CREATE Embedding advanced urban material stock methods within governance processes to enable circular economy and cities resilience

Requirement Analysis Report

D 3.1

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Abstract	This deliverable comprises three main chapters: - State-of-the-art analysis of existing tools - Requirements identification of the data gathering platform - KPI definition for the life cycle assessment for buildings Firstly, the existing tools on stock and flow materials were analysed based on several identified and listed criteria. This helps to identify development opportunities for CREATE project and represents a great source of information by identifying gaps in the literature. Secondly, having as basis the results from the literature review, semi-structured interviews, and questionnaire studies depicted in D2.1 “Stakeholder practices and needs”, the requirements of the data gathering platform and a list of KPIs that will measure circular economy targets were presented.
Keywords	circular economy, construction sector, policies, lifecycle assessment, metabolism study, stock and flow analysis

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V0.5	2024/07/16	Leonardo Rosado (CHALMERS)	

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1 INTRODUCTION

1.1 CREATE – project description

CREATE project aims at supporting urban transformation processes towards the circular economy by making an inventory of the existing material stocks within urban construction, developing reliable scenarios for future expected material flows, and providing governance arrangements on how to approach the circular economy transition. The project will focus on the largest urban infrastructures and communal assets, namely buildings, municipal roads, water, and wastewater pipes. A truly transdisciplinary consortium will work with a mixed research design that integrates quantitative modelling with qualitative study and design of governance aspects.

The project will further improve already existing, validated, and applied tools and arrangements and combine them with new digitalization technologies to inform decision-makers and enable a circular built environment. This will be achieved by engaging with a wide range of stakeholders in a co-creation process with four urban living labs in four countries, which will result in numerous capacity building moments throughout the entire project.

A thorough analysis of best practices of cities steering the circular economy transition together with new governance interventions will result in concrete proposals of tailored governance arrangements for the participating cities including a concrete proposal for an upscaling strategy for Europe.

The CREATE project follows a set of strategic underpinnings that connect the different work packages in three dimensions:

1. A living lab approach that is used throughout all work packages and allows for an integrated co-production of the project with stakeholders from the quadruple helix;
2. A multi-scalar capacity building approach, where the use of the living labs as the focal point of the work developed, complemented by the dissemination of knowledge to fellow cities and an outreach to urban networks in Europe, will allow for an optimized scalable process;
3. A tailored and adaptable approach that is based on the pre-existing conditions of the urban living labs and fellow cities, i.e., existing data, methods and governance procedures already being utilized by the stakeholders and providing them with new knowledge.

1.2 Objectives of WP3: Data gathering and visualization tool prototype

The main objectives of WP3 are:

- to develop a data visualization prototype, displayed online, based on open-source components from CitiSim (Cesium) and Digital Twin Cities Platform (https://dtcc.chalmers.se/);
- to provide data in a specific structure and format that enables decision-making, focused on usability, understandability and learnability of the tool and techniques.

1.3 Task 3.1: Requirement Analysis

This task will define a set of KPIs related to the characteristics and challenges of the urban living labs. Key stakeholders related with the occurrence of unplanned events in the context of spatial planning and routine services of the city will be identified. The requirements for the blueprint (reference architecture) of the data gathering platform will be defined and utilized to implement the requirements on the existing systems of stakeholders.

Sub-tasks:

- 3.1.1. Analysis of existing tools
    - State of the art analysis on data visualization tools / software / solutions for material stock and flow.
- 3.1.2 List of requirements
    - Present a list of requirements for the definition of the data gathering platform based on the activities undertaken in WP2.

2 STATE OF THE ART ANALYSIS OF EXISTING TOOLS

2.1 Introduction

Even though the concept of CE (Circular Economy) recently reached the 50th anniversary, the principles and methods have only just begun to be widely adopted by different stakeholders.

Cities host more than half of the world`s population and are thought to be both the source of many environmental problems and the hub of innovations. Historical assessments of the consumption of materials show that cities have grown over time. Urban planners, decision-making bodies, policymakers, and academia are also interested in urban expansion.

Goods that are used for a long time, usually more than a year, are referred to as material stocks. Buildings and infrastructure make up the majority of the world`s material stocks because they are by definition durable items. Since these materials are seen as the enhancers of human growth and economic activity, interest in the role of material stocks ahs increased in the past years.

Researchers have demonstrated in several scientific articles that quantitative results of material stock and flow studies can assist policy makers and planners in making decision that can increase city circularity, even though it is unclear to what extent and for which practices.

The creation of circular cities involves an interdisciplinary approach that relies on the collaboration between various stakeholders at various scales.

The CREATE project specifically targets the built environment with an emphasis on the physical, governing, environmental, and economic aspects of decisions made by governments on significant infrastructure projects and buildings.

The project will enable and assist transformative capacity building across many sectors for a sustainable and resilient urban transformation to the CE by designing a scalable process and testing it in several urban living labs based on real-world examples. This will be accomplished by enhancing currently available tools as well as creating new decision-support tools and governance frameworks that incorporate cutting-edge techniques to enable the CE and assess its effects on the urban built environment.

The living labs' applied co-creation approach will enable output customization to meet the demands and specifications of the relevant stakeholders, including data on material stocks and flows, decision-support tools and visualizations, and new governance structures. Additionally, the co-creation process enables the expansion of best practices to neighboring cities and beyond.

2.2 Goal and general method

The work focuses on analyzing several existing materials stock and flow tools, which could help to discern development opportunities for CREATE project and sources of information by identifying gaps in the literature.

The tool list presented in Table 1 is not exhaustive but presents a large panorama of possibilities of existing tools. The tools that emerged during consortium discussion were analyzed according to a multi-criteria grid. Some types of tools from the list stand out.

This state-of-the-art study aims to be presented to city decision-makers. The main scope is to aggregate, operate, or represent the needs of these territories (data, tools, achievements, difficulties, and levers used).

2.3 List of stock and flow material tools identified for possible use in CREATE Project

TABLE 1. List of stock and flow material tools identified for possible use in CREATE Project

Category	Name	Author (country)	Type
International Stock and Flows	Panorama	CML-Leiden, BRGM (EU)	Web, data platform
	MaterialFlows	TU Wien (Wo)	Web, data platform
	Sourcemap	Sourcemap (US)	Platform
	Resource trade	Chatam house (Wo)	Web, data platform
	Datavizta	Boavizta (Fr)	Online data
	Climatiq	Climatiq (US)	Online Database
Mapping tools for "smart city" data	Snap4City	SNAP4CITY (It) DISIT Lab – University of Florence Via Santa Marta, 3 50139 Firenze FI – Italy	Platform
	CitiSim	Abalia (Es)	Platform
	CityVis	(Wo)	Mapping tool
	ArcGIS	ESRI	Mapping tool
	Builder	CARTO	Mapping tool

	Smart City platform	SIRADEL	Mapping tool
Material exchange platform	Platform U	Metabolism of cities (Be)	Material exchange platform
	Refair	La Fab (Fr)	Material exchange platform
Database inventory	Circular economy data hub	DigiCirc (Fr)	Online datasets
Local Stock and Flows and other local data for district and building	Urban Print	Efficacity, CSTB (Fr)	Software
	EvalMetab	Gustave Eiffel university (Fr)	Tool online
	CirculApp	CiteSource (Fr)	Platform
	Demolition database (BTPFlux)(+ BNNB)(+TyPy)	APUR, CSTB (Fr)	Report+ tool in dvlpmt
	Building National Observatory	URBS (Fr)	Platform
Passport product	Madaster	Madaster (Nl)	Platform

2.3.1 Analysis criteria

In order to perform the comparison between all these identified existing tools, several criteria were selected:

Context data:

- General information: Name, Author, Country, type of tool (for example, platform, software, mapping tool, etc.);
- Way to access: Open access, Open source, free or to be paid;
- Geographic perimeter of the data or service;
- Geographic accuracy of the data;
- Object of study: Stock, Flow, product;
- Type of studied material: for building, civil engineering, metal, waste or other.

Tool characteristics:

- Destination: researchers, city decision makers, construction professionals
- Form of the results: multicriteria/monocriteria, material exchange platform, maps, graph, table or pop up;
- Possible interaction: only database or interaction existence;
- Kind of criteria: Stock and Flows, Environmental criteria, health criteria, other;
- Environmental method used: LCA, Carbon footprint, Carbon assessment, I/O, MFA.

2.3.2 Matrix filling

Each tool has been evaluated according to the criteria and to the level of accessibility of the information. For tools that are not free, only the information available on the website has been collected.

2.3.3 Results of the matrix

This analysis of existing tools permits to spotlight three things:

1. First, tools have different shapes:
   - Database of stocks and flows;
   - Environmental database;
   - Data visualization software;
   - Inventory of Databases;
   - Platform of setting in relation.
2. Secondly, they put forward different categories of information:
   - Stock and flows;
   - Environmental data;
   - Passport product;
   - Other data: commercial, productivity, CSTB data .
3. Lastly, they focus on different scales:
   - Object/process;
   - City/ district;
   - Country /Europe/World.

To summarize, the matrix permits to distinguishing five prominent tool categories:

- International Stock and flows: database or visualisation of the database with *Panorama, MaterialFlows, Sourcemap, Ressource trade, Datavizta and Climatiq*;
- Mapping tools: mainly for “smart city” data with *Snap4city, Citisim, CityVis, ArcGIS, Builder and Smart City Platform;*
- Material exchange platform including *Platform U and Refair*;
- Database inventory such as *Circular economy data hub;*
- Local stocks and flows database or visualisation of database: national, district, or building level: We can mention *Urban Print, EvalMetab, CirculApp, Demolition database and Building National Observatory*;

- Passport product software, like *Madaster.*

To be able to go forward with the process, it is necessary to reflect on two questions regarding the tools that the CREATE project wants to develop. An important aspect is to examine the desired purpose of the tool:

- If the objective is to identify the flows and stocks of materials and waste at the local level:
  - First find local data base in tools like EvalMetab for building, or Circular economy datahub;
  - Then display the data in a software, such as, CirculApp or Démolition database (for France);
  - Other data presentation as Platform U (or Refair), Madaster (product passport) or "smart cities" platforms may be interesting.
- If the objective is to identify the flows and stocks of materials and waste at the international level
  - First find international data on Panorama (metals), Material Flows (raw materials), Circular economy datahub;
  - Then display the data in a software (see next bullet point).
- If the objective is to find a visualisation method
  - To represent global flows and stock in a maps: Material Flows, Climatiq or Ressource Trade;
  - To represent global flows and stock in graph and represent multicriteria data: Material Flows;
  - To represent a balance sheet of stocks of a project (local level): EvalMetab or for a better graphic quality the software for smart cities.

2.3.4 Description of tools

This section will present a detailed presentation of the tools that are particularly interesting for further work in the CREATE project.

2.3.4.1 Evalmetab

Evalmetab is a tool for estimating the metabolism of development projects. Developed by the Chaire Economie Circulaire et Metabolisme Urbain from Université Gustave Eiffel. Based on the characteristics of the existing (to be demolished) and projected (to be built) buildings, the volumes of incoming and outgoing flows required for the site are quantified by type of material. Thus, it allows establishing a link between existing materials of building on site and necessary materials for building construction project. It also calculates the cost and GHG emissions of scenarios of transport of evacuated waste and raw materials needed for the new construction.

The structure of the tool is presented in Figure 1:

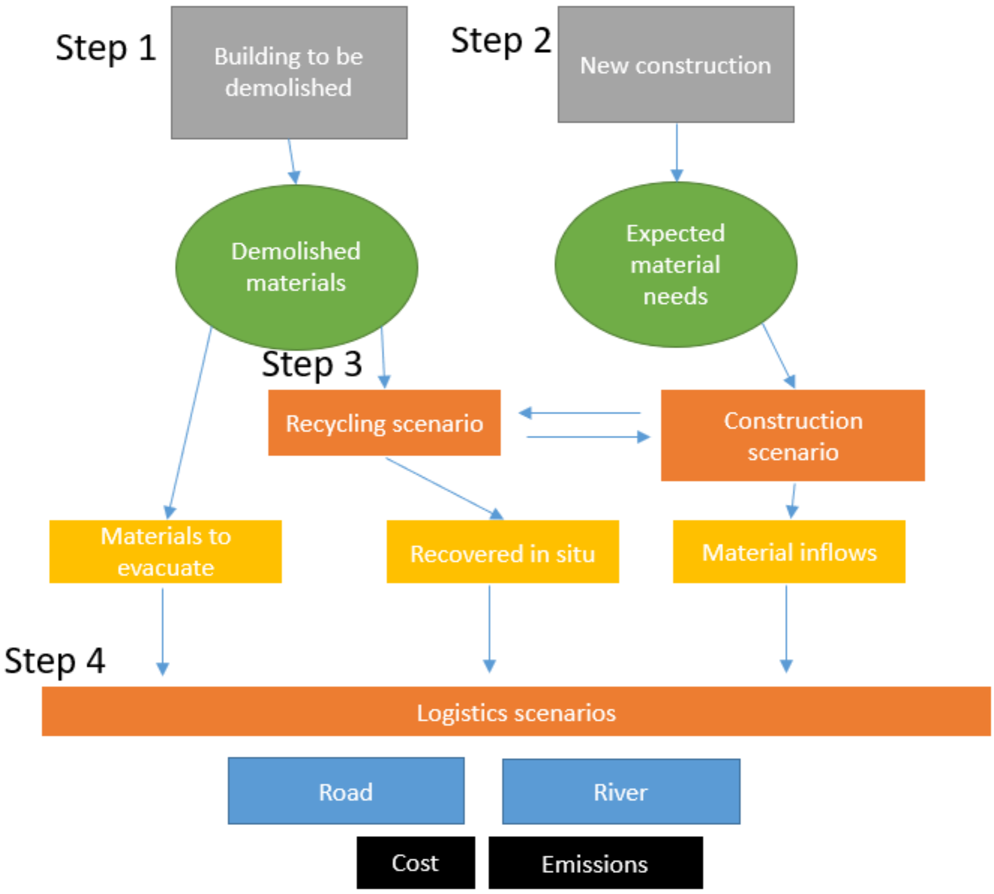

Figure 1. Evalmetab tool arhitecture

2.3.4.2 Circulapp

CirculApp was developed by CitéSource in the framework of the RUDI MetaData pilot project co-financed by Rennes Métropole. RUDI (Rennes Urban Data Interface) is a project piloted by Rennes Métropole with the financial support of the European Union.

CirculApp is a digital solution for interactive mapping of local actors for the circular economy in the construction industry and of waste deposits and material needs (by type of construction site or operation, material, year) (Figure 2). The solution allows the user to explore data interactively, find local actors, create custom maps, download graphics (Sankey and pie charts). It also offers the possibility to enter or complete data on actors, with moderation by the client municipality or CitéSource. The solution respects the confidentiality of certain data, by restricting its distribution to certain users only. It provides transparent information indicating the sources and methods used.

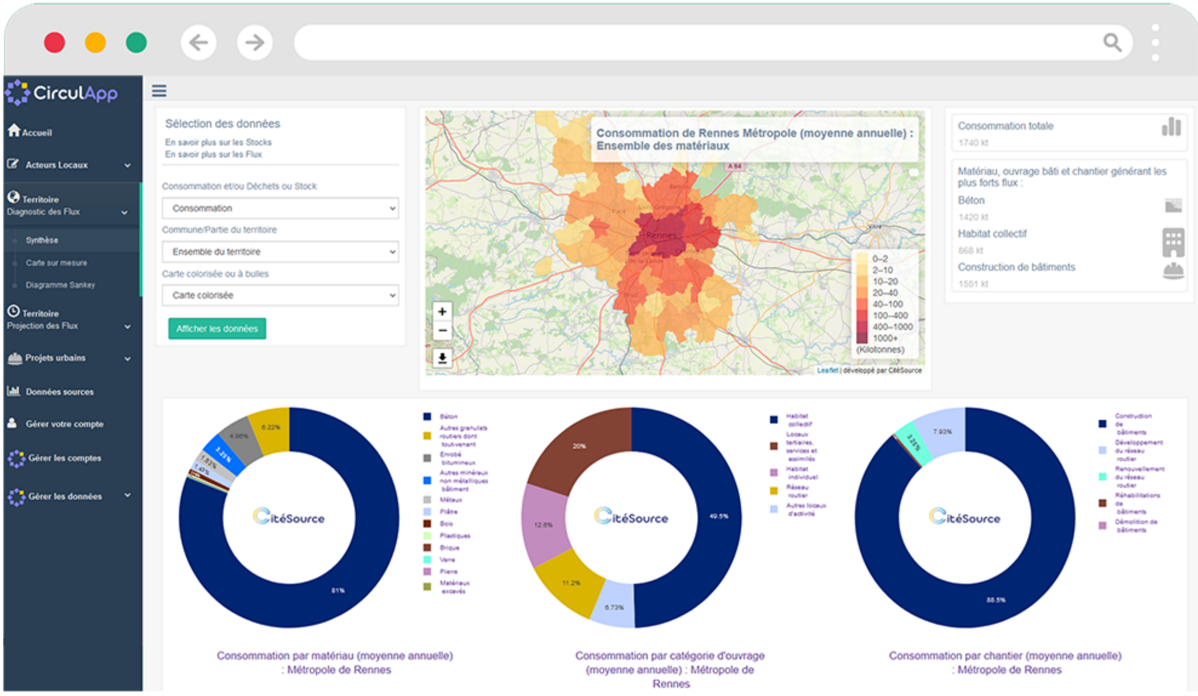

Figure 2. CirculApp tool overview

2.3.4.3 Madaster

Madaster is an online library of information on materials and products. It permits to create and inventory of material passport i.e materials and objects that are incorporated in a building or infrastructure. Madaster[1] (Figure 3) develops also other indicator on circular economy which are include in the passport.

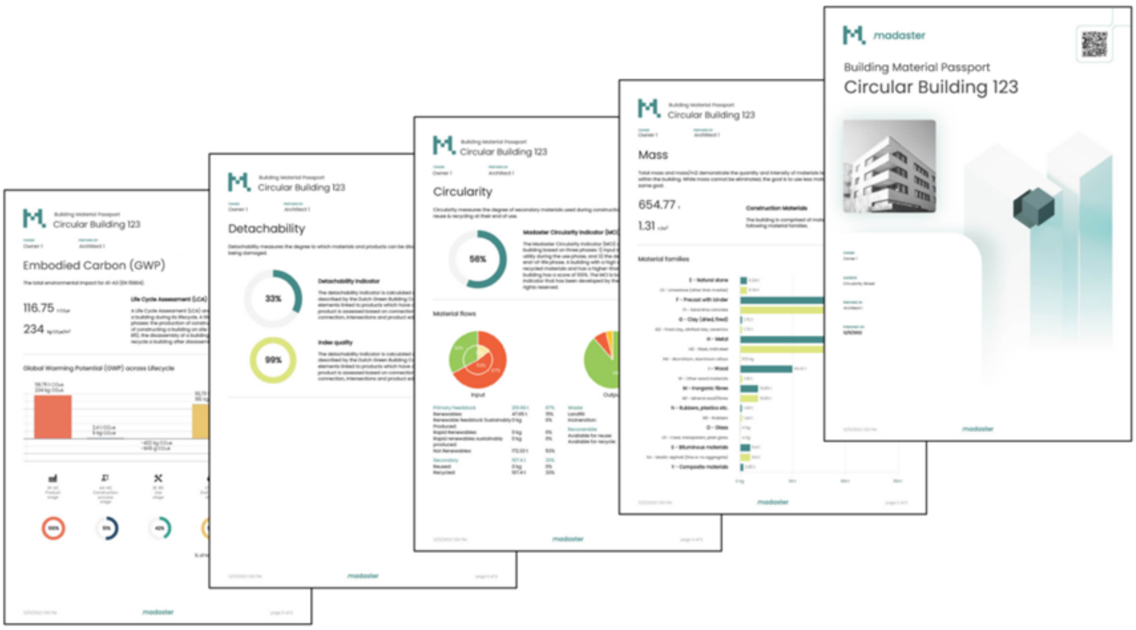

Figure 3. Madaster online library

[1] Madaster: https://madaster.com/

2.3.4.4 Urbanprint

Urbanprint[2], developed by Efficacity, is a software to evaluate the life cycle assessment of the environmental impacts of an urban development project (Figure 4).

Based on a life cycle methodology, the aim is to highlight at each phase of the project the key issues and the most effective action levers, from an Energy/Carbon point of view and by means of complementary environmental indicators on the circular economy, resource depletion, health, biodiversity, etc.

The operating diagram is as follows:

- Modelling of the study area (dimensions, floor area),
- Description of the project (program, strategy) (materials, systems...),
- Calculation (dynamic thermic simulation, LCA)

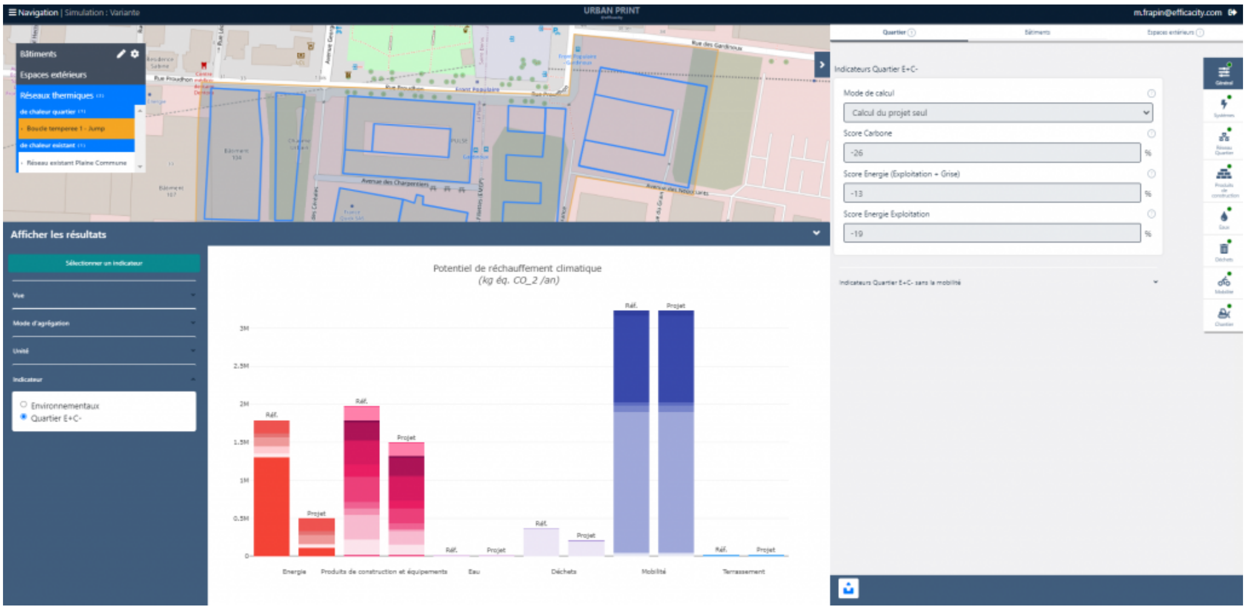

Figure 4. Urbanprint software

2.3.4.5 Citisim

CitiSim is an ITEA3 R&D Project involving industrial Partners and Universities from Romania and Spain in the business of Smart Cities.

CitiSim Smart Services Platform integrates sensors and other data sources for continuously monitoring multiple variables of the city, and it also develops technical solutions for 2D/3D data visualization, simulation and interaction useful for different stakeholders. Use cases:

- Smart Energy Business Intelligence

[2] Urbanprint: https://efficacity.com/quartiers-bas-carbone/nos-logiciels/urbanprint/

The Business Intelligence Tool (Figure 5) is a service for simulating the financial viability of ESCO investments.

- Energy consumption / production data
- Environmental data
- ROI, NPV, IRR
- Scenario comparison

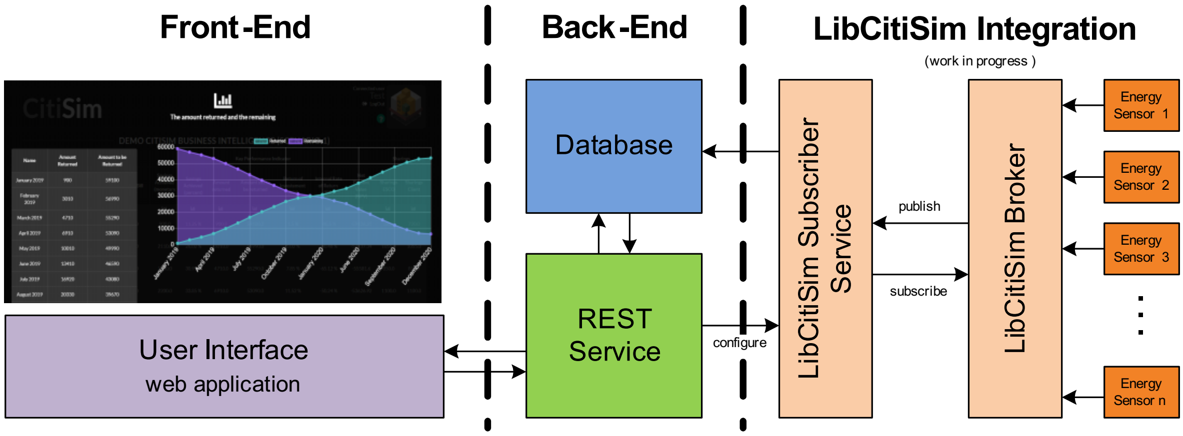

Figure 5. CitiSim Business Intelligence Tool

- Urban mobility and citizen reporting service

By using E.M.A., as a Smart Mobility Service (Figure 6), environmental and motion parameters (CO2, Alcohol Concentration, Temperature, Humidity, Air Quality, Dust, Speed, Accelerations, Rotations, etc) are continuously measured and stored for any user context, insightful visualizations being provided through a mobile and a web application.

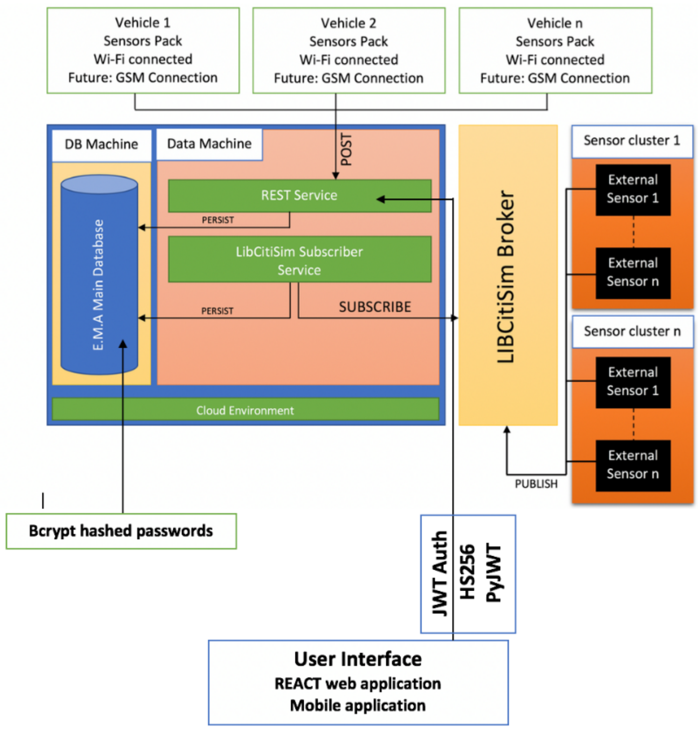

Figure 6. CitiSim Smart Mobility Service

By using the CitiSim incident reporting tool (Figure 7), citizens can report events (location + picture / info regarding the incident), which will be reported to public authorities. These incidents can also be viewed by other app uses, for example in case of life-threatening situations.

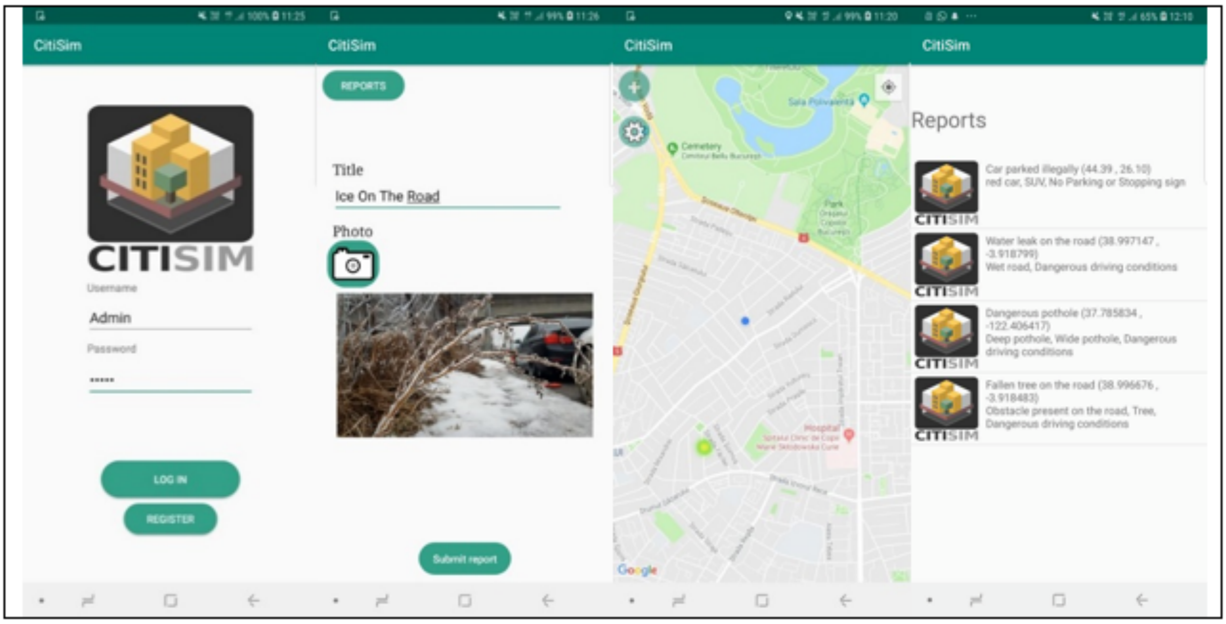

Figure 7. CitiSim citizen reporting

2.4 Conclusions

This section presented the state-of-the-art analysis on several existing tools on stock and flow materials, which could help to discern development opportunities for CREATE project and sources of information by identifying gaps in the literature.

The *Evalmetab* tool developed in France is maybe the one most aligned with CREATE project objectives. Based on BRGM-CSTB data of 2012 (very generic data for material composition of buildings in France)

LCA tools represent a very competitive sector. Business practices are increasing constantly to involve sustainability, climate change, and the circular economy. As a result, the market for LCA tools is growing rapidly.

3 REQUIREMENTS IDENTIFICATION OF THE DATA GATHERING PLATFORM

3.1 Summary of stakeholder needs

Work in WP2 comprised three interrelated exploration methods: literature review, interviews with key actors and an online questionnaire.

The results from Deliverable D2.1 “Stakeholder practices and needs” confirm the interest of better producing and sharing data on material stocks and flows at an urban scale (project or territory) as a decision support for urban development projects or urban planning.

Some ideas appear from case studies in living labs:

- Be interoperable with internal systems & added value to existing information
  - Urban building database + infrastructure;
  - Demolition data (demolished surfaces);
  - In reality very few BIM data;
  - Other data that cities ignores.
- Evaluate circular economy strategies
  - Evaluate scenarios;
  - Evaluate impacts of circular economy strategies (carbon, resources…).
- LCA is being performed at construction material level, building level and in some cases at project level

3.2 Requirements and KPIs definition

3.2.1 Living labs status

From WP2, D2.1 “Stakeholder practices and needs” studies, the following results were observed based on the literature review, semi-structured interviews, and questionnaire:

- <u>Practices of the living labs in terms of circular economy</u>

The three municipalities (Rennes Métropole, Nijmegen, and Gothenburg) have objectives for circular economy at national level, which are either provided in a separate document or included in a larger plan. Usually, they wish to go beyond this framework and establish more challenging targets. When it comes to circular economy, municipalities mostly target carbon emission reduction when speaking of circular economy.

To increase awareness, set voluntary goals, and identify cooperative solutions, local strategies are designed in collaboration with local businesses in the construction industry (developers of urban and construction projects, producers of building materials, and waste management). At the building level for construction projects, environmental assessments based on a lifecycle approach are frequently employed and help to achieve circular goals more effectively. Currently, there aren't many environmental studies carried out at the urban project level, but they are becoming more prevalent.

- <u>Barriers/Levers for Circular Economy in construction</u>

For the three living labs, there are four main obstacles to the circular economy in the building sector: *legislation, cost, a lack of skills and activities, and knowledge.* Municipalities note that certain practices and knowledge necessary for reuse and recycling are frequently lacking in their city.

The development of reuse/recycling practices is one action that can be encouraged. Setting and achieving goals with local stakeholders in the building sector depends on the plans and programs that cities establish.

Data and information are also essential for decision-making. To achieve some circular goals, environmental assessments at the building level are used. It is helpful to better understand local problems and increase awareness through larger-scale investigations like metabolic studies.

Other obstacles and levers could be seen, but they are not mentioned here because the CREATE project's focus is on the tools, studies, and data needed to enable circular economy in the construction industry.

- <u>Tools and studies used to implement circular policies and projects</u>

Although some urban metabolism studies are noted, few studies are conducted at the city level. These studies include some details on the material stock that are now in existence as well as occasionally on present and potential flows (consumption and waste), as well as local construction industry players. All local stakeholders can access the data generated by a metabolism study online.

Some studies are carried out at the level of urban projects and occasionally use a lifecycle approach. They seek to discover the local renewable resources that are readily available or to better anticipate future flows generated by the urban project. Most studies conducted nowadays are lifecycle-based and realized at the building level. They occasionally make mention of a full circular economy framework (with various criteria including building flexibility).

- <u>Needs in terms of tools and data</u>

Statistics regarding all material inflows (materials utilized) and outflows (waste created) at the municipal level are expressed in terms of needs.

A second set of information is required about the accessibility of regional primary and secondary resources as well as the effects of these materials on the environment. Another concern addressed is the price of employing secondary resources. To better optimize the current building stock and minimize flows, it is also essential to better understand how buildings are used.

In terms of technological or logistical answers to reuse or recycle secondary materials.

Table 2 presents the requirements of the data visualization platform based on the work results in Deliverables D2.1 and D2.2 from WP2.

Results of task 2.1 and the focused workshops and complementary interviews carried on in Task 2.2 show that the living labs of the CREATE project (Göteborg, Nijmegen and Rennes Métropole) and the multiplier city (Vienna) share some common points about some challenges, barriers, practices and needs of data and tools relating to the implementation of circular economy strategies in the construction sector. For instance, a variety of barriers regarding issues such as lack of knowledge and information (information on potential secondary resources which is missing or produced/shared too late to help decision making) can be observed for all the living labs.

However, each city also has some very specific practices and needs. Indeed, for Rennes Métropole, the main challenges for circular economy in the construction sector are to include CE criteria in the decision making of urban projects at the predesign and design stages and to support the development of business offers for reuse and recycling and the production of local materials or materials with lower environmental impact. In Göteborg, the main challenge is to set ambitious objectives at the local level about secondary material reuse and therefore to better share information on potential secondary materials for reuse. In Nijmegen, it is to assess at the region/city level the impact of CE practices of each construction project (real objectives reached, impact at city level) Therefore, in order to address those specific needs, 4 different action plans are developed.

These actions are defined in this report firstly by analysing for each city the questions related to the new data that could be produced during the CREATE project (data about stocks and flows of construction materials and their environmental impacts), in particular information about which data, why, when, who would produce and use the data, who could also have access to the data, and identified challenges and enablers. Answers to these questions lead to the definition of an action plan for data production for each city which includes specifications for each task of the plan about its objective, content (what), organizations in charge (who) and timeline (when).

TABLE 2. Requirements for the development of the visualization tool

Category	Requirements
	• Data on the flows of materials, potential waste, and associated environmental impacts generated by different scenarios in an urban project (e.g., demolishing or refurbishing a building, using timber or concrete). • Material intensity data for non-residential buildings. • Data about stocks of materials in all buildings in Göteborg, future availability of secondary construction materials and components for reuse, and associated environmental impacts. • Data about environmental impacts related to outflows from stocks.

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- Data about the circularity of the Hezelpoort project based on the Circulair Impactladder framework.
- Data about the impacts and feasibility of circular economy concepts in the Rothneusiedl development area.

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<tr><td rowspan="4">Tool development</td><td>

<u>**Main Functions**</u>

1. **Scenario Parameter Setting**
    - Ability to set parameters for various scenarios related to materials in urban projects (e.g., demolishing or refurbishing a building, using timber or concrete).
2. **Scenario Comparison for Decision Making**
    - Visualization of impacts of different scenarios at predesign and design stages.
    - Comparison of scenarios based on key criteria/indicators about material resources and environmental impacts.
3. **Calculation of Data on Flows and Impacts**

Support calculation of data related to material flows and environmental impacts (functionality to be confirmed).

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<u>**Information Sharing Features**</u>

- **Types and/or Mass of Materials**
    - Information about the types and/or mass of materials in buildings to be refurbished or demolished.
- **Associated Environmental Impacts**
    - Data on the environmental impacts associated with these materials.
- **Building Ownership**
    - Information on building ownership.
- **Building Location and Footprint**
    - GIS data to show building location and footprint on a map.
- **Key Building Information**

Details such as construction year, structure, and number of floors.

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<u>**Data Management and Interaction**</u>

- **Data Entry by Project Owners**
    - Project owners can directly add data, such as building diagnosis about materials, refurbishment/demolition permits, and other relevant information.
- **Interactive Platform**
    - The platform should be interactive, allowing data entry and updates by project owners in real-time.

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<u>**Support for Circular Economy (CE) Strategies**</u>

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	• **Assessment of CE Impacts**
	  ○ The tool should help the region and city set specifications to assess CE impacts of all projects using data collected.
	• **Integration with Circular Impact Ladder**
	  ○ Integrate with the Circulair Impactladder framework for assessing circularity impacts.
	• **Modeling for Decision Making**
	  ○ Provide a basis for decision-making to implement circular economy strategies and policies.
	  ○ Couple existing stock and flow data with life cycle assessment methods to derive potential impacts of CE strategies, particularly modeled on the Rothneusiedl case study.

The desired/expected features of the platform should include decision making functions:

- Comparing the impacts on i) flows of scenarios materials required, availability, cost, environmental impact and ii) waste flows scenarios according to different waste management strategies;
- Support project developers to design (demolish/refurbish) and choose the best materials and waste management solutions according to different criteria and scenarios by considering local issues (stocks of primary and secondary resources and material use at the urban level), facilities (extraction sites, waste recycling site…), potential synergies between construction sites (common materials, flows generated at the same time, short distance...).

4 KPI DEFINITION FOR THE LIFE CYCLE ASSESMENT FOR BUILDINGS

Similar to a product LCA, a whole building LCA treats the building itself as the product[3]. This thorough method encompasses all the materials and elements that make up a building, evaluating their environmental impacts across the building's entire life cycle. Buildings are constructed with a long life span in mind and can serve various functions over time. This makes applying Life Cycle Assessment (LCA) to buildings particularly challenging, as LCA was originally developed for evaluating simpler products.

Life Cycle Analysis (LCA) can only evaluate quantifiable metrics like carbon emissions, often giving greater weight to these aspects in decision-making. Consequently, LCA might overlook impacts that are difficult to measure or not well understood, such as plastic pollution or the long-term consequences of landfill runoff. For instance, LCA struggles to accurately assess the environmental advantages of reuse models for plastic packaging compared to disposing of single-use plastics in landfills, where, from a carbon standpoint, landfills might be considered a form of 'carbon storage'.

Why is building LCA important? Buildings cause 39% of global carbon emissions. Construction professionals and investors need to take responsibility for the environmental impact of their projects and portfolios[4].

The EU action plan for the Circular Economy [5]aims to promote the transition to a more circular economy, where the values of products and materials is maintained in the economy for as long as possible, thus minimizing the production of waste and reducing/avoiding the extraction of new resources.

The main barriers in the construction sector towards the circular principles are the lack of appropriate design methodologies to enable a better use of C&DW and the lack of links and cooperation between the long chain of stakeholders in the construction process[6].

A comprehensive whole building LCA includes the entire range of materials and components used in the construction, operation, and demolition of a building. This encompasses everything

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[3] Life Cycle Assessment for the circular economy : https://www.ellenmacarthurfoundation.org/life-cycle-assessment-for-the-circular-economy

[4] https://oneclicklca.com/en/resources/articles/10-essential-facts-about-building-life-cycle-assessment

[5] COM(2015) 614 final, Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the regions, Closing the loop – An EU action plan for the Circular Economy, Brussels.

[6] Bohne, R., Wærner, E., Barriers for Deconstruction and Reuse/Recycling of Construction Materials. Nakajima, S; Russell, M. (Eds.), CIB Publication 397, pp. 89-107, CIB General Secreteriat, 2014.

from the foundation, structural elements, and insulation to finishes, fixtures, and systems like HVAC (heating, ventilation, and air conditioning).

Stages of the Building Life Cycle:

- Design and Planning: Impact assessment starts from the initial design and planning phases, considering the choice of materials and construction techniques.
- Construction: Evaluates the environmental impacts associated with the extraction, production, and transportation of materials, as well as the construction process itself.
- Operation and Maintenance: Assesses energy and water usage, maintenance requirements, and the replacement of building components over the building's service life.
- End-of-Life: Includes demolition, waste management, recycling, and disposal of building materials.

Simplified Whole Building LCA

- Focus on Major Materials: To simplify the LCA process, it may focus on materials with the greatest abundance or those with the most significant environmental impact, such as concrete, steel, insulation, and major finishes.
- Reduction of Complexity: This approach reduces the data collection burden and computational complexity, making the assessment more manageable while still providing valuable insights.
- Selective Life Cycle Stages: Simplification may also involve focusing on specific life cycle stages. For example, assessing only the construction phase or the operational phase, depending on the primary objective of the LCA.

Application and Benefits of the whole building LCA:

- Decision-Making Tool: Whole building LCA provides critical insights for architects, engineers, builders, and policymakers, helping them make informed decisions to enhance sustainability.
- Environmental Impact Reduction: Identifies key areas where environmental impacts can be minimized, such as choosing low-impact materials, optimizing building design for energy efficiency, and planning for effective end-of-life recycling.
- Performance Benchmarking: Allows for benchmarking against other buildings, setting performance targets, and tracking improvements over time.

Whole building LCA concepts can also be put to a range of uses, such as:

- Providing insight into design and material selections for buildings (including new products).
- To demonstrate the advantages of refurbishment versus demolition + reconstruction;
- To compare structural systems and finish choices for reduced environmental impact;
- To achieve an LCA-based certification or to make environmental claims about buildings;
- To provide decision support for policy design, including the introduction of new building technologies;
- To provide guidance on product and process development, marketing, and selection of suppliers or subcontractors.

As a brief introduction to LCA, the standard methodological framework for conducting LCA consists of goal and scope definitions, life cycle inventory analysis, life cycle impact assessment, and interpretation[7].

According to the EN 15978[8] standard, the life cycle stages for a building (Figure 8) include product stage (i.e. raw materials supply, transport to production site, and manufacturing), construction stage (transport to construction site, and construction), use stage (emissions during use, maintenance, repair, replacement, refurbishment, operational energy and water use), and end-of-life stage (de-construction/demolition, transporting wastes to sorting/recycling or to end-of-life disposal sites, waste processing, and disposal). There are generally three methods used to conduct LCA: process, economic input-output, and hybrid methods[9],[10].

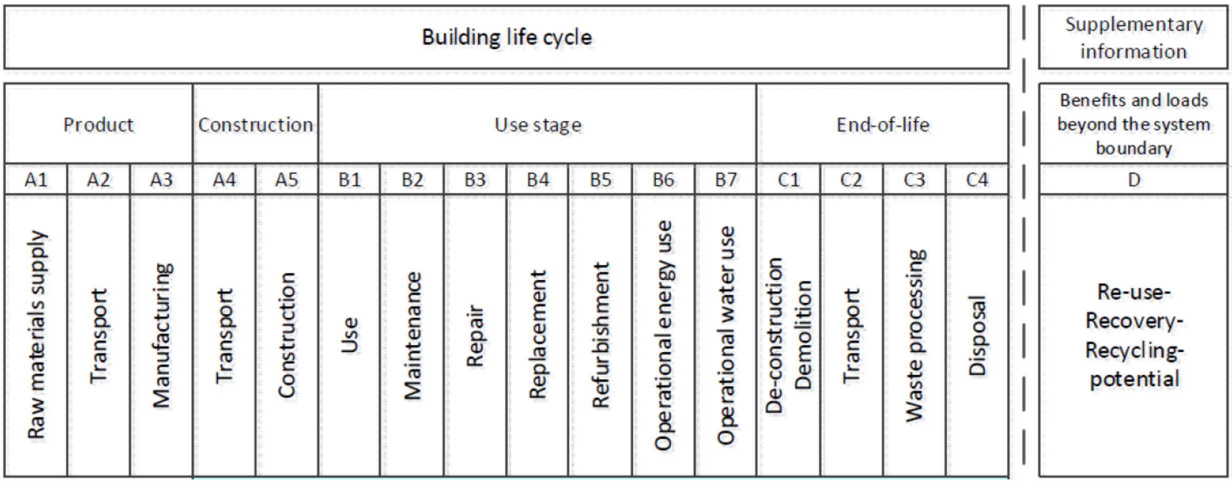

Figure 8. Life Cycle Stages for Buildings

Environmental Building Performance (EBP) is commonly quantified using eight indicator categories: energy, emissions, water, waste, land/building area, building materials, indoor environmental quality, and reuse/recycling potential. Most studies emphasize energy and emissions indicators, while there is a noticeable lack of research on indoor environmental quality and reuse potential, highlighting gaps in the existing research. Considering the interdependencies among these categories, EBP evaluations should encompass all identified categories, not just energy and emissions. Additionally, to effectively quantify EBP, it is recommended to clearly define the building life cycle and consider various operation and maintenance scenarios[11].

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[7] ISO. (2006). 14040: Environmental management–life cycle assessment–principles and framework. London: British Standards Institution.
[8] EN, B. (2011). 15978: 2011. Sustainability of Construction Works—Assessment of Environmental Performance of buildings—Calculation Method.
[9] Säynäjoki, A., Heinonen, J., Junnila, S., & Horvath, A. (2017). Can life-cycle assessment produce reliable policy guidelines in the building sector? Environmental Research Letters, 12(1), pp. 013001.
[10] Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., & Suh, S. (2009). Recent developments in life cycle assessment. Journal of Environmental Management, 91(1), pp. 1-21.
[11] Maslesa, E., Jensen, P. A., & Birkved, M. (2018). Indicators for quantifying Environmental Building Performance:

To draft a simplified LCA, Key Performance Indicators (LPIs) that assess the potential human and ecological effects of energy, water, and materials usage and the environmental releases can be used as a basis[12]. Based on the information presented above and on the stakeholders needs identified in Deliverables D2.1 and D2.2, Table 4 present the identified KPIs for the CREATE visualisation tool.

Table 3. KPIs to be addresses in the CREATE visualization tool

KPIs	Description	Target Value
Materials usage effectiveness	The amount of materials effectively used in the construction	95 %
Construction use of recycled and biobased materials	Increase percentage	10%
Waste management	Percentage of reduction	15 %
Optimisation of transport routes	Time reduction leading to reduced carbon footprint	10 %
Energy Consumption	Optimisation of energy usage	15%
Water management	Optimisation of water usage at construction site	15%

A systematic literature review. Journal of Building Engineering, 19, 552-560. https://doi.org/10.1016/j.jobe.2018.06.006

[12] DGNB System – New buildings criteria set - ERSION 2020 INTERNATIONAL - ENV1.1 / BUILDING LIFE CYCLE ASSESSMENT

5 GENERAL CONCLUSIONS

Deliverable D3.1 “Requirement Analysis Report” presented a state-of-the-art analysis on several existing tools on stock and flow materials, which could help to discern development opportunities for CREATE project and sources of information by identifying gaps in the literature according to a multi-criteria grid.

The requirements of the data gathering platform were presented in accordance with the results of WP2, D2.1 “Stakeholder practices and needs” which presented the results of the literature review, semi-structured interviews, and questionnaire.

Moreover, a list of KPIs for the life cycle assessment of buildings is presented. The interpretation of the results of an LCA study is often complex, and making this information more accessible remains a real challenge.

Considering the number of elements and materials available in the context of CE, we settled on basic frameworks for LCA and environmental impact through requirements and KPIs.

The framework of LCA is effectively governed in the three living labs by national construction guidelines/rules. However, the LCA of buildings is primarily influenced by building use during the whole life span and energy performance.