evaluation, submitted on M16.

7 Porto LL audits and plans for transferability

7.1 LL vision

SONAE aspires to become a great example of sustainability, reduce GHG emissions, and increase the use of clean energy. Porto Living Lab, located at Sonae Campus, aims to inspire a collective change and mobilise stakeholders by becoming a reference sustainable campus, raising awareness and promoting technical innovations that will have a positive impact in the environment.

On a technical approach, Porto Living Lab wants to increase the use of green energy and implement solutions that allow a better energy management, giving preference to the consumption of renewable energy produced in loco. By raising awareness for sustainability, the goal is to create knowledge for the community and positively influence the campus population to make better decisions regarding energy consumption, involving stakeholders.

To boost biodiversity by creating natural green spaces in the campus is another goal of the Porto living lab vision for achieving a GBN. These initiatives will have an impact on the architecture and spatial qualities of the campus targeting its employees and serving as a hub for team building, learning and empowerment of the communities.

After its implementation, Porto Living Lab will be a real proof of a true GBN, fulfilling its technical, social, natural and physical components and creating a thriving ecosystem that allows for experimentation with huge potential for replication. SONAE will move forward on a path of carbon neutrality and creating knowledge for the community.

7.2 LL transferability and contribution to the GBN concept

The renewable energy community (collective auto consumption) implemented within the campus can serve as a real test project for collaborative energy management, effective governance mechanisms, stakeholders engagement strategies, and innovative energy-sharing mechanisms, very important to the governance model inside the TEC. Lessons learned and best practices can inspire other communities interested in creating their own renewable energy communities or collective auto consumption, and can better prepare other locations against the main challenges within the process of developing and implementing a REC. Collaboration with the Brussels Living Lab further enhances knowledge sharing and the potential for impactful and sustainable solutions.

Additionally, the LL will document and share insights from the implementation of innovative pilot projects of new technologies at SONAE Campus. Methodologies, experiences, and outcomes associated with these technologies can offer valuable insights to other Living Labs and green building neighbourhoods seeking to deploy similar solutions.

The plan is to share the main results, knowledge, lessons learned, and insights generated through the Porto Living Lab project, through access to documentation, case studies, or other types of resources. This will inspire and inform other Living Labs, green building neighbourhoods, and stakeholders interested in sustainable practices.

The benefits to the GBN as well as the criteria for contributing to the GBN framework from the implemented innovations is further described in the next section.

7.2.1 Porto LL contribution to the GBN concept

The Porto LL will contribute to the attributes of a GBN as described in Table 12. The table also details how the implemented PROBONO innovations will contribute to the GBN framework and under what criteria.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (Specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met in order for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Technical			
Increase the use of clean renewable energy and minimize CO2 emissions	Micro electrolyser pilot; Building integrated photovoltaics; Solar-to-vehicle; Renewable Energy Community - REC;	Installation and operation of the referred technologies for green energy production	Amount of green energy production; Amount of shared renewable energy;
Better energy management; Promote synergies in energy;	REC; 2nd life batteries; Solar-2-vehicle; Vehicle-2-grid; PCM; Smart EV hub;	Availability and integration of second-life battery systems	Percentage of energy consumption from renewable sources
Promote sustainable mobility	Solar-2-vehicle; Vehicle-2-grid; Smart EV Hub;	Adequate space for the installation of solar panels or solar charging infrastructure. Availability of bi-directional charging infrastructure. Efficient communication between vehicles and charging infrastructure	Charging station utilization over time. Amount of energy used to charge the vehicles
Physical			
Creation of green spaces	Community garden	Integration of sustainable landscaping and vegetation	Area of green spaces created or improved
Social			
Boost social, community and neighbourhood engagement and promote public health and wellbeing	Community garden	Promotion of community involvement and collaboration	Number of community events organized
Natural			
Multiply in-campus biodiversity; Enhance Biodiversity;	Community garden; Green wall; House of birds;	Provision of habitats and nesting areas for wildlife	Increase in wildlife species observed in the campus

Table 12: Porto LL contribution to the GBN attributes

7.2.2 LL targeted impacts and KPIs

In the course of the project the LL impacts and KPIs will be achieved through the implemented innovations further described in chapter 7.4.

Table 13 lists the LL targeted impacts, as described in the PROBONO Evaluation Framework (D6.1), and draws links and causal relationships with the integrated technologies (last column), and the retrofitted demo sites (LL objective) for each situation prior to retrofitting (LL baseline).

Impacts	**Unit**	**Pillar**	**LL objective**	**Implemented measure(s)/ innovation(s) to achieve impact**
Primary energy savings	GWh/year	Energy	Energy demand 15.0 GWh/year: Savings: 0.6 GWh/year	Very difficult to measure as lots of changes in buildings and occupancy have happened and are still happening

Investments in sustainable energy	million €	Economic	3 Million € invested	PV solar installed in the Campus - Some MW already have been invested since the beginning of the project, but as it is from different owners it is difficult to analyse the investment
Demonstration sites that go beyond NZEB performance	Not defined	Energy	Not defined *Intented target to achieve nZEB or positive energy status	Green areas of the campus for biodiversity interventions
Reduction of GHG emissions for the total life-cycle	tCO2-eq/year or %	Environmental	Improvement: 30%	REC establishment – ongoing; PV solar panels installed in the campus
Reduction of the embodied energy in buildings	GJ or %	Energy	Energy savings per year 986.4 MWh/year; Improvement 30%	Very difficult to measure as lots of changes in buildings and occupancy have happened and are still happening
Reduction of air pollutants for the total life-cycle	Not defined	Environmental	Not defined *The tech hub projects will have a future impact in the air pollulants	Not defined

Table 13: Porto LL targeted impacts and KPIs

7.3 Prerequisites and preparatory work for implementation

The PROBONO technologies selected for implementation by the Porto LL are summarized in *Table 14*. Further information about the potential locations for implementation are provided in section 7.4.
The timeplan for implementation of the different PROBONO innovations in the Porto LL is shown in Table 3.

Technology / provider	Location
Phase Change Material Technologies (external provider)	Logistics Warehouse
SHIP pilot (Solar Heat for Industrial Processes) (external provider)	Smart Street Area
Green Hydrogen Pilot (external provider)	
Mobility: Solar2V and 2nd Life Storage, V2G (tbd)	
BIPV (external provider)	
Cool Roof with Bi-facial PV (SOP provider of cool roof technology, PV by external provider)	
Smart EV Hub (external provider)	Logistics Warehouse (Floor -1)

Table 14: Selected E3, E4 and E5 technologies for the Porto LL

Details about the implementation requirements, assembly requirements, local constraints and data for future adaptations are provided in the following sections.

7.3.1 Technology implementation preparation

For each innovative technology to be implemented in Porto LL, a systematic approach is being followed:

- Analysis of the proposed innovations outlined in the PROBONO project;
- Reassessment of the relevance and suitability of their development;
- Procurement of planned solutions and exploration of new options, considering the elapsed time;
- Validation of budget alignment;
- Identification of potential locations and assessment of implementation feasibility;
- Adjudication and licensing procedures;
- Installation and commissioning.

7.3.1.1 Phase Change Materials – PCM

- **Implementation requirements**:

TBD at a later stage.

- **Assembly requirements:**

TBD at a later stage.

- **Local constraints:**

Use of the existing logistics warehouse. Daily 24/7 operations must be respected.

- **Data for future adaptations:**

Analysis on energy savings and costs for incorporating into a building/material as well as analysis of system integration and compatibility with existing infrastructure will allow to assess the feasibility (viability) of transferability to other GBNs.

- **Other preparatory work needed for implementation:**

Under discussion with logistics team.

7.3.1.2 Smart EV Hub

- **Implementation requirements:**

EV chargers with LAN communication, ModBus and OCPP protocol. Compatible Load Management System

- **Assembly requirements:**

TBD at a later stage

- **Local constraints:**

LAN communication and available power

- **Data for future adaptations:**

Usage data, charging rates, and charging infrastructure performance will allow to assess the feasibility of transferability to other GBNs.

7.3.1.3 Green hydrogen production

- **Implementation requirements:**

The initially submitted project envisioned a small electrolyser for hydrogen production and its possible integration in the campus grid to decarbonize a specific heat consumption. Currently the scope of this technology is under revision to include broader possibilities of applications. The technology that is being assessed right now encompasses hydrogen production, gas compression, gas storage, and fuel cells. Therefore, the main technical requirements should be: equipment for green hydrogen production, consumption and storage; infrastructure; electrical power supply (AC); feed water supply; drains and vents; electrical output connection (AC/DC).

- **Assembly requirements:**

Connection between indoor hydrogen production/consumption module and outdoor gas storage rack (if technology being assessed is selected).

- **Local constraints:**

If technology being assessed is selected, hydrogen production/consumption module should be installed indoors, and gas storage rack should be installed outdoors. Precise location of gas storage rack is still TBD to meet all safety constraints.

- **Data for future adaptations:**

Data on the tested use-cases, performance of the system as well as analysis of hydrogen storage and transportation options will allow to assess the feasibility of transferability to other GBNs.

7.3.1.4 Solar Heat for Industrial Processes – SHIP

- **Implementation requirements**

SHIP technology equipment; infrastructure; thermal fluid inlet/outlet.

- **Assembly requirements:**

Connection point to the CHP plant.

- **Local constraints:**

SHIP thermal fluid outlet should be connected to the CHP plant in the campus, but still under analysis, depending on the technology to be deployed. Technology design should provide an outlet thermal fluid suitable for one of following available connection points:

- 1: superheated water at 140-160ºC and 8-16bar
- 2: superheated water at 197ºC and 8-10-20bar
- 3: water at 20-250ºC
- 4: water at 80-100ºC and 4-5bar.

- **Data for future adaptations:**

Analysis of system integration and compatibility with existing infrastructure. Sizing of output temperature and pressure for the industrial processes.

- **Other preparatory work needed for implementation:**

The previously identified potential partner no longer provides this technology. Currently, there are challenges in finding a new partner who can offer a technology that fits within our budget. The suitability of SHIP is being reevaluated, and if this technology proves to be non-viable, it will be proposed to reallocate the associated budget. To reassess the technology, several studies need to be conducted. The engineering team responsible for one of these studies is currently in the procurement process but will only be contracted once most of the innovations have been defined.

7.3.1.5 2nd life batteries

- **Implementation requirements:**

2nd life battery system; power inverter; infrastructure.

- **Assembly requirements:**

TBD with electrical project.

- **Local constraints:**

Preliminary location for 2nd life battery system implementation already selected.

- **Data for future adaptations:**

Data on the tested use cases and performance of the system will allow to assess the feasibility of transferability to other GBNs.

- **Other preparatory work needed for implementation:**

The technology provider under evaluation is BEEP who could provide a 2nd life battery system of around 80 kWh. Ongoing: procurement of power inverter.

7.3.1.6 Building Integrated Photovoltaics – BIPV

- **Implementation requirements:**

Building structure for installation; BIPV panels; mounting system; inverter; infrastructure

- **Assembly requirements**:

Mounting system of BIPV panels should be adapted for PV panels and the structure of the building where they will be installed.

- **Local constraints**:

Several locations are possible for BIPV implementation. The choice of location should consider the type of PV panels and their impact on energy production, architectural features, and technology visibility.

- **Data for future adaptations**:

Assessment of BIPV modules' performance and Civil/architectural data on integration with existing buildings.

- **Other preparatory work needed for implementation:**

Ongoing: procurement of BIPV panels (in discussions with several technology providers). It should be mentioned that we are facing challenges in attracting the interest of suppliers due to the low quantity of PV panels involved in the project.

7.3.1.7 Bi-facial PV

- **Implementation requirements:**

Bi-facial PV panels; waterproofing membrane; cool roof paint; inverter; infrastructure.

- **Assembly requirements:**

Cool roof paint should be suitable for application on the installed waterproofing membrane.

- **Local constraints:**

Technology to be installed on a roof of a renovated old building. Overload with PV panels should be checked before installation. Validation should be possible after receiving the results of bi-facial PV system design.

- **Data for future adaptations:**

Cool roof performance test results will allow to evaluate cooling efficiency and photovoltaic electricity generation. This evaluation will be crucial in determining the feasibility of replicating the technology in other GBNs.

- **Other preparatory work needed for implementation:**

This technology was not included in the project proposal, and as a result, it does not have an associated budget. Therefore, the implementation of this technology is dependent on whether the global technologies' budget will cover the cost of Bi-facial PV or not. Currently, the technology design is being undertaken by Soprema.

7.3.1.8 Vehicle-to-Grid - V2G

- **Implementation requirements:**

V2G EV charger; infrastructure; compatible EV.

- **Assembly requirements**:

TBD with electrical project.

- **Local constraints**:

Location of EV charging station already selected. Current car fleet might not be compatible with V2G charger and in that case must be adapted.

- **Data for future adaptations**:

Analysis of costs for technology implementation and evaluation of compatibility with various electric vehicle models. These insights will be valuable in determining the potential for transferring and integrating V2G technology into other locations.

- **Other preparatory work needed for implementation**:

Procurement of V2G charging station ongoing. Currently, there is no potential partner offering V2G as a commercial product. However, active efforts are being made to establish a cooperation protocol with manufacturers for the development of a V2G product, even if it is not yet available for commercial purposes. Discussions are being held with several potential providers, such as Scame, Wallbox, E-Mob, and Nuvve.

7.3.1.9 Solar-to-Vehicle - S2V

- **Implementation requirements:**

Technical studies and software development activities; software implementation.

- **Assembly requirements:**

Software connection to EV charger, access to PV production and battery system data.

- **Local constraints**:

S2V development requires previous definition of EV charger to be installed for V2G innovation.

- **Data for future adaptations**:

The framework for software implementation and replication will serve as a guide for other projects looking to implement S2V solutions. Data on charging with solar energy will provide insights into the efficiency and performance of the technology aiding in its potential transferability to other locations.

- **Other preparatory work needed for implementation:**

Potential partner for software development and implementation was already approached. Next steps should start after definition of EV charger to be installed for V2G.

7.3.1.10 Renewable Energy Community – REC

The preparatory actions for the establishment of the Sonae Campus renewable energy community are currently underway.

- **Implementation requirements:**

Compliance with the legal provisions for the establishment of collective self-consumption; REC (Collective auto consumption) official registration already sent to DGEG.
Platform for energy community management - negotiations are on-going in order to have the licensing of the platform available and further developments needed.

- **Assembly requirements:**

The need of smart sub-meters in the Campus is under analysis.

- **Local constraints:**

Fulfilment of the legal provisions regarding geographic proximity and also all the negotiations between partners that are part of the REC.

- **Data for future adaptations**:

Data on energy demand and consumption within the community enables future adaptations. Understanding energy patterns and consumption behaviour helps assess scalability and replicability in other contexts.

- **Other preparatory work needed for implementation:**

Establishment of collective self-consumption for the purpose of testing the community management platform.

7.3.2 Construction preparation

Sonae Campus Smart Street, which is under construction and renovation, is illustrated in *Figure* ***18***.

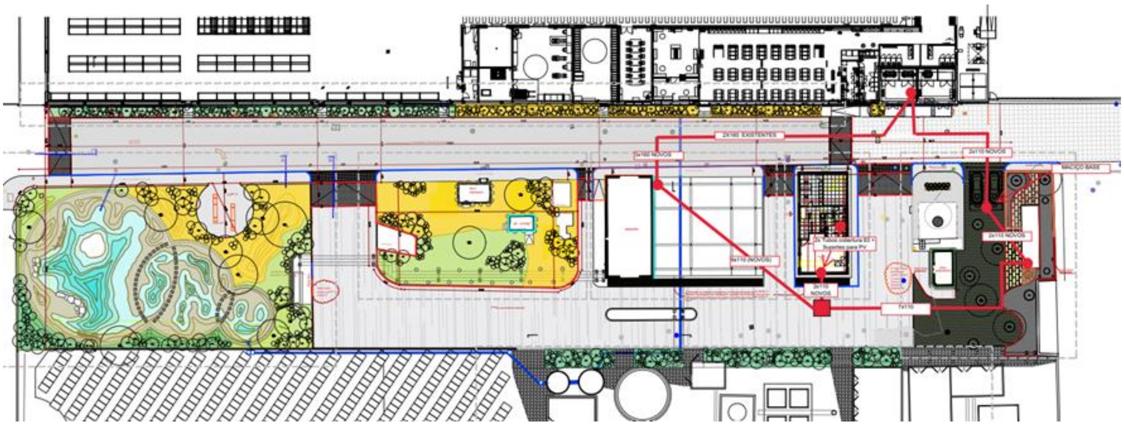


Figure 18: Sonae Campus Smart Street

Currently, the necessary infrastructure for the implementation of the technologies is being constructed and adapted based on the engineering project mentioned above. This includes, for example, the installation of piping to modify the existing electrical setup to meet the requirements of the future technologies.

Furthermore, civil works are underway. As shown in *Figure* ***19***, the maintenance building is undergoing development. If bi-facial PV technology is chosen, this building will accommodate this technology along with a reflective roof, supplied by Soprema.

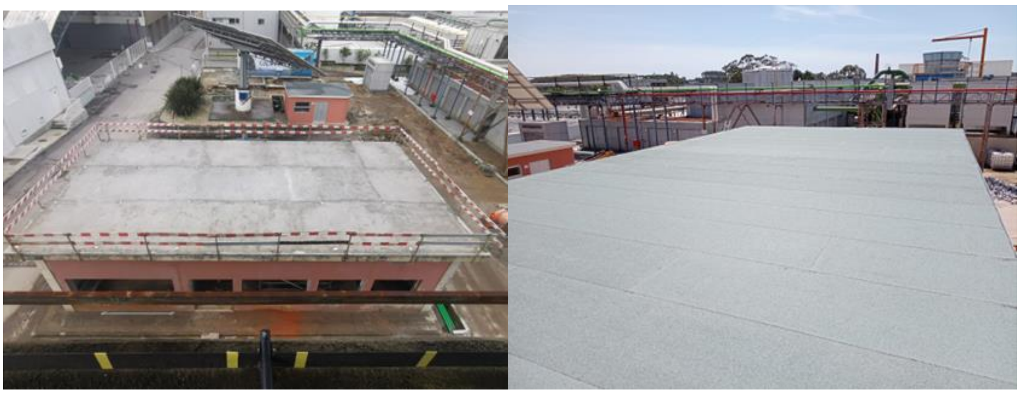


Figure 19: Maintenance building – accommodation of bi-facial PV cool roof technology

It is noteworthy that the current focus of Porto LL is on confirming the technologies to be implemented, determining their locations, establishing the associated budget, and planning how these technologies will be interconnected to create synergies.

7.3.3 Permits acquisition

The analysis of technologies to implement and suitable locations is currently ongoing. Following this assessment, the necessary licensing projects for the implementation of these innovations will be initiated.

Licensing preparations may be required specifically for electrical, telecommunications, piping and mechanical installations.

7.4 Initial site conditions

In order to determine the initial site conditions the LL has performed a starting architectural and an energy audit. The main findings are reported below.

7.4.1 Results of architectural diagnosis

The Sonae Campus Smart Street is under development at the campus. This area, as shown in Table 14 will house the majority of the technologies to be implemented for Porto LL. *Figure* ***20*** shows the Campus and the location of the Smart Street.

Figure 20: SONAE Campus and location of the Smart Street

Figure ***21*** bellow illustrates the Smart Street and the preliminary locations of some of the potential technologies to be implemented.

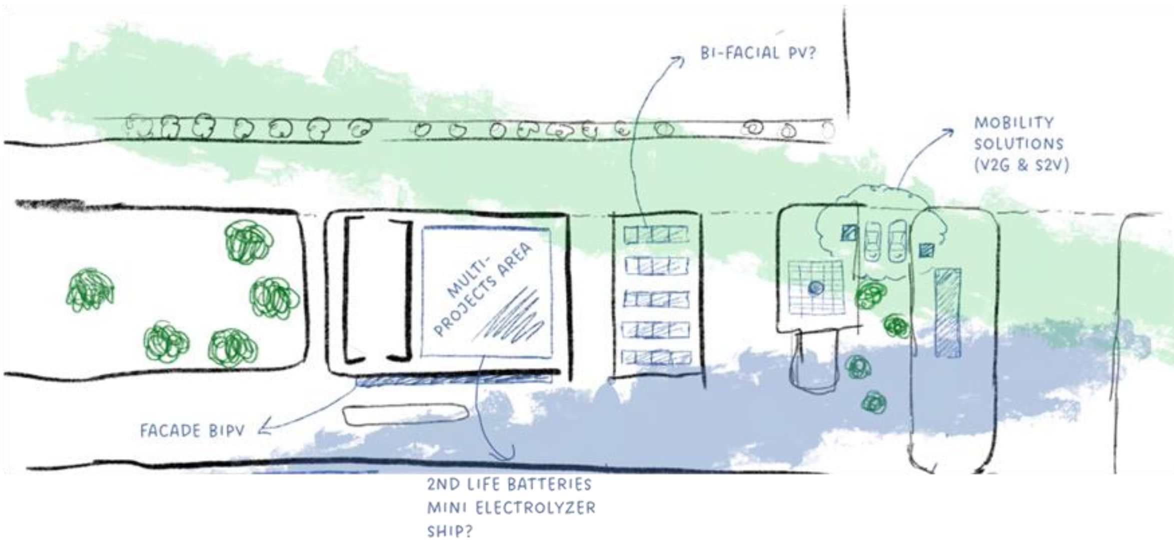


Figure 21: Smart Street and the preliminary locations of some of the potential technologies to be implemented

Works for the Smart Street infrastructure are already under preparation. *Figure* ***22*** and *Figure* ***23*** show, respectively, show the multi-project area and the area dedicated to mobility innovations.

Figure 22: Multi-project area

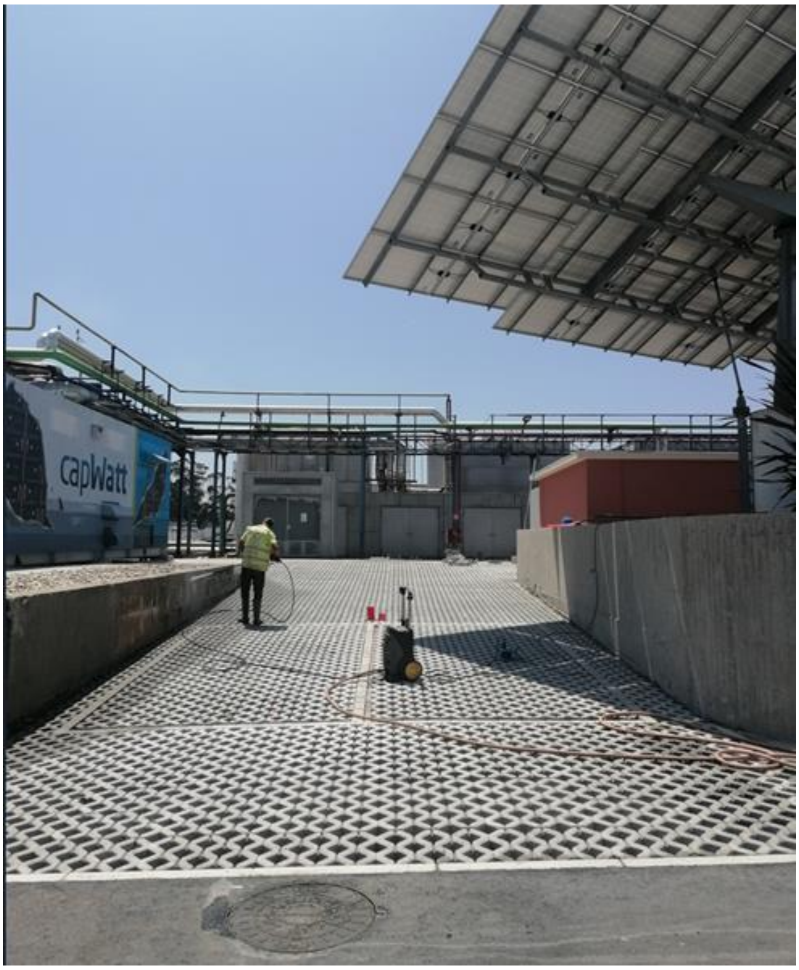


Figure 23: Area dedicated to mobility innovations

The PCM technology will be implemented in the logistics warehouse (Entreposto Sonae), as indicated in red in *Figure* ***24***.

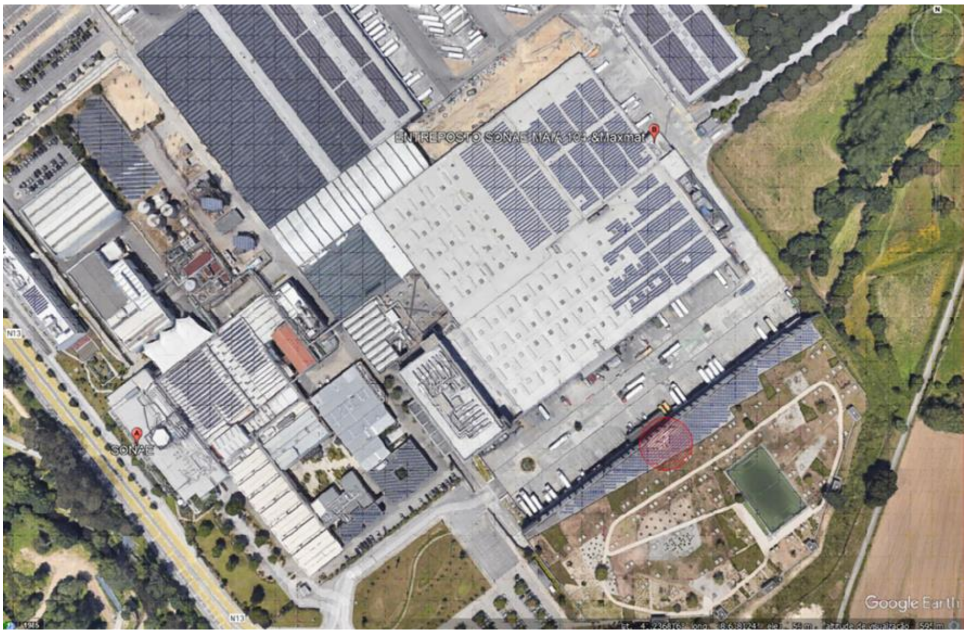


Figure 24: Logistics warehouse (Entreposto Sonae)

The Smart EV Hub is located in the same area mentioned above but on floor –1 of the parking lot (*Figure* ***25***).

Figure 25: Multi-project area - floor –1 of the parking lot

At SONAE Campus, a vegetable community garden, houses of birds and a green wall have also been implemented.
The community garden is implemented on the green rooftop in the top of one of the logistics warehouses (*Figure* ***26***).

Figure 26: Community garden

There are a total of 25 houses of birds implemented across the campus in different green areas (*Figure **27***).


Figure 27: Houses of birds

The green wall which is 100% natural and without carbon footprint is in development on the façade of the Sonae Holding building (*Figure **28***).


Figure 28: Green wall

*Figure **29***, specifies the locations of all biodiversity projects on the SONAE Campus.

Figure 29: SONAE campus biodiversity projects

Biodiversity and engagement with our community are imperative. Consequently, aside from the biodiversity initiatives undertaken as part of the PROBONO project, we are actively pursuing additional initiatives beyond the project's scope. These include the establishment of a green wall in Maia Business Centre, the creation of a butterfly garden, the construction of dry walls and cairns, the development of a lake, the implementation of a strategy to reduce grass cutting frequency and a beekeeping project.

7.4.2 Results of energy audit

The scope of the Porto LL involves a complete campus approach i.e. an energy community (involving several buildings and energy systems all together and not individually) that maintains the same use post-intervention. The collected baseline data are reported in detail in D6.2 Baseline Evaluation, submitted on M16.

8 Brussels LL audits and plans for transferability

8.1 LL vision

Introducing "De l'autre côté de l'ecole" (ACE), the PROBONO Living Lab school located in Auderghem, a Commune of Brussels. Our mission is to empower stakeholders, raise awareness, and promote innovation in technical, social, natural, and physical aspects, ultimately in collaboration with our neighbours and the Commune, transform our neighbourhood. At ACE, students are not mere spectators but active participants, as we strive to empower our neighbourhood toward becoming a GBN community across the technical, physical, social, and natural dimensions from which a GBN is made.

We are dedicated to showcasing the positive impact of data-driven knowledge and its translation into practical reality on sustainability decision-making. By influencing behaviour and promoting the use of technology where appropriate, particularly in energy control, mobility, and well-being, we aim to maximize social and technical innovation and Quality of Life. The pedagogy practised in the school provides an excellent opportunity to foster social innovation, expand and build the community and highlight the neighbourhood's attractiveness.

While emphasizing the technical and physical components as perceived by GBN stakeholders and social behaviours, we also recognize the significance of natural elements, such as the parks and the nearby Soignes forest. This recognition extends to the daily management and operation of our school, encompassing areas like facilities, sustainable procurement, (micro)mobility, and circular economy approaches. We ensure that these efforts align with the educational, technical, and social needs of the school. Additionally, we support LL decision-makers in green fundraising, technical expertise, and administrative management. A comprehensive GBN approach is crucial in mitigating risk and showcasing the return on investment in new holistic and sustainable approaches.

Strengthening connections and fostering collaboration with local neighbourhood stakeholders is crucial for transforming a mere building renovation into a project that ignites stakeholder momentum around various neighbourhood initiatives. These initiatives encompass significant aspects like green energy, transport safety, circular economy and Just Transition. By doing so, we aim to cultivate a stronger sense of community and collectively work towards a sustainable future.

8.2 LL transferability and contribution to the GBN concept

The Brussels LL will be the only LL in which PROBONO will be able to participate and support both the procurement process of the architect as well as the green finance fund raising process. The outcomes of both will provide rich material for knowledge and understanding in the process of sustainable renovation and GBN development. To support this, WP1 ST1.2.1 and ST1.2.3 will be looking at ESG, Green Finance and Investment Analysis in the context of GBNs and sustainability renovations. WP1 leader moderated a panel session at the launch of the Sustainable Energy Finance Association, specifically to build presence and understanding for both these two sub-tasks as well as for the needs of the Brussels LL. SEFA, part of another H2020 project under DG ENER, has also output a range of green finance tools for the entire green finance supply chain, from lenders to borrowers and all in-between, so as to simplify and speed the process and encourage greater green financing uptake. This range of tools will be trialed for the real world needs of ACE. Findings and process will be used in terms of transferability for the other LLs, in particular in Madrid, where an investors workshop is to be held to address green financing and ESG issues in relation to policy and legislation. The Brussels LL outputs in this context will also be transferred into a WP8 green paper on ESG and green financing.

The PROBONO project support to the procurement process of the architect will also provide valuable learning to the development of GBNs and renovation of buildings that will be included into transferability outputs.
In advance of the ACE renovation, the baseline energy monitoring needs of the school has been adapted into a Sensors Monitoring and Behaviours study to monitor and understand how, from the data derived from energy sensors, energy efficiency can be understood through building use and behaviours. This study, in collaboration with technical partners in WP3 and WP4, as well as social sciences in WP2, will provide significant outputs for transfer both across PROBONO itself, as well as externally. Significant discussions have already been had in this respect, for example with CERN in Geneva, who have organized a PROBONO/CERN workshop to explore and discuss more in relation to renovation of buildings and development of GBNs. As these initiatives mature, actions from the original transferability statements will be resurrected in line with the new developments.
The benefits to the GBN as well as the criteria for contributing to the GBN framework from the implemented innovations is further described in the next section.

8.2.1 Brussels LL contribution to the GBN framework

The Brussels LL will contribute to the attributes of a GBN as described in Table 15. The table also details how the implemented PROBONO innovations will contribute to the GBN framework and under what criteria.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Technical			
Sensors, Monitoring & Behaviours Study	Monitoring infrastructure for the GBN demand and response platform	Metering and communication infrastructure needs to be installed. The study will first establish a baseline of the electricity usage in specified areas of the school.	TBD
Physical			
Mobility by design	Integrate some mobility components in the renovation of the building. (1) Green energy to support future e-mobility use (e-bikes, e-steps, e-cars) of ACE and neighbourhood (to be explored) (2) secured bike storage	(1) To be included in the procurement phase; usability of green energy by neighbourhood for e-mobility still to be explored; permit is required for neighbourhood level (2) challenge related to the limited available space to fill in the bike needs	(1) Volume of green energy to be produced and directly used by building users and neighbourhood for mobility purposes (2) Nb of extra bike spots compared to the baseline situation (=before renovation)
Solar green roof	Green roof by Soprema including PVs	Acceptable additional static load, permit information and access to roof	Temperature decrease for the classrooms under the flat roof; increase of biodiversity; green energy production; electricity consumption and cost reduction.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Social			
Sensors, Monitoring & Behaviours Study	Engage students to do the actual observations using Behavioural Economics, Social Psychology, Psychology, Sociology or Anthropology expertise. The experiments we are planning to perform will be very relevant for these areas and the data would then be available for the students to use for their assignments.	TBD	TBD
Quality of Life changes in the neighbourhood	Auderghem Commune Discovery Event	Commune specific communication of the event, supported by the Mayor's office, and an informal workshop event where we listen to and encourage the ACE neighbours to express their thoughts and desires across the key GBN characteristics of Social, Physical, Natural and Technical innovations.	TBD
Mobility as a community catalyst	Leverage the already foreseen actions and extend the target group to the neighbourhood (when relevant/possible) on the entire lifetime of PROBONO.	ACE school travel plan to include neighbours	To be defined accordingly to the actions planned in the school travel plan.
Safer and more sustainable mobility	Monitor mobility behavioural changes amongst school users and direct neighbourhood.	Extension of the school travel plan of ACE to include (1) school users (2) neighbours	KPIs to be defined: directly (e.g. modal split) or indirectly related to behavioural change (e.g. car traffic flows, air quality, nb of bike spots in the neighbourhood …)

Table 15: Brussels LL contribution to the GBN attributes

8.2.2 Targeted impacts and KPIs

In the course of the project the LL impacts and KPIs will be achieved through the implemented innovations further described in chapter 8.3.

Table 16 lists the LL targeted impacts, as described in the PROBONO Evaluation Framework (D6.1), and draws links and causal relationships with the integrated technologies (last column), and the retrofitted demo sites (LL objective) for each situation prior to retrofitting (LL baseline).

Impacts	**Unit**	**Pillar**	**LL objective**	**Implemented measure(s)/ innovation(s) to achieve impact**
Primary energy savings	GWh/year	Energy	Energy demand 15.0 GWh/year: Savings: 0.6 GWh/year	TPF/STAM Platform

				Soprema Green Roof
Demonstration sites that go beyond NZEB performance	Not defined	Energy	Savings flagship building: 0.5 GWh/year Improvement related to NZEB: 40% *Intented target to achieve nZEB or positive energy status	TPF/STAM Platform Soprema Green Roof

Table 16: Brussels LL targeted impacts and KPIs

8.3 Prerequisites and preparatory work for implementation

Since project start, various adaptations to the needs of ACE with regard to its renovation as well as the role it will play as a GBN catalyst, have taken place. Firstly, the context of the renovation has changed. Initially conceived as 2000 sq. mt the renovation requirements have increased in scope to now include Lower Ground, fourth floor and the roof.

Extensive discussions were originally held with all of the relevant technical partners which resulted in an initial renovation technology plan. The technologies discussed that would support these goals were:

- TPF/TSRV sensors and meters,
- SOP insulation materials and green roof and solar panels
- COWI for the energy community and network system
- VISB and BEEP for the batteries
- CIDAUT for solar energy and
- BOVLABS for charging stations
- Anerdgy for 3 D simulation for various scenarios for PV cost efficiency analysis.

The principle behind the selected technologies for the renovation (further elaborated in D7.1) remain but due to various external circumstances, the procurement of an architect and then the subsequent fund raising for the renovation, a mix between public and private funds, has been delayed to Q4 2023. Detailed design and the 'Fonds de Guarantie' fund raising process will full commence circa Dec '23 into early 2024.

However, the school is highly interested in SOPREMA technologies and energy consumption sensors and meters, and they were both selected to be part of the school renovation. The works for the green roof and solar panel will start once ACE can obtain a loan from banks.

Despite the delays in the appointment of a new architect, in advance of the ACE renovation, a detailed study on necessary sensors and meters to serve all of the monitoring needs i.e. baseline energy collection, behaviour study and data communication with the TPF/STAM platform was performed. TPF led the work of the study with strong contributions from STAM, TSRV, ACE, SERCO and SIN. The monitoring system will be installed during the summer of 2023.

The timeplan for implementation of the selected PROBONO innovations in the Brussels LL is shown in Table 3.

Further information about the potential locations for implementation are provided in section 8.4.

Details about the implementation requirements, assembly requirements, local constraints and data for future adaptations are provided in the following sections.

8.3.1 Technology implementation preparation

8.3.1.1 Monitoring system (TPF/STAM/TSRV)

- **Implementation requirements**

Various scenarios were envisaged as monitoring electric, gas and water consumption. It was then adapted due to budget constraint and to answer requirements for the WP2, WP4 and WP6 as inner air quality, humidity, CO2 concentration, behavioural habits of the students regarding the use of the classrooms. It also includes the monitoring of gas and electrical consumption for the building.
The proposed scenario is the following (Table 17):

HARDWARE DETAILS	PARTNER PROVIDING	ESTIMATED COST
2 gas meters • D80 / D100 • Mbus	TPF	**Around 4.000€ (total)** Still need to be validated during a visit with an expert
2 gateways Mbus à WIFI • For the gas meters	STAM	**tbd**
6 electricity meters	TSRV	**Around 1.000€ (Total)** Estimated price of 120€ per meter.
4 CO2 & temperature sensors	TSRV	**Around 250€**
12 Door & Windows opening sensors	TSRV	**Around 300€**
1 Local wifi gateway	TSRV	**Not more than 500€**
1 Wifi router (if necessary)	TSRV	**Not more than 500€**
4G connection plan if needed to stay independent of School's Wifi	TPF	**Around 450€ (Total)** Estimated price of 10€ per month during the whole project
TOTAL BUDGET		**Around 7.000€**
Installation costs (provided by TPF on hours spent)		**0 €**

Table 17: implementation scenario for Brussels LL monitoring system

- **Assembly requirements**

- Configuration of the meters by TSRV
- Definition of period for installing the meters / sensors with ACE, TPF, TSRV
- Installation of the meters → TPF
- Connection of the system → TSRV and STAM

- **Local constraints**

The infrastructure of the building with its current electric system, gas arrivals shared with the neighbour, and the regulation about safety might have an influence on the deployment however technical partners are aware of these.

- **Data for future adaptation**

Regarding the gas consumption, this may lead to an adaptation of the heating managing system in terms of schedule and temperature.
Data on the tested use-cases, performance of the system, and analysis of the harvested data will allow to assess the feasibility of transferability to other GBNs (relevance for the behaviourial studies of WP2).

- **Other preparation works**

- Technical visit from TPF for last details
- Validation of the subject classes by ACE and SIN with help of technical knowledge / visit of TPF

- Timings are under discussion due to the holiday period - implementation will be during the ACE summer break

8.3.1.2 Hybrid green roof with photovoltaic panels (SOP)

- **Implementation requirements**

The most important requirements are the data about the acceptable additional static load, permit information and access to roof.

- **Assembly requirements**
  - Definition of the acceptable additional static load of the flat roof established to 350kg/m2
  - Height of the parapets of the flat roof
  - Accessibility (by external crane) to the roof

- **Local constraints**

The previous local regulations were very heavy however they have changed for the better.
The building position made access to the flat roof impossible from the street. A crane needs to be installed in the backyard to work on the flat roof.
Also, the flat roof is accessible only with a straight ladder which limits the type of green roof option for maintenance. The same applies to the PV, depending on their type.
Soprema offers the material but will not do the work due to the budget constraint.
Tenders for architect and works to include green roof (extensive) and photovoltaic panels.

- **Data for future adaptation**

Based on the energy production, costs savings and decrease of temperatures, it might be possible to extend the use of the technologies to the other part of the building belonging to the other tenants and create an energy community.

- **Other preparation work**

A tender for work needs to be included in the tender for architect; to find a company able to work with Soprema technologies.
The tender for the architect is under drafting to be ready by the end of the year.

8.3.2 Construction preparation

The areas to be renovated are already chosen. No clear plan or design are currently available as the architect has not been chosen yet. Indeed, a tender is necessary to appoint the architect. The document is under drafting currently to be ready by the end of this year.

8.3.3 Permits acquisition

Permits obtention varies from commune to commune in Brussels.
In Auderghem, the permit exemption exists for the installation of photovoltaic panels on sloping roofs not visible from the street. It is now extended to flat roofs. Thus, no permit is needed for the flat roof to be installed in the LL Brussels.

Permit exemption also applies for the modification of the covering of a flat roof as well as its possible extension, to allow the installation of insulation, a rainwater storage for rainwater, or an extensive green roof not accessible which is the case for ACE.

8.4 Initial site conditions

In order to determine the initial site conditions the LL has performed a starting architectural and an energy audit. The main findings are reported below.

8.4.1 Results of architectural diagnosis

The potential locations for the considered PROBONO technologies are illustrated below.

Figure 30: Typical ACE classroom considered for sensors installation

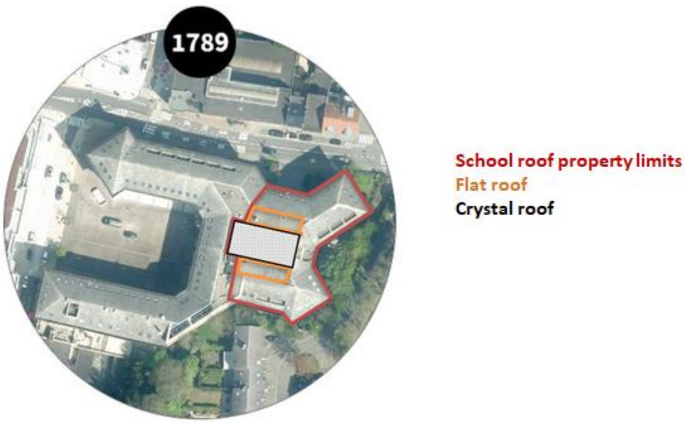


Figure 31: ACE school building roof

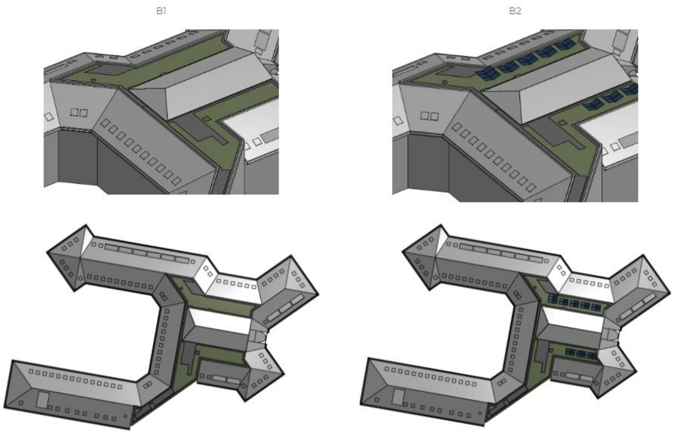


Figure 32: Green roof and solar green roof options for the school roof (roof renovation analysis by ANERDGY, Task 4.4)

8.4.2 Results of energy audit

The scope of the Brussels LL is renovation of an existing building that maintains the same use post-renovation. As such, the baseline definition is based on the LLs current status (pre-intervention status). The collected baseline data are reported in detail in D6.2 Baseline Evaluation, submitted on M16.

9 Aarhus LL audits and plans for transferability

9.1 LL vision

Aarhus University's LL is paving the way towards a sustainable future with its ground-breaking initiatives!
The LL's overall purpose is to curate new research and apply evidence-based holistic action research, focusing on social sustainability concepts in real construction projects ultimately for contributing to the development of a modern sustainable city integrated Campus, known as Campus 2.0.
The Living Lab encompasses a diverse range of areas, including technological, social, natural, and physical aspects, all of which play crucial roles in the creation of a Green Building Neighbourhood (GBN). Here's how the LL is making a difference across various aspects:

- Technological: The LL is at the forefront of developing and testing cutting-edge technologies and tools. We are working on an enhanced decision-support tool for architects and engineers, to facilitate better decision-making in the early phases of construction projects.
- Social: Making the intangible social sustainability tangible and quantifiable is the LL's aim. We are creating social sustainability subcategories and generating valuable knowledge and experience that can be applied in real-world projects, fostering a more inclusive and sustainable society.
- Natural: The LL is committed to achieving net-zero environmental sustainability. We are promoting functional architecture, testing and prototyping green deal transitional examples, and aiming for DGNB gold certifications for their sustainability goals.
- Physical: Through the LL's efforts, the campus district is undergoing a remarkable physical transformation. We are deeply refurbishing existing buildings, adding new ones, and ensuring architectural and structural features are preserved while meeting the needs of the university and its users.

Looking ahead, the vision for the Aarhus Living Lab and Aarhus University's Campus 2.0 is to "Make the intangible qualities, tangible." We aspire to translate social sustainability concepts into concrete, measurable outcomes. By integrating our findings, the LL will contribute to a modern, sustainable, and vibrant University City connected to the University Park.

9.2 LL transferability and contribution to the GBN concept

A large focus point in the LL is to ensure that the experience and knowledge generated through the project will be operable. This will be done through the Living Lab´s focus on development and testing in actual buildings while keeping functional architecture intact and striving towards net zero environmental sustainability. This approach encourages the translation of research into building industry-relevant products, and prototyping green deal transitional examples. One of these intended products is the delivery of an enhanced decision-support tool, directed towards the architect and engineering team in order to make better decisions earlier in the process. This will be a step towards making social sustainability (and its related values quantifiable and showing the effect on a full university, by making the architectural qualities as a building part it is possible to embed more qualities in the early phases.
The primary technologies to be implemented in the AU LL are VISB flow batteries, Soprema solar panels, continual verification of intended social values through a building's operational life with a focus on air quality, incorporating advanced construction processes with a focus on concrete, and new upcycling analyses as a renovation decision support tool.

The AU LL encompasses a number of buildings at various stages of renovation, that are serving as cases for "lessons learnt" as to when and how technologies can be pitched and incorporated into a running construction project. For example, as described in Section 9.3.1 it has thus far been a slow process in gaining approval from the building owners in the case of the BSS building for large changes in concrete processes and reacting to upcycling analyses with design changes. On the other hand, the three technologies that can be "plugged in" to a design while needing only relatively small design changes are still being pursued, namely installing flow batteries, solar panels, and digital twins that continually verify social qualities.
A key indicator is the grade achieved in the green certification system DGNB-DK which is used in Denmark and Germany (in a modified form). Demonstrating that a building meets social criteria in DGNB is of particular interest, where numerous social criteria are under-specified in the certification system and thus it is not clear how a building should achieve a particular "point" nor whether this promotes more (socially) sustainable buildings. For example, points can be gained in DGNB if art is placed within a building, although the specific placement, art content, and desired sensory experience of the art is not specified, and so a building design may be awarded at this point with no gain in social value and well-being to the occupants.
The benefits to the GBN as well as the criteria for contributing to the GBN framework from the implemented innovations is further described in the next section.

9.2.1 Aarhus LL contribution to the GBN concept

The Aarhus LL will contribute to the attributes of a GBN as described in Table 18. The table also details how the implemented PROBONO innovations will contribute to the GBN framework and under what criteria.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met in order for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Technical			
More sustainable energy management through flow battery storage. More cost-effective energy purchase/sale from/to the grid.	Installation of flow batteries in BSS and Campus Viborg.	Rigorous life cycle assessment to establish that there will be net gain long term via Consequential LCA. Agreement from building owners FEAS on installing the batteries. Coordination with architects and design team.	Primary energy savings (GWh/year) used in BSS with University City, and Viborg Campus. Annual energy cost (DKK).
Improved solar energy generation capacity.	Installation of Soprema solar panels on BSS and University City buildings.	Rigorous life cycle assessment to establish that there will be net gain long term via Consequential LCA. Agreement from building owners FEAS on installing the batteries. Coordination with architects and design team.	Primary energy savings (GWh/year) used in BSS with University City, and Viborg Campus. Annual energy cost (DKK).
Physical			
Significantly more sustainable design and	Detailed LCA analysis (with a focus on advanced	Agreement by building owners FEAS and	Significantly improved embodied CO_2 of *final*

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met in order for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
building construction processes and design decisions in BSS and Katrinebjerg projects, through advanced concrete processes and upcycling of onsite materials and components.	concrete processes) and new upcycling analysis techniques by COWI.	coordination with architect design teams.	design as per latest LCA techniques (i.e. with most accurate analysis techniques as per research community standards) compared to alternative designs under consideration.
Social			
Improved well-being with respect to air quality in The Kitchen 2.0, BSS, and Campus Viborg.	Facility management protocols and automated HVAC operational systems via digital twin using ITA INNOVA air quality simulations and AU human-centred analysis framework.	Coordination with facility management teams, and building owners FEAS.	Monitored attributes (CO_2, temperature) stay within safe and comfortable ranges for longer throughout year.
Transforming the Campus Viborg site into a real, functioning, livable campus, with appropriate facilities (housing, social spaces), supports people in undertaken all necessary campus activities (physical areas for social activities, extra-curriculum activities, sports)	GeoDesign workshop in order to assess the final (2026) vision and backtrack the interventions needed.	Coordination and "green light" from technical director of Viborg Campus ("Bygningschef") and project leader for development of Campus Viborg.	Student satisfaction via surveys, LCA calculations (to confirm net-zero campus, i.e. embedded CO_2 equivalent, energy consumed during operation)

Table 18: Aarhus LL contribution to the GBN attributes

9.2.2 Targeted impacts and KPIs

In the course of the project the LL impacts and KPIs will be achieved through the implemented innovations further described in chapter 9.3.

Table 19 lists the LL targeted impacts, as described in the PROBONO Evaluation Framework (D6.1), and draws links and causal relationships with the integrated technologies (last column), and the retrofitted demo sites (LL objective) for each situation prior to retrofitting (LL baseline).

Impacts	**Unit**	**Pillar**	**LL objective**	**Implemented measure(s)/ innovation(s) to achieve impact**
Primary energy savings	GWh/year	Energy	Flagship Building energy demand: 1.2 GWh/year Savings: 0.8 GWh/year GBN projection: 3 GWh/year	VISB flow batteris in BSS, Campus Viborg; Soprema solar panels in BSS
Investments in sustainable energy	million €	Economic	40 million € invested	

Demonstration sites that go beyond NZEB performance	Not defined	Energy	Flagship building specific heating and cooling demand: 0.7 kWh/m2/year Savings flagship building: 0.5 GWh/year Improvement related to nZEB 40% *Intented target to achieve nZEB or positive energy status	BSS, The Kitchen 2.0, Campus Viborg, Katrinebjerg
High energy performance	%	Energy	Achieve gold grade in the DGNB-DK certification system. Achieve Class 2 in the Danish voluntary energy regulation	VISB flow batteries; Soprema solar panels
Reduction of the embodied energy in buildings	GJ or %	Energy	Achieve gold grade in the DGNB-DK certification system. Achieve Class 2 in the Danish voluntary energy regulation	Advanced concrete construction processes and upcycling (COWI) in Katrinebjerg and BSS

Table 19: Aarhus LL targeted impacts and KPIs

9.3 Prerequisites and preparatory work for implementation

To specify Aarhus LL place within the development of Aarhus University's development towards Campus 2.0, the following three cases have been selected as the initial focus point of the LL:

1. deep refurbishment of one of Europe's largest business schools "AU BSS, 37.000m2.
2. AU innovation hub "The Kitchen 2" 3.500m2.
3. Energy Park development at AU Viborg

The PROBONO technologies selected for implementation by the Aarhus LL are summarized in Table 20. Further information about the potential locations for implementation are provided in section 9.3.

The timeplan for implementation of the different PROBONO innovations in the Aarhus LL is shown in Table 3.

Technology / provider	**Location**
Flow Batteries (VISB)	Campus Viborg - Industrial size BSS (University City) –Display size
Biobased/ upcycle materials (SOP)	Campus Viborg
Upcycle materials. Water collecting roof + mounting PV brackets. (SOP)	BSS (University City)
Human-centred analysis system (ITA INNOVA, AU)	The Kitchen 2.0 (University City)
Advanced concrete construction processes (COWI)	BSS (University City) Katrinebjerg
Upcycling (COWI)	Campus Viborg

Table 20: Selected E3, E4 and E5 technologies for the Aarhus LL

Details about the implementation requirements, assembly requirements, local constraints and data for future adaptations are provided in the following sections.

9.3.1 Technology implementation preparation

9.3.1.1 Flow batteries (VISB)

- **Implementation requirements:**

VISB needs usage data; where new buildings are concerned, we are using data from similar sized buildings to estimate capacity. As mentioned previously, the design of BSS in the University City is already very optimised for space, and so finding a suitable physical location to house the batteries is a current challenge.

- **Assembly requirements:**

The flow battery technology can be stored as water tanks and take up some space but overall installation is straightforward.

- **Local constraints:**

Local regulations make it more economical to use the power stored on site. Transportation to another site creates costs resulting in usage of the power grid with taxation. Therefore, there is ongoing dialog on creating two separate batteries, one at Campus Viborg and one at the main Campus, University City.

- **Data for future adaptions:**

Energy savings, costs for incorporating into a design, design changes required at a late design stage for incorporating batteries.

9.3.1.2 Sustainable insulation (SOP)

- **Implementation requirements:**

Insulation has a large fireproofing-code in Denmark. Aarhus LL and Soprema are discussing with the developer and the building owner for the BSS project on changing the intended insulation material to a upcycle product.

- **Assembly requirements:**

Installation is not complicated but the dialog of replacing the intended standard material is time consuming, also concerning legislation. Dialog is circulating back and forth between architect, developer, building owner.

- **Local constraints:**

Product insurance can be an issue. But very recently, April 2023, one upcycles sales platform (Green Dozer) has secured the re-use and manufacturer's liability for the upcycle product. The fire-resistant code is still a significant issue.

- **Data for future adaptions:**

Data and LCA calculations for future adaptations will be based on the cost in Kr/Euro but also in the currency of CO2.

- **Other preparatory work needed for implementation:**

SOP are developing data on CO_2 reduction with their product and using the climate calculations as argument for replacing the old standard material.

9.3.1.3 LCA calculations method development (COWI)

Note: this is an analysis method, not a technology that is directly installed in the design.

- **Implementation requirements:**

Assessment and clarifications on the impact of using consequential LCA calculations, whereas the most dominant LCA calculations are attributional. The idea is that consequential LCA has a wider and more correct assessment on the climate impact.

- **Local constraints:**

The industry is just about to start using the attributional LCA, changing to Consequential is not market ready.

- **Data for future adaptions:**

Local climate. Building conditions (Regulation) updated EPD databases instead of generic databases.

- **Other preparatory work needed for implementation**:

In early stages of LCA calculations in the building industry less work intense methods are expected.

9.3.2 Construction preparation

The preconstruction check-list for the Aarhus LL and status of each of the activities on the list is provided in *Table 21* below.
As described, the BSS is already in construction and so no major changes to the structural concrete are possible.

VISB flow batteries (BSS)	**Status**
Energy saving simulations	Completed
Incorporating batteries into BIM model design	In progress
Construction of building(s)	In progress
Installation of batteries	Planned (2024)
VISB flow batteries (Campus Viborg)	**Status**
Energy saving simulations	Completed
Complete detailed design of buildings	Planned
Incorporating batteries into BIM model design	Planned
Construction of building(s)	Planned
Installation of batteries	Planned
Katrinebjerg	**Status**
Early stage of design	In progress
LCA calculations and upcycling analysis for decision support	Planned
Complete detailed design of buildings with green modifications	Planned
Construction of building(s)	Planned (2025)

Table 21: Preconstruction check-list for the Aarhus LL

9.3.3 Permits acquisition

Permit acquisition is not applicable in any of the AU LL projects thus far. The interventions being proposed can be implemented by the design team with the permission of the building owners (e.g. installation of flow batteries, modification of the HVAC system, etc.).

9.4 Initial site conditions

In order to determine the initial site conditions the LL has performed a starting architectural and an energy audit. The main findings are reported below.

9.4.1 Results of architectural diagnosis

The four projects in the AU LL are:

- The Kitchen 2.0 (in University City)
- School of Business and Social Sciences (in University City)
- Campus Viborg (60 km west of central Aarhus)
- Katrinebjerg (near University City)

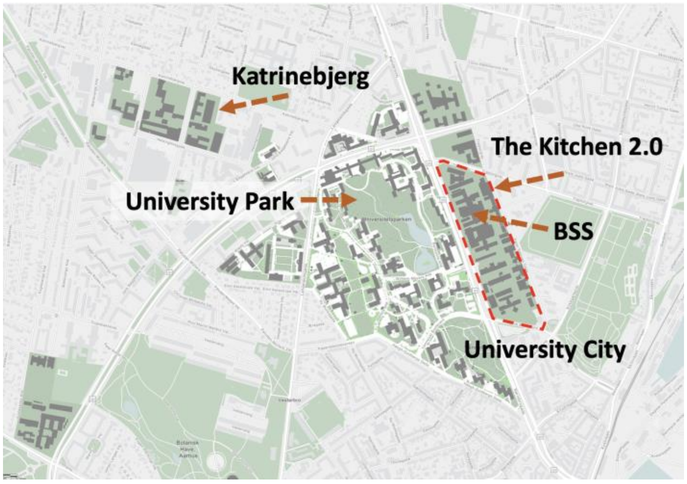


Figure 33: Map of central Aarhus, with locations of The Kitchen 2.0, BSS, Katrinebjerg, and important surroundings

<u>Project (1) The Kitchen 2.0 and Project (2) BSS (University City)</u>

The Kitchen 2.0 and BSS are in an advanced stage of design. Construction preparation is already underway.

The detailed BIM models (at the design stage) were provided by the architects to conduct the following studies:

- The BIM models and additional information about the case are being used to develop human-centred decision support tools with a focus on air quality as a case study (*Figure **34***);
- The BIM model of the BSS was used to conduct an extensive LCA analysis towards proposing viable design changes that have a significant positive impact on reducing the CO2 footprint of the design, with a focus on structural concrete as a case study [COWI, detailed extensively in deliverable D3.7];

- The BIM model of the BSS was used to conduct an energy-savings analysis with the installation of a small flow battery (10kW with 30kWh).

Due to the advanced stage of design of these two building projects, major changes to the design resulting from the aforementioned analyses are not possible (e.g. drastically rearranging the layout, materials used, etc.).

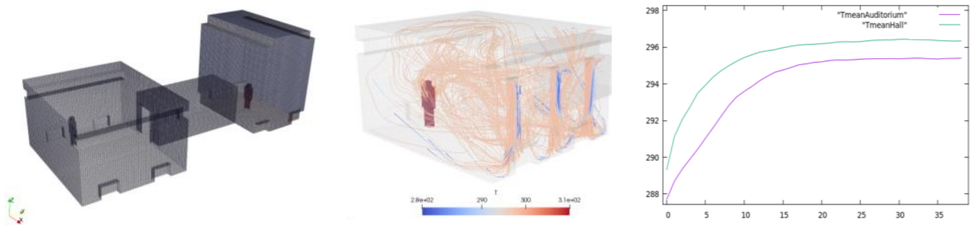
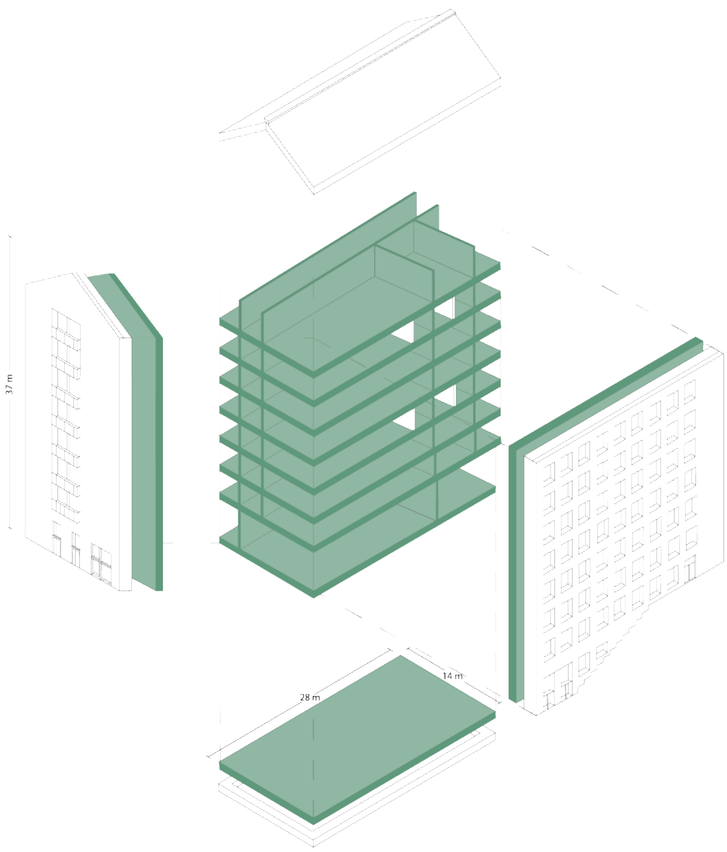


Figure 34: Examples of air quality simulation output and visualisations of The Kitchen 2.0 from ITA INNOVA.



Building geometry		
Total floor area	3398 m² *	
Stabilizing walls	250 mm	2772 m²
Facade wall elements	250 mm	1692 m²
Interior wall elements	250 mm	512 m²
Hollow core slabs	270 mm	3528 m²
Ground floor, concrete overlay **	195 mm	392 m²
Foundations	Not included	
External cladding	Not included	
Roof	Not included	
Non-load-bearing partitions	Not included	

Material parameters			
	Concrete		Y-steel
Characteristic strength	$f_{ck,wall}$	$f_{ck,HCS}$	f_{yk}
	40 MPa	50 MPa	550 MPa
Partial coefficient	γ_c		γ_s
	140		120
Design strength	f_{cd}	f_{cd}	f_{yd}
	28.6 MPa	35.7 MPa	458 MPa
Cover reinforcement			c
			25mm

Load specification	
Characteristic permanent load HCS, $g_{HCS,k}$	3.80 kN/m²
Characteristic lower permanent load, $g_{inf,k}$	3.70 kN/m²
Characteristic upper permanent load, $g_{sup,k}$	7.50 kN/m²
Characteristic permanent load wall, $g_{wall,k}$	23.1 kN/m
Characteristic live load, $_{qk}$	2.5 kN/m²
Characteristic snow load, $_{Sk}$	0.8 kN/m²

Figure 35: Example of case model developed by COWI focusing on structural concrete analysis towards reducing embedded CO2 in the design of BSS. Documented in detail in deliverable D3.7.

A summary of COWI's analysis is as follows. To get an effective estimation on where the carbon savings toward Carbon Net zero is greatest, COWI developed a simple method on finding the 20% largest emitters at a building site and targeting them. The target for this first pilot case was the structural concrete. The findings were that there is a minimum weight loadbearing on ordering new components but no upper level. The casting of lower strength takes 28 days, but the stronger classes have shorter production times, and the money cost of the largely increased cement is not significant, but the "CO2 cost" is much higher.

- The findings of COWI's LCA improvement analysis with a focus on structural concrete was presented to the architects (AART architects) mid-May 2023, thereby spreading knowledge towards impacting subsequent design projects (*Figure* ***35***).
- More importantly, by presenting the BSS analysis we have a particular aim of gaining leverage with the owners and design teams on another project that is still in the early design stage (Katrinebjerg, described below) where major impact are design changes are feasible. If we gain access to the Katrinebjerg project, then this will be used to pilot two analysis tools, with the expectation of changing the design in response to the analysis results: LCA improvement (as done on BSS) and upcycling analysis.

The flow battery analysis in the BSS was successful, with initial simulations showing that the installation of a small flow battery will indeed bring the BSS project firmly towards a Gold rating in DGNB. This was well received by the owners and design team. The current issue that VISB and the design team are working on is finding physical space in the design to house the batteries. This is also a consequence of the projects being in an advanced stage of design.

The human-centred design tools are still in development, and analysis results are not yet ready to be presented to the design team. This is in line with the aims of the proposed interventions, as many such interventions can be employed during the operational phase via digital twins and other non-automated aspects of running the buildings, e.g. automated facility management policies, appropriate event scheduling (e.g. to avoid unacceptable situations where the occupants have overly poor air quality, restricted movement, etc.).

<u>Project (3) Campus Viborg</u>

VISB has conducted a simulation that shows the energy-saving potential of using flow batteries. This analysis is currently being used to lobby in favour of installing flow batteries in Campus Viborg (*Figure* ***36***). The battery can be subsequently scaled up, enabling the owners to trial a smaller version, thereby lowering barriers to implementation.

Figure 36: Aerial view of Campus Viborg

<u>Project (4) Katrinebjerg</u>

This project is a combination of renovation and new construction for the computer science department and houses an innovation incubator called INCUBA (*Figure* ***37***). It is currently in the early design stage.

Figure 37: Site layout of the Katrinebjerg project

As described above, we are currently pursuing meetings with key people in both the design team and the owner organisations to gain access to the project, where we can expect to have an impact on the design in response to LCA analysis and upcycling analysis.

9.4.2 Results of energy audit

The scope of the Aarhus LL is deep renovation of an old hospital campus that will have a different use post-renovation. Effectively, it will be treated as new construction and the baseline will be based on code, normative or information from similar facilities/buildings in the existing university campus. The collected baseline data are reported in detail in D6.2 Baseline Evaluation, submitted on M16.

10 Prague LL audits and plans for transferability

10.1 LL vision

The vision of Prague Living Lab involves the dissemination of GBN (Green Building Neighbourhood) through the application of present and future expertise in passive building solutions, smart energy management solutions aimed at improved efficiency, and advanced technologies such as digital twin. However, it is of utmost importance to maintain a clear understanding of what GBN truly entails.

It is crucial to identify the key stakeholders involved. GBN is not merely concerned with the technical aspects of buildings and their surroundings, but also emphasizes the engagement of citizens, the consideration of natural aspects, the significance of physical attributes, and the inclusion of the political dimension.

Policy makers play a pivotal role as they impact various aspects of public life within the district. Furthermore, the objective is to leverage the gained experience for future urban policy planning and provide support for subsequent adoption of innovative practices.

This approach offers numerous advantages. Firstly, it reduces the negative environmental impact, enhances the quality of life for the neighbourhood residents, boosts economic performance, and leads to reduced operating costs in the long run. The beneficial impact of a green building neighbourhood on society can be substantial, resulting in increased satisfaction with the quality of life and the relationship with nature in the surroundings. Additionally, it improves air quality, enhances the city's resilience to climate change, and promotes safety and health for residents. Such an area becomes more attractive for additional investments, thereby generating economic benefits and creating new opportunities. The objective of Prague Living Lab is to engage citizens in this emerging trend and showcase new options for future comfortable urban living.

10.2 LL transferability and contribution to the GBN concept

Sustainable renovation and GBN development are the central focal points of the refurbishment of the Building B of the Faculty of Civil Engineering at CTU in Prague which will serve as an exemplar and living lab for students, professionals and the general public. Transferability will lie not in individual interventions but in adoption of complex solutions by other buildings and neighbourhoods. However, the further development of the project is being blocked by financial deficiency and lengthy discussions within the University.

An important transferable output is the “White Paper on Green Neighbourhood Sustainability Planning and Construction” which will be based on SBToolCZ[12] methodology and is the most important part in public procurement. According to the FIDIC yellow book terminology this will be related to ‘Employer’s Requirements’, i.e. definition of complex quality and sustainability.

Some of the interventions, for example BIPV, will provide unique know-how, experience and later measurable outcomes as a base for further deployment. Sharing results, knowledge and experience of the Prague LL through open-source materials and data can inspire all stakeholders interested in sustainable practices.

Next to building refurbishment a VR application will be developed as a digital twin allowing specific personnel i.e. a maintenance personnel to orientate where particular mains are located, i.e. to see them in VR while walking in the building. The application and supporting hardware will be innovative and ready for transfer to other buildings to complement the BIM for facility management.

The benefits to the GBN as well as the criteria for contributing to the GBN framework from the implemented innovations is further described in the next section.

10.2.1 Prague LL contribution to GBN framework

The Prague LL will contribute to the attributes of a GBN as follows in Table 22. The table also details how the implemented PROBONO innovations will contribute to the GBN framework and under what criteria.

What are the **contributions** of the LL to the attribute?	How exactly is each of the contributions achieved? (specify the **implemented measure, innovation** etc)	What are the **criteria** that need to be met in order for each contribution to be possible.	What are the **measurable Indicators** which allow the assessment of whether or not each of the criteria have been met?
Technical			
Digitally enhanced maintenance procedures	Human-machine interface (AR) for PROBONO Digital Twin for use by the facility manager	The digital twin should be capable of transferring a BIM model along with the metadata (if needed and if applicable) based on a specific location-dependent request from the AR tool.	Valid demonstration within the LL.
Physical			
Optimum sizing of building openings and HVAC system	Ventilation scenario rung with the help of the ventilation tool of ITA	Coordination with design team; availability of BIM model; tool developed for the Aarhus LL first	Improved energy efficiency and IEQ.
Social			
Improved productivity and well-being with respect to air quality and thermal comfort.	Improved ventilation through optimally sized building openings and HVAC system (use of ventilation tool from ITA during design phase)	Coordination with design team; availability of BIM model; tool developed for the Aarhus LL first	Air quality and thermal comfort from natural ventilation stay within safe and comfortable ranges for longer throughout year.

Table 22: Contribution of Prague LL to the GBN concept

10.2.2 Targeted impacts and KPIs

The Prague LL has not specific impacts form the proposal phase to be achieved (as explained in D6.1) but the main actions of the LL will be in line with the reduction of CO_2 emissions, energy efficiency enhancement and indoor and outdoor environmental conditions. Namely, the Prague Living Lab will contribute mainly to I1. Primary energy savings, I2. Investments in sustainable energy, I3. Demonstration sites that go beyond the NZEB performance, I4. High energy performance, I5. Reduction of GHG emissions for the total life-cycle and I10. Improved indoor environmental quality. The two PROBONO innovations selected for the Prague LL are expected to contribute to all of these impacts.

10.3 Prerequisites and preparatory work for implementation

The objective of the retrofit of Building B of the Engineering department of CTU will undergo major retrofit. Numerous interventions are planned. The Prague LL is interested in some of the E3 and E4 technologies of PROBONO but it is yet subject to confirmation and additional negotiation, also based on the final (external to PROBONO) budget for the retrofit.

The PROBONO innovation to be used in this process are the following:

- Ventilation tool (ITA)
- Human-machine interface (AR) for PROBONO Digital Twin (CTU)

The timeplan for implementation of the PROBONO innovations in the Prague LL is shown in Table 3.
The building permit still has to be secured. At the moment, the initiation of the building permit process is frozen due to obstacles in obtaining the necessary funding for the whole construction.

10.4 Initial site conditions

Indicative interior and exterior visuals of the pre-retrofit state of Building B are offered in *Figure **38*** - *Figure **41***. Although the façade is expected to change significantly, the internal layout is expected to remain similar to the current one.

Figure 38: South façade of Building B

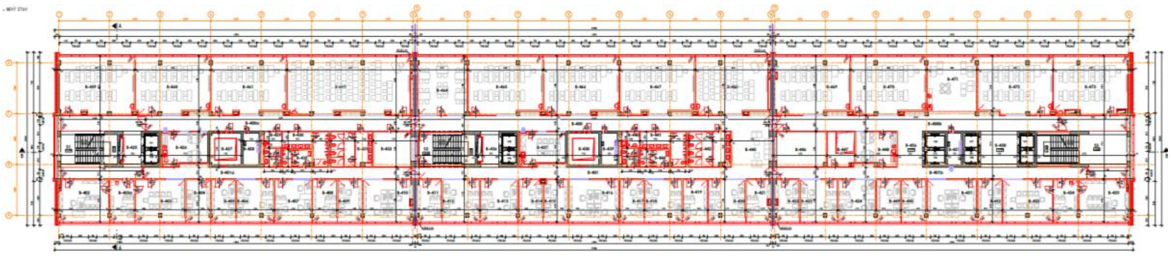


Figure 39: Office plan

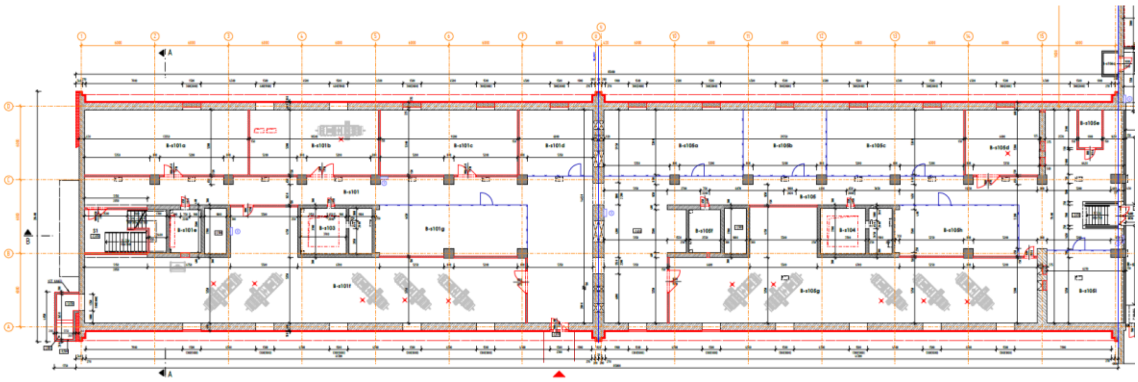


Figure 40: Basement 101

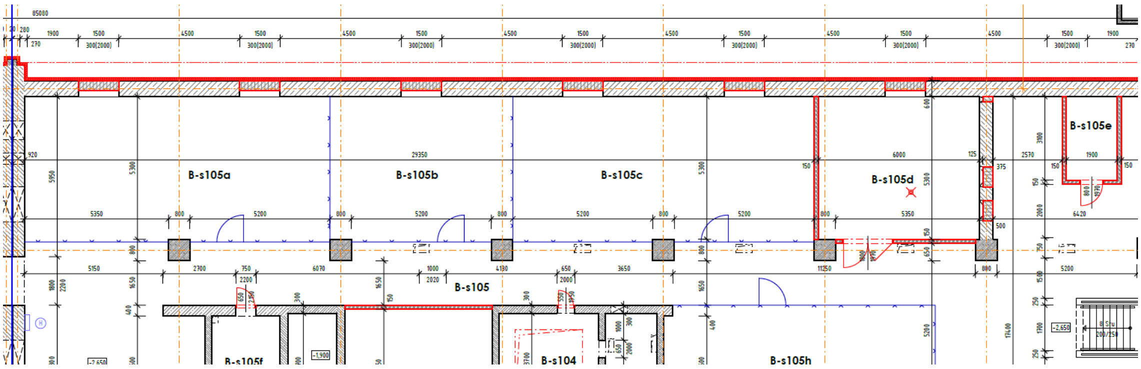


Figure 41: Basement 105

The scope of the Prague LL is deep renovation of an existing university building that will maintain the same use post-renovation. As such, the baseline definition is based on the LLs current status (pre-intervention status). The collected baseline data are reported in detail in D6.2 Baseline Evaluation, submitted on M16.

11 Conclusions

The PROBONO Living Labs, although having a unique scope of activities, use a common toolset of enablers and follow a common implementation approach (as detailed in Figure 3). Each of them will provide both an experimentation and innovation environment and testbed for GBN innovative solutions. A key output from the LLs will be an open directory of more than 40 validated maturing GBN innovations. These have been selected to highlight the transferability nature of all innovations and benefits achieved, refined, and configured with local parameters and data sets.

The current list of maturing innovations selected by the LLs is summarised in Table 2 of this report while further details usable for transferability, replicability, and sustainability actions of WP9 are provided in the individual Living Lab reports (chapters 5-10). The LL specific details for the selected technologies include:

- Transferability plan for technologies and know-how
- LL contribution to the GBN concept
- Implemented measure(s)/ innovation(s) to achieve LL expect impacts in the duration of the project
- Implementation and assembly requirements
- Local constraints for implementation
- Data for future adaptation i.e. data that will be available after the implementation of the technology that will help adapt it and make it more transferable to other GBNs.
- Initial architectural diagnosis with identification of the most probable locations for the implementation of each of the technologies.

The abovementioned information will provide input to Task 9.2 PROBONO GBN Exploitation, Replication and Sustainability Strategy.

The Living Labs are at different maturity levels. At the moment, the list of selected technologies is considered final for Dublin, Madrid, Porto and Aarhus. By the end of 2023, as part of WP7, all Living Labs will have produced their Initial Design and Construction Plans which will also serve the refinement of decisions on technologies and the production of more detailed information about their implementation. Once the list of selected technologies is finalised, these technologies will be mapped against the pairs of sustainability indicators prescribed in ISO 37101 and demonstrate that PROBONO actions have a holistic GBN impact.

An energy audit that served to obtain suitable information for elaborating the baseline energy consumption for the LL impact assessment activities has been performed in WP6 and reported in D6.2 (Baseline Evaluation). Supporting architectural diagnosis information have also been collected through this process.

References

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