



Creating materials banks  
from digital urban mining

## D1.6 Integration scheme

VERSION 1.0

28 October 2025

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PUBLIC

Associated with document Ref. 101129961

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Creating materials banks from digital urban mining

<b>Deliverable ID</b>	D1.6
<b>Deliverable name</b>	Integration scheme
<b>Lead partner</b>	THUAS
<b>Contributors</b>	CONC, BLOCKM

PUBLIC

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## **DOCUMENT INFORMATION**

<b>Document name</b>	D1.6 Integration scheme
<b>Version</b>	1.0
<b>Due date</b>	31 October 2025
<b>Report date</b>	28 October 2025
<b>Number of pages</b>	24+19
<b>Lead Author</b>	Daniëlle Strydom & Rizal Sebastian (THUAS)
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<b>Dissemination level</b>	Public

## **REVISION HISTORY**

<b>Rev.</b>	<b>Date</b>	<b>Description of revision</b>
0.1	01/10/2025	Initial version
0.2	24/10/2025	Revised draft
1.0	28/10/2025	Final version (approved)

## **DOCUMENT APPROVAL**

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## **EXECUTIVE SUMMARY**

This report explores how auxiliary data and legacy systems can be integrated into the SUM4Re information architecture to support the creation and enrichment of Digital Material Passports (DMPs) and Digital Product Passports (DPPs). While scanning technologies play a central role in capturing detailed building data for reuse, a wealth of existing information is already available before scanning begins. Harnessing this information strengthens the baseline for assessment, guides the scanning process, and enables a more complete and interoperable representation of building materials.

The research addressed the following key question: How can auxiliary data be integrated into the information architecture developed in SUM4Re? In answering this, the report also clarifies the role of legal and economic systems, identifies how calculation tools (notably in the Cirdax platform) support SUM4Re's KPIs, and considers the role of material identification strategies.

The results are:

- An extended information architecture that incorporates auxiliary data alongside scan data.
- An overview of how calculation tools support SUM4Re KPIs, particularly in relation to LCA, circularity, and reuse potential.
- A proposed approach to material identification strategies, supported by legal and economic perspectives to ensure interoperability and scalability.

In sum, the report demonstrates that auxiliary data is not only a complement to scan data, but also a crucial enabler for building a robust, interoperable framework for digital material and product passports. By linking existing data systems through a central identifier structure and integrating them with scan-derived information, SUM4Re advances towards a more reliable and scalable digital ecosystem for material reuse.

## **GLOSSARY**

### **Terms, Abbreviations, and Acronyms**

EC	European Commission
LCA	Life Cycle Assessment
DMP	Digital Material Passport
DPP	Digital Product Passport
IFC	Industry Foundation Classes
BIM	Building Information Modelling
C-BIM	Circular Building Information Modelling
UUID	Universally Unique Identifier

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## 1. Introduction

### 1.1 Background

In SUM4Re, scanning technologies add important building data to material inventories for reuse purposes. However, before buildings are scanned, various sources of building data are already available. This auxiliary information takes three forms:

1. Auxiliary data, which includes all the data pertaining to the building that is already available, for example printed 2D drawings, inspection and demolition reports, photographs, photogrammetry scans and existing BIM models. This can also include data in municipal and national repositories, such as land registers, as well as data stored in legacy systems, for example asset management applications used by building managers.
2. Data pertaining to legal and building regulations.
3. Existing Life Cycle Assessment (LCA) calculations.

This auxiliary information is an important complement to scan data, as it provides a baseline for assessment, informs the scanning process, and can be combined with scan data to ensure a complete assessment and enrichment of Digital Material Passports (DMPs) and Digital Product Passports (DPPs). Additionally, data available from origin and other sources influence the methods used to analyse and incorporate material data into DMPs and DPPs.

### 1.2 Research Question

The key research question addressed in this deliverable is how auxiliary data can be integrated into the information architecture developed in SUM4Re. Additionally, clarification was required as to the role of legal and economic systems, the support of SUM4Re objectives through calculation tools, and the role of material identification strategies.

### 1.3 Objective

The objective was to indicate the possibility of integrating auxiliary data into the information architecture developed in SUM4Re task 1.5 and propose methods for achieving this. Additional objectives were to clarify the role of calculation tools and material identification strategies.

### 1.4 Methodology

In task 1.5 of SUM4Re, a data workflow to integrate scan data into the three platforms used in SUM4Re was made. This workflow illustrates how data can be shared and retrieved between the Concular, Cirdax and Genia platforms.

In this task, an overview of existing auxiliary information and legacy systems for the donor buildings in the three pilot cases of SUM4Re was made. These sources and systems were then integrated into the information architecture developed in SUM4Re task 1.5 to demonstrate how this data can enrich DMPs and DPPs.

Additionally, research was done to identify which of SUM4Re's KPIs could be supported using the calculation tools in the Cirdax platform, and the role of material identification strategies.

### 1.5 Results

The results are an information architecture that incorporates auxiliary data, an overview of how calculation tools support the various SUM4Re KPIs, and a proposed approach to material identification strategies from a law and economics perspective. This architecture is aligned with solutions developed in SUM4Re D6.1, and will be further built upon in work package 7.

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## 2. Overview of existing data and legacy systems in SUM4Re case studies

In order to determine what auxiliary data is available regarding materials in the pilot donor buildings, and how this data complements that obtained from the scanning methods, an inventory was made for each of the pilot donor buildings. This inventory outlines what is already available, in what format, who owns it, and whether its quality is sufficient for use.

The Hague Spiegelstad provides precise geometric and locational information, forming the spatial foundation for linking materials to their real-world context. Matterport scans contribute detailed geometric data along with insights into material surface conditions, visible damage, and deviations from original drawings, also supporting the assessment of accessibility for demolition. 2D drawings serve as a baseline for evaluating material composition and identifying structural changes or deterioration over time. Demolition plans supply information on materials to be removed, their estimated volumes, and associated legal and logistical considerations, offering valuable input for LCA calculations and reuse planning.

The detailed inventories for each donor building can be found in [Appendix 1: Data Inventories for the Pilot Donor Buildings](#).

**Table 1. Overview of auxiliary data and legacy systems used in the donor buildings from the three pilot cases**

Data Item	The Hague, Kindcentrum Binckhorst	Svalbard, Elvesletta Nord – Blokk G	San Sebastian, Vestíbulo de Anoeta	San Sebastian, Zardoya-Otis factory
Ownership history	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Original architectural drawings	<input checked="" type="checkbox"/> Photos of 2D DWGs	<input checked="" type="checkbox"/> PDF	<input checked="" type="checkbox"/> PDF	<input checked="" type="checkbox"/> PDF
Structural plans	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fire safety documentation (relevant to materials)	<input type="checkbox"/>	<input checked="" type="checkbox"/> PDF	<input type="checkbox"/>	<input type="checkbox"/>
Maintenance records	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3D/other scans	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Historical use(s)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Asbestos and hazardous material reports	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Reusable material inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Photos	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Main materials	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Amount of generated waste per LER code	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Demolition process	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Material Recycling Plan	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Estimated rubble (m3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Data Management System/Source	N/A	FAMAC	Tender Dossier	Demolition Project data
Owner	Gemeente Den Haag	Store Norske Boliger AS	Public Administration	MOYUA HOMES

### 3. Calculation Tools for Cirdax

To determine which additional calculation tools or calculation rules are required by the SUM4RE activities, Block Materials examined which of the 19 SUM4RE objectives could be clarified, supported, or alleviated by such calculation tools. To this end, we examined each SUM4RE objective from five perspectives: Data, Alleviation, Labour Productivity, the Role of Time, and Market Strategy. The results are presented in Table 2 below.

This allows us to see how the SUM4RE KPIs can be clarified and whether there are specific analysis results that can be further implemented in the further course of the project using calculation tools in Cirdax. Cirdax has a separate environment for this function, allowing stakeholders to better organize their own project needs and in which further calculations can be made based on data from the materials inventory. This was done, for example, in tasks 1.4 and 6.3, where reference is made to the CO2 calculation tool in Cirdax. An example that could possibly be followed if the results for realising the KPIs for SUM4Re would also give reason to do so.

The results of the analysis are presented in the table below. On the left-hand side, the 19 core KPIs for SUM4Re are listed. Next to it are the findings of the research. A lot of qualifications addressed in the cells in the matrix are already covered by the tools and information that are listed in section 2 or cannot be translated in calculations tools. In the last case the matrix cell is empty. Everything linked to the amount of the value of materials is already covered. The same applies for the integration of time, because of the introduction of UUID's as part of the C-BIM-model.

However, information on inventory strategies, including the use of an inventory tool, for example from WA2, could be translated into a decision-making tool. The same counts for the Material Recovery Potential Index. These are tools that can be part of Cirdax and/or the Concular environment, and can be included in the additional functionalities like described in WP7.

For educational purposes the matrix below could serve as a reference point for presenting the KPIs for SUM4Re in a transparent way.

**Table 2. Analysis of SUM4Re KPIs that can be clarified and supported through relevant calculation tools**

Goals SUM4Re	Data	Allevia-tions	Labour Productivity	The role of time	Market strategy
1: SUM4Re will integrate in 1 interface following an open C-BIM standard (central point for managing, tracking, processing & handling) at least 5 different materials (asphalt, structural steel, reinforced concrete, timber, and concrete), aligned with EEA's benchmark of current standards, maximizing traceability in the lifecycle and interoperability to make the process for secondary materials uses more efficient, transparent, and accessible.	Overview of quantities of asphalt, steel, concrete, reinforced concrete and wood	EEA-benchmark of current standards			How the process for secondary materials can be made more efficient, transparent and accessible.
2: SUM4Re will address the most relevant construction entities, at least 3 different typologies of buildings (residential, tertiary & industrial) and 1 typology of infrastructure assets (asphalts).	Typologies of buildings and infrastructure				
3: SUM4Re will deeply analyse uses for deconstructed materials/products from different perspectives: technological, economic, legal/regulatory, information matching the Waste Framework Directive and the Construction Products Regulation.			Clarifying the information with examples from a information, technological or law and economic perspective.	Clarifying the economic perspective of law with examples for the time aspect	Clarifying economic perspectives with examples
4: The requirements for the extension of at least 2 existing digital materials databases (CIRDAX and CONCLAR) will be set.				Time is implemented using UUID.	

<p>5: SUM4Re will be demonstrated through 3 case studies addressing 5Re of circularity: O7 (Reuse&amp;Recycle), O8 (Reduce&amp;Renovate) and O9 (Reuse&amp;Repair), including service life extension and material banks creation.</p>	<p>Making 5R aspects transparent</p>				
<p>6: The analysis focuses on reviewing the EU legal framework on waste/products legislations that determine how secondary materials must be categorised and treated with a consensus on the waste/non-waste categorisation of the existing materials in 3 countries, and legal status information in material databases.</p>	<p>Making the value of materials transparent</p>		<p>Making the value of materials transparent. Indicate which interventions affect the status of a material, either directly or indirectly (economically). Positive values are products, negative values are waste</p>		<p>Making the value of materials transparent</p>
<p>7: SUM4Re will combine various techniques for characterization before physical intervention: visible (AR-iMMS-RGB) with time reduction of 50% for 3D models generation and materials identification; hidden components and geometric modelling (MFT), harmful materials and chemical-mineral composition (XRF), reinforced concrete structural-mechanical identification (GPR &amp; ECT), and timber pathologies detection (AHS) with an increase of productivity of 90% (real time vs. sample collection and laboratory analysis).</p>	<p>Making the value of materials transparent</p>	<p>Make inventory strategy per object transparent based on initial overview of available materials</p>	<p>Making the value of materials transparent. Indicate which interventions affect the status of a material, either directly or indirectly (economically). Positive values are products, negative values are waste</p>		<p>Making the value of materials transparent</p>
<p>8: Reuse of large structural components will be assessed through the structural condition index (FOS in combination with transfer learning) to</p>	<p>Making the value of materials transparent</p>	<p>Make inventory strategy per object transparent based</p>	<p>Making the value of materials transparent. Indicate which interventions</p>		<p>Making the value of materials transparent</p>

detect structural alterations, reducing time for assessing mechanical behaviour over 60%, when involving repetitive structural patterns		on initial overview of available materials	affect the status of a material, either directly or indirectly (economically). Positive values are products, negative values are waste		
9: Plugin to extend GENIA platform for data acquisition & integration of all the techniques included and for the assessment of structural components in accordance with their recyclability potential.					
10: For heterogeneous CDW composed by multiple mineral fractions, all in-one TRAZIA will characterize material composition and mineral stream. It is composed by LIBS, Raman, RGB-D, NIR, UV. AI will be used to process (identify, quantify and classify) construction materials and assets for a C-BIM. CDW quality control process and/recycled materials with capacity to process 1-3 t/h will be developed and tested in a real case study.	Making the value of materials transparent		Making the value of materials transparent		Making the value of materials transparent
11: Integration of 3 national construction material databases (NCMD) on 2 existing data platforms aligned to EU frameworks for data sharing. The data will be prepared for further analysis on the 'Material Recovery Potential Index' and the EU R-ladder for circular economy.	Researching, making transparent, and visualizing the Material Recovery Potential Index. Putting the R-ladder into perspective.				
12: Implementation LCA and quality improvements of secondary materials	Investigate, make transparent and				Making the value of materials transparent

<p>considering economic, environmental, and social viability. Increase of 3% in the use of secondary materials to be reused at a high quality, at least 5% in pilot demonstrators.</p>	<p>visualize LCA data from the prevention of production of new materials (Module D)</p>				
<p>13: To follow different go-to-the-market strategies to optimize the added value of secondary materials. It will increase the supply of 10% the circular material flows, at least 25% in pilot demonstrators; reducing CDW of 10%, at least 25% in pilot demonstrators.</p>	<p>Making (the value of) materials transparent</p>		<p>Making the value of materials transparent</p>		<p>Making the value of materials transparent</p>
<p>14: To carry out min. 2 rounds of interviews (at least 10 contacts per participant country/round) focused on, i) social acceptance of SUM4Re approach; ii) current know-how in sustainable reuses &amp; CDW management.</p>	<p>Collect information from previous KPIs and make it transparent, so that questionnaires can also be based on data</p>				
<p>15: To transfer the outcomes to representatives of the Commission. At least 10 member states policy actors will be personally contacted for dissemination and feedback</p>	<p>Collect information from previous KPIs and make it transparent, so that policy recommendations can also be based on data</p>				
<p>16: At least, 2 face-to-face &amp; virtual training sessions (sector companies) organized in each participant country (targeted, 50 persons/country).</p>	<p>Collect information from previous KPIs and make it transparent, so that training sessions can also be based on data</p>		<p>Collect information from previous KPIs and make it transparent, so that training sessions can also be based on data</p>		

<p>17: To produce training materials/programmes on 2 different axes (construction materials used in EU regions; smart digital solutions &amp; platforms-construction databases) based on AR/VR for human interaction training and skills development in the construction sector.</p>	<p>Collect information from previous KPIs and make it transparent, so that training sessions can also be based on data</p>		<p>Collect information from previous KPIs and make it transparent, so that training sessions can also be based on data</p>		
<p>18: Reduction of 10% of time needed for circular assessment of the construction project (SUM4Re's solutions vs manual approach).</p>		<p>Make inventory strategy per object transparent based on initial overview of available materials</p>	<p>Repeat labour productivity analysis and questionnaires after 1.5 and 2.5 years to identify differences in insights, data, etc., so that 10% per project can be demonstrated in the project module in Cirdax.</p>		
<p>19: Increased supply of secondary materials in pilots in 25% and reduction in construction CDW in 25% (SUM4Re's solutions vs manual).</p>	<p>Making the value of materials transparent</p>	<p>Make inventory strategy per object transparent based on initial overview of available materials</p>	<p>Making the value of materials transparent. Indicate which interventions affect the status of a material, either directly or indirectly (economically). Positive values are products, negative values are waste</p>		<p>Making the value of materials transparent</p>

### 3.1. On the Importance of Material Identification Strategies and Database Development for Labour Productivity in Building Inventories

In the context of scientific research into material flows, reuse strategies and sustainable building practices, the ability to correctly identify and characterise materials present in existing buildings is of fundamental importance. When conducting an inventory, whether for renovation, demolition, or research purposes, obtaining reliable and comprehensive information about the materials used is a critical step. However, this process can be both time-consuming and labour-intensive. To improve efficiency and reduce duplication of effort, it is essential to develop systematic approaches to material identification, supported by structured data collection and long-term knowledge management.

Two complementary strategies can be distinguished in this regard.

The first strategy focuses on tracing the origin of the product by identifying the original manufacturer. Once a product can be reliably linked to a known producer, a wide range of technical documentation becomes accessible, that may be already or could be part of a Digital Product Passport. This may include product data sheets, material safety data sheets, environmental product declarations, and other relevant factory-issued specifications. These documents typically contain detailed information regarding the composition, performance, treatment, lifespan and recyclability of the product. As such, identification of the manufacturer allows researchers and practitioners to gain substantial insight with relatively limited effort. The ability to make this link quickly and accurately contributes significantly to labour productivity, as it avoids the need for extensive physical or laboratory-based analysis.

The second strategy applies when the original manufacturer cannot be determined—for example, in older buildings, or in cases where materials have been modified or repurposed. Here, the approach must rely on the direct observation and recording of material characteristics using available technologies. This may involve visual inspection, material sampling, spectroscopy, 3D scanning, non-destructive testing, or other forms of on-site data collection, like the research that is performed in WA2 of SUM4RE. The findings can then be compared against industry standards and classification systems to infer material types and properties. Although more flexible and widely applicable, this approach requires more time and specialised labour, thereby affecting project timelines and cost structures.

For this reason, it is of strategic value to invest in the development of a comprehensive and accessible database containing verified material profiles. Such a database functions as a central reference point, enabling practitioners to compare newly inventoried materials with existing data. The more extensive the database, the more likely it is that future materials can be identified efficiently via similarity matching or classification. This reduces the need for full analyses in each individual case and shifts the practice from project-specific problem solving to knowledge-based decision making and the integration of data, including the use of UUID's and C-BIM. We have made a start with this approach in task 1.5 and 6.1, which will be further elaborated in WP7.

Database development should thus be regarded as an essential investment in improving long-term labour productivity. By reducing redundant work, shortening identification time and standardising procedures across projects, the database streamlines the inventory process and ensures that knowledge gathered in one setting becomes applicable in others. Particularly in large-scale material inventories or initiatives aimed at circular construction, the reuse of material knowledge across contexts is crucial to achieving scale and systemic impact.

### 3.2. Strategic Considerations in the Selection and Recording of Material Characteristics

The distinction between the two identification strategies—either matching a material to an existing entry or developing a material profile from scratch—has direct consequences for the

kind of data that must be collected during a building inventory. These two approaches differ not only in effort and resource intensity, but also in the informational focus they require.

In cases where the goal is to match a material to an existing database entry or to manufacturer-issued documentation, it is important to focus on those characteristics that are most likely to support reliable identification. These may include visual aspects such as colour, texture, finish, or form factor, as well as standardised dimensions, visible markings, contextual clues or remaining product labels. The aim here is to collect a limited but discriminating set of data points that enable confident comparison with previously catalogued materials. Efficiency is achieved through targeted precision: comprehensive profiling is unnecessary if a match can be made with selective traits.

Conversely, when no match is expected—due to the material's age, rarity, damage, or lack of documentation—a more comprehensive profiling strategy is required. This involves documenting a broader range of physical, chemical and mechanical properties, like describes earlier under 1.6.2. considering the information and calculation tools we are still missing. Such properties may include strength, composition, density, ageing behaviour and environmental performance. Where applicable, this data is gathered via in-situ measurements or laboratory testing, in line with WA2 of SUM4Re. Though resource-intensive, this process results in a robust and reusable database entry, contributing to future matching efforts.

The decision regarding which characteristics to document should therefore be informed by the anticipated outcome: is the objective to identify an existing product, or to establish a new material profile? Being aware of this distinction not only helps allocate resources effectively but also ensures that the collected data is consistent, relevant, and usable in subsequent analyses. Over time, this strategic approach strengthens the database, thereby enhancing the accuracy and efficiency of future inventories.

## 4. Legal and economic added values of reusable materials

### 4.1. Legal Classification and Certification Challenges in the Context of Material Reuse

In addition to technical and procedural factors, material inventory efforts are constrained by legal frameworks that define how materials may be reused. A critical legal distinction is that between waste and product, like we have seen in task 1.2 of SUM4RE. This classification is not merely terminological: it determines the administrative and procedural burden associated with the reuse of a material.

According to prevailing regulations, materials removed from buildings are often classified as waste unless they can be clearly identified, verified as safe, and shown to be suitable for reuse. This legal designation triggers obligations in terms of transport, handling, treatment and sometimes disposal. Moreover, waste may not be reintroduced into the market without undergoing formal requalification or certification.

This creates a significant paradox. While sustainability goals increasingly advocate for material reuse, the regulatory system tends to impose stricter requirements on reused materials than on newly produced ones. In the case of factory-new products, certification is generally applied at the process level. If the production process is certified, all resulting products are assumed to conform to standard performance benchmarks, making individual certification unnecessary.

However, materials encountered in buildings typically lack such provenance. Once removed from their original context, they are treated as discrete entities without a documented production history. This often necessitates individual testing and certification, significantly increasing the labour and administrative burden and discouraging widespread reuse.

To enable the practical and scalable reuse of materials, it is therefore necessary to develop credible alternatives to full documentation. A robust and trusted material database can play a central role in this regard. If regulatory authorities accept database-backed identification and verification as a valid proxy for factory certification, this could enable materials with limited traceability to be legally reclassified as products rather than waste.

Such a system would require coordinated efforts between the research community, industry stakeholders and regulatory bodies to establish criteria for database validation, expert endorsement and material equivalence. Over time, a database structured around verified profiles and successful reuse cases could serve not only as a research tool but also as an operational and legal resource, helping bridge the gap between practice and regulation.

### 4.2. Conceptual Basis for a Decision Flow Guiding the Use of Tools and Equipment in Material Inventories

Given the diversity of available technologies in building inventories—from hand-held scanners and mobile spectrometers to imaging tools and destructive sampling methods—a structured approach is required to determine the appropriate sequence and combination of tools. This is achieved through a decision flow, which guides practitioners in selecting the right equipment at the right time, based on the objective and expected outcome of the analysis.

The core branching point in this decision flow is again the distinction between matching and profiling. If there is a realistic chance that a material matches an existing database entry or factory-issued product, the priority is to perform a targeted and efficient assessment. In this context, only a limited set of tools may be required—typically those that can confirm visual or dimensional properties with minimal effort. This supports rapid identification and conserves resources.

If a match is unlikely, the process shifts to comprehensive material profiling. Here, the use of tools is both broader and more methodologically layered. Multiple forms of measurement and

analysis are needed to develop a full profile, and the sequence in which tools are applied becomes critical. Some tools may provide preliminary data necessary to justify further investigation, while others may be reserved for specific material classes or use-cases.

The value of such a decision flow is multifold:

- a. It promotes efficiency by avoiding unnecessary analysis.
- b. It ensures relevance by selecting tools appropriate to the material and context.
- c. It enhances standardisation by enforcing comparable methods across teams.
- d. It supports database growth through methodologically sound profiling.
- e. It aligns procedural effort with legal and regulatory needs.

Importantly, the decision flow should not be fixed but adaptable to project-specific constraints, the availability of expertise, and evolving technological capabilities. As the database expands and knowledge accumulates, the decision flow itself can become more refined—thereby enabling increasingly efficient, standardised, and legally compliant material inventories across a wide variety of building contexts.

**The issue regarding Law and Economics is covered and further elaborated in the other SUM4Re deliverables, i.e. D6.2 and D6.3 as well as D1.2 and D1.4.**

## 5. Conclusion: Integration scheme of auxiliary data in SUM4Re information architecture

### 5.1. The decentralized Data Ecosystem and the Role of the UUID

As illustrated in Figure 1, the SUM4Re framework is built upon a decentralized data architecture, not a single, monolithic database. This model allows for specialized, decentralized data storage while maintaining a unified and coherent data profile for each building component through a central identification system. The key to this architecture is the Universally Unique Identifier (UUID).

The process begins with the aggregation of all available data, from modern "scan-to-BIM" files to legacy documents and auxiliary data from external databases. Once this initial data is collected, every relevant product and material identified within the asset is registered in the central UUID system. This critical step assigns a persistent and unique digital identity to each physical object.

This UUID acts as a "golden thread," linking the core entity to a rich ecosystem of distributed data. Instead of storing all information centrally, specialized platforms interact with the system via a Search API. For example:

**CONCULAR** can pull baseline data using an object's UUID to perform in-depth analysis on material properties like reusability, CO2 impact, and market value.

**CIRDAX** can retrieve the same baseline data to calculate circularity metrics and generate formal DPPs and DMPs.

**GENIA** can access the system to visualize the detailed data and associated passports for any given component.

The enriched data generated by these platforms (such as the DPP or a circularity report) resides within their respective systems. However, it is always linked back to the physical asset through the central UUID. This approach prevents data duplication and ensures that the C-BIM can be dynamically enriched with the most current, expert-validated information from multiple sources, creating a comprehensive and actionable digital twin for the circular economy.

### 5.2. Schematic representation of proposed extension of architecture

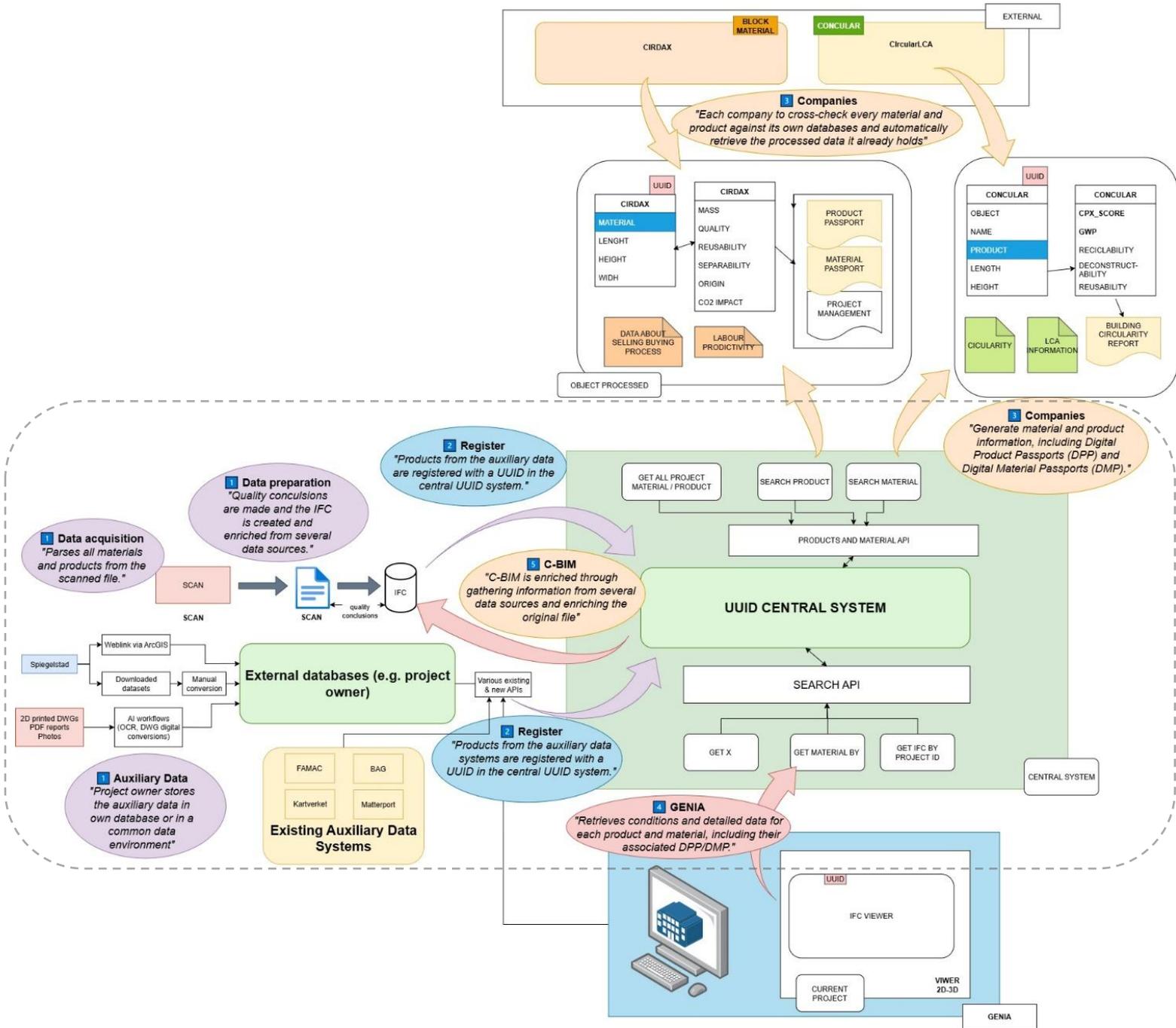


Figure 1. Integration scheme of auxiliary data in SUM4Re information architecture

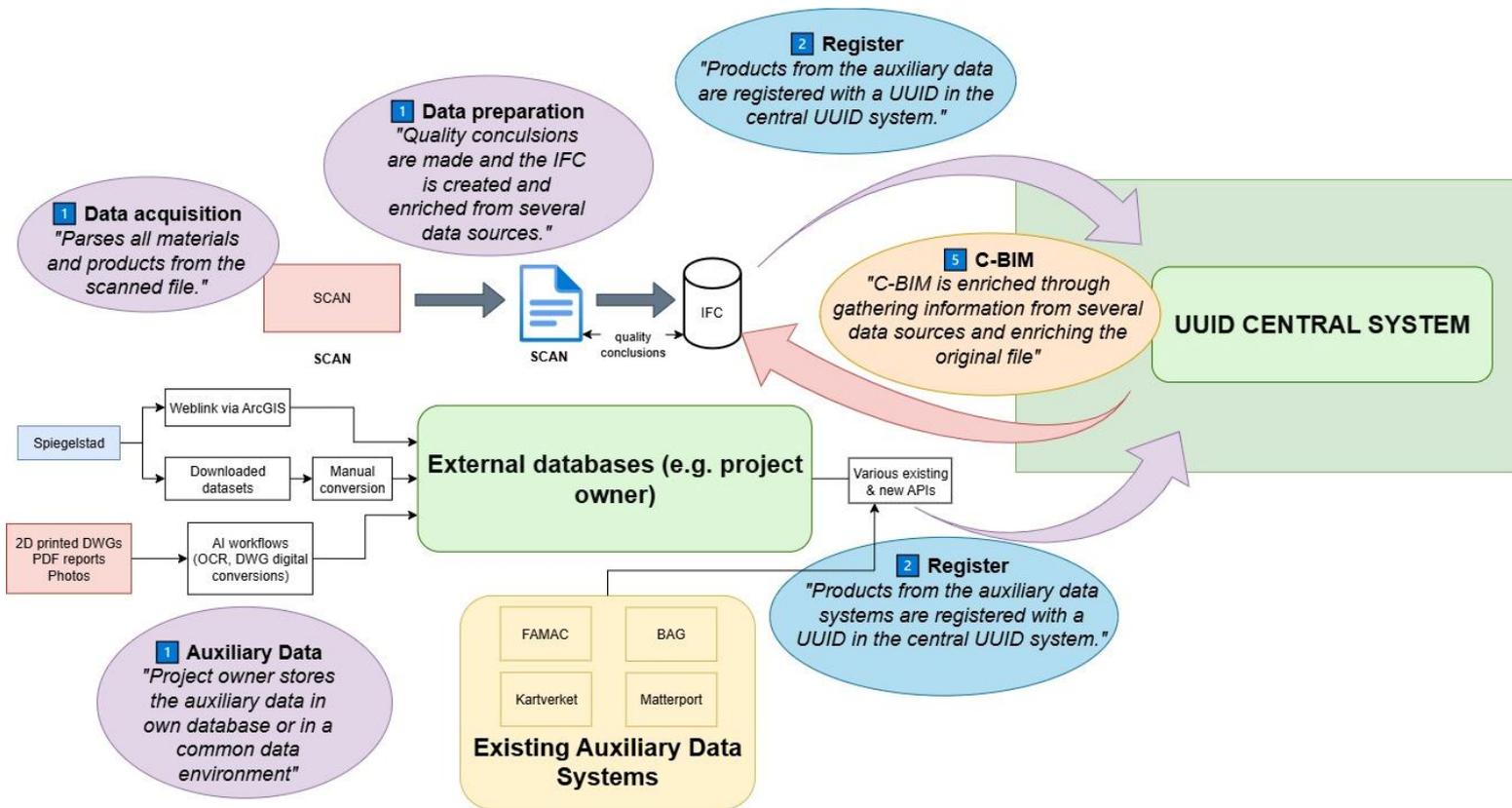


Figure 2. Segment of the information architecture schema focusing on auxiliary data integration

### 5.3. Recommendations for upscaling

To upscale and implement the SUM4Re information architecture, we recommend establishing the UUID system as a shared digital backbone, acting as a neutral service that links data across registries and platforms. This should be supported by crosswalks with existing identifiers (for example the BAG, Kartverket, FAMAC), and standardized data exchange protocols. Importantly, AI-based methods can be applied to extract structured information from semi-structured sources such as 2D drawings, inspection reports, or photographs, enabling this data to be normalized and linked into the UUID system. A clear governance and access framework will be essential to define responsibilities, data rights, and confidentiality. Scaling should proceed progressively, ensuring interoperability, stakeholder incentives, and long-term adoption.



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## APPENDICES

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## APPENDIX A Data Inventories for the Pilot Donor Buildings

### 1.1 Binckhorst, The Hague

City: The Hague

Address: Sint Barbaraweg 4, 2516 BT Den Haag

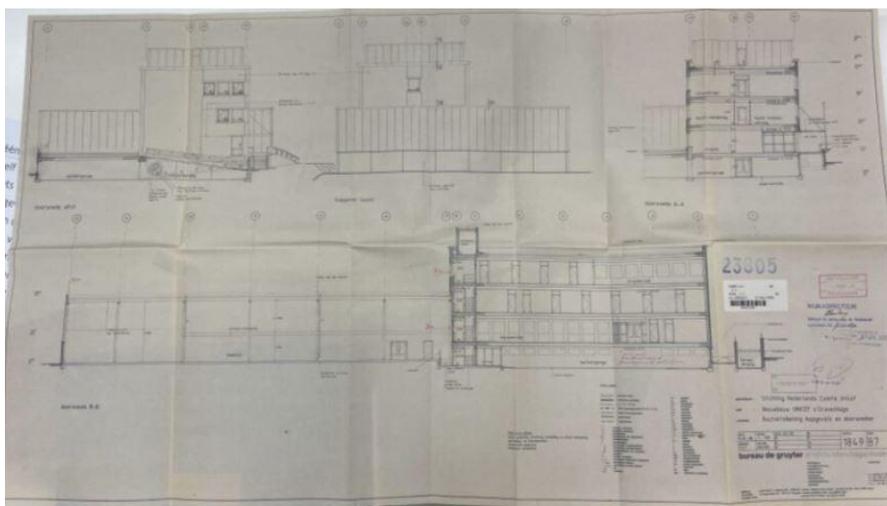
Building Name/ID: Kindcentrum Binckhorst

Pilot Manager: Gemeente Den Haag

Year of Construction: 1992

*Table 1-A. Overview of auxiliary data and legacy systems for the donor building in The Hague.*

Data Item	Available (Y/N)	Owner	Source/System	Format (PDF, DWG, CSV, ...)	Accessibility (Open, Private, Paywall, ...)	Quality (Usable/Not Usable)
Historical use(s) of the building	☒	The municipality	N/A	PDF	Private	Usable
Original architectural drawings	☒	The municipality	N/A	PDF	Private	Usable
Structural plans	☒	The municipality	N/A	PDF	Private	Usable
Photos	☒	Selfmade	N/A	JPEG	Private	Usable



*Figure 1-A. Photographs of 2D drawings of the donor building from the municipal archives of the Gemeente Den Haag.*

### 1.1.1 The Hague Mirror City (Spiegelstad)

The Den Haag 3D Stadsmodel, also known as the 3D Mirror City, is a detailed and interactive digital twin of The Hague, maintained by the municipality and developed using ArcGIS. Since 2010, the city has built a virtual model, publicly accessible as open data since 2017, and fully renewed in 2022 with higher detail, including roof shapes, dormers, extensions, pillars, underpasses, and other urban features. New buildings are continuously added, and the model links objects to real-world locations, providing detailed information such as tree species, street classifications, monuments, and protected city areas. By integrating multiple authoritative data sources - including the BAG, Monumentenzorg Den Haag, and the municipal service department - the platform enables advanced visualization and analysis of the city's infrastructure and environment, supporting functionalities like daylight simulation, weather effects, shadow casting, and line-of-sight analysis for a comprehensive view of urban dynamics.

Datasets from the mirror city can be downloaded, and the webservices can be connected to other applications via links provided by the municipality.

The Hague Mirror City can be accessed here: [The Hague Mirror City](#)



*Figure 2-A. An excerpt from the donor building in The Hague's Mirror City.*

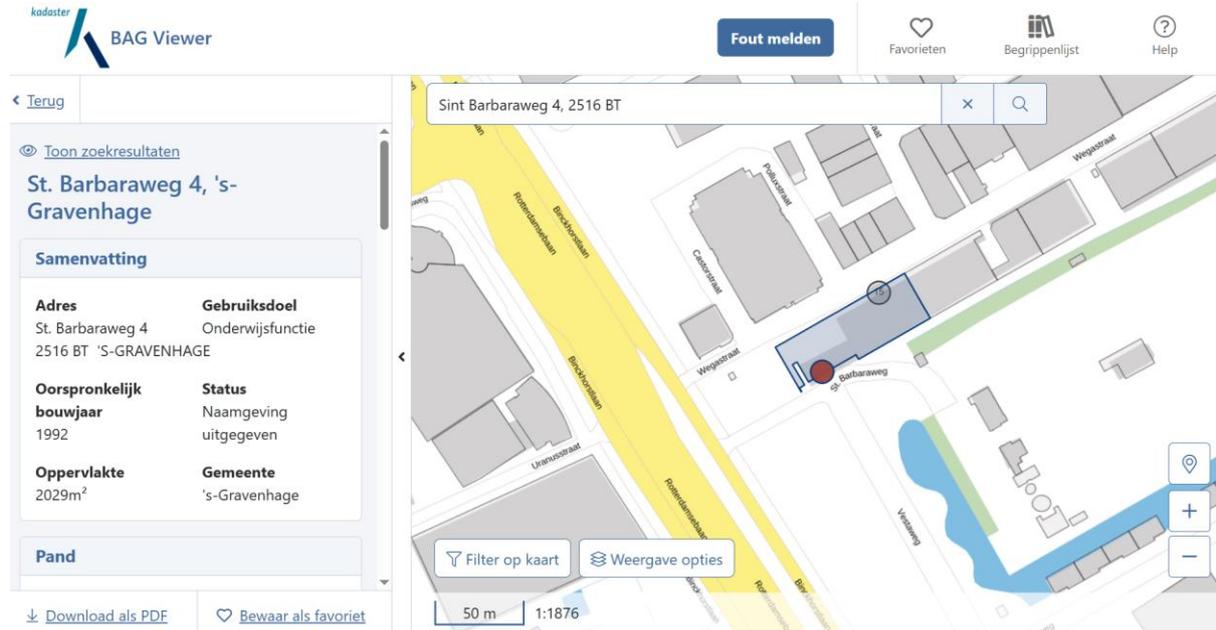
### 1.1.2 The BAG Viewer

The Basisregistratie Adressen en Gebouwen (BAG) is the Dutch national register of addresses and buildings. Managed by the Kadaster, it consolidates data from all municipalities in the Netherlands into a centralized system known as the Landelijke Voorziening BAG (LV BAG). This register includes information on five object types: buildings, residential units, address identifiers, public spaces, and municipalities. Key attributes include:

- building status
- area
- geometry
- coordinates
- construction year
- intended use

A linked dataset for the BAG is available, as well as an existing REST API, both of which can be requested from the owner, *Dienst voor het kadaster en de operbare registers (Rijk)*.

The BAG can be accessed here: [BAG](#)



**Figure 3-A. An excerpt from the donor building in the BAG Viewer.**

## 1.2 Svalbard, Norway

City: Longyearbyen

Address: Vei 509 3, 9170 Longyearbyen, Svalbard

Building Name/ID: Elvesletta Nord – Blokk G

Pilot Manager: Emil Lindberg

Year of Construction: 2006

Type: Donor Building

*Table 2-A. Overview of auxiliary data and legacy systems for the donor building in Svalbard.*

Data Item	Available (Y/N)	Owner	Source/ System	Format (PDF, DWG, CSV, ...)	Accessibility (Open, Private, Paywall, ...)	Quality
Ownership history	<input checked="" type="checkbox"/>	Store Norske Boliger AS	FAMAC	FAMAC	PRIVATE	Usable
Original architectural drawings	<input checked="" type="checkbox"/>	Store Norske Boliger AS	FAMAC	PDF	OPEN	Usable
Fire safety documentation (relevant to building materials)	<input checked="" type="checkbox"/>	Store Norske Boliger AS	FAMAC	PDF	OPEN	Usable
Maintenance records	<input checked="" type="checkbox"/>	Store Norske Boliger AS	FAMAC	FAMAC	PRIVATE	Usable
3D/other scans	<input checked="" type="checkbox"/>	Store Norske Boliger AS	FAMAC	3D	OPEN	Usable

### 1.2.1 The FAMAC System

The FAMAC is a data management that system integrates with several existing software systems and platforms. It also has an API allowing data exchange with the system and other 3<sup>rd</sup> party applications.



Bygginformasjon	
Besøksadresse	, 9170 Longyearbyen
Byggeier	Store Norske Boliger AS
Bygggruppe	Bolig SNB utleie
Gårdsnr.	22
Bruksnr.	535
Seksjonsnr.	
Bygningsnr.	
Risikoklasse	
Brannklasse	
Besøk postnr-/sted	9170 Longyearbyen
Byggnavn	509 3
Eies/Leies/Annet	Eies
Postadresse	
Postnummer	
Kommune	Svalbard
Kommunenr.	2100
Bygningstype	
Tomteareal	0.00 m <sup>2</sup>
Bruttoareal	398.00 m <sup>2</sup>
Bruksareal	0.00 m <sup>2</sup>
Nettoareal	362.00 m <sup>2</sup>
Oppvarmet areal	362.00 m <sup>2</sup>
Antall etasjer	3
Antall kjelleretasjer	
Byggeår	2006
Påbygningsår	
Energikarakter	
Oppvarmingskarakter	
Bygningsbeskrivelse	
Arealbeskrivelse	
Brannobjektkategori	
Brannseksjoner	
Maks tillatt antall personer i bygget	
Lagringstillatelse for brannfarlig vare	

Vis mindre ^

Figure 4-A. An excerpt from the FAMAC system illustrating data pertaining to the donor building.

### 1.2.2 Photogrammetry scan (Matterport)

A photogrammetry scan of one of the buildings have been made with Matterport. This scan allows a 3D walk-through with 360-degree views, making a visual inspection of surfaces possible. Measurements can be made on the platform in both 2D and 3D views, and room areas are automatically calculated.

This can be viewed on the Matterport platform or exported as a .e57 pointcloud.

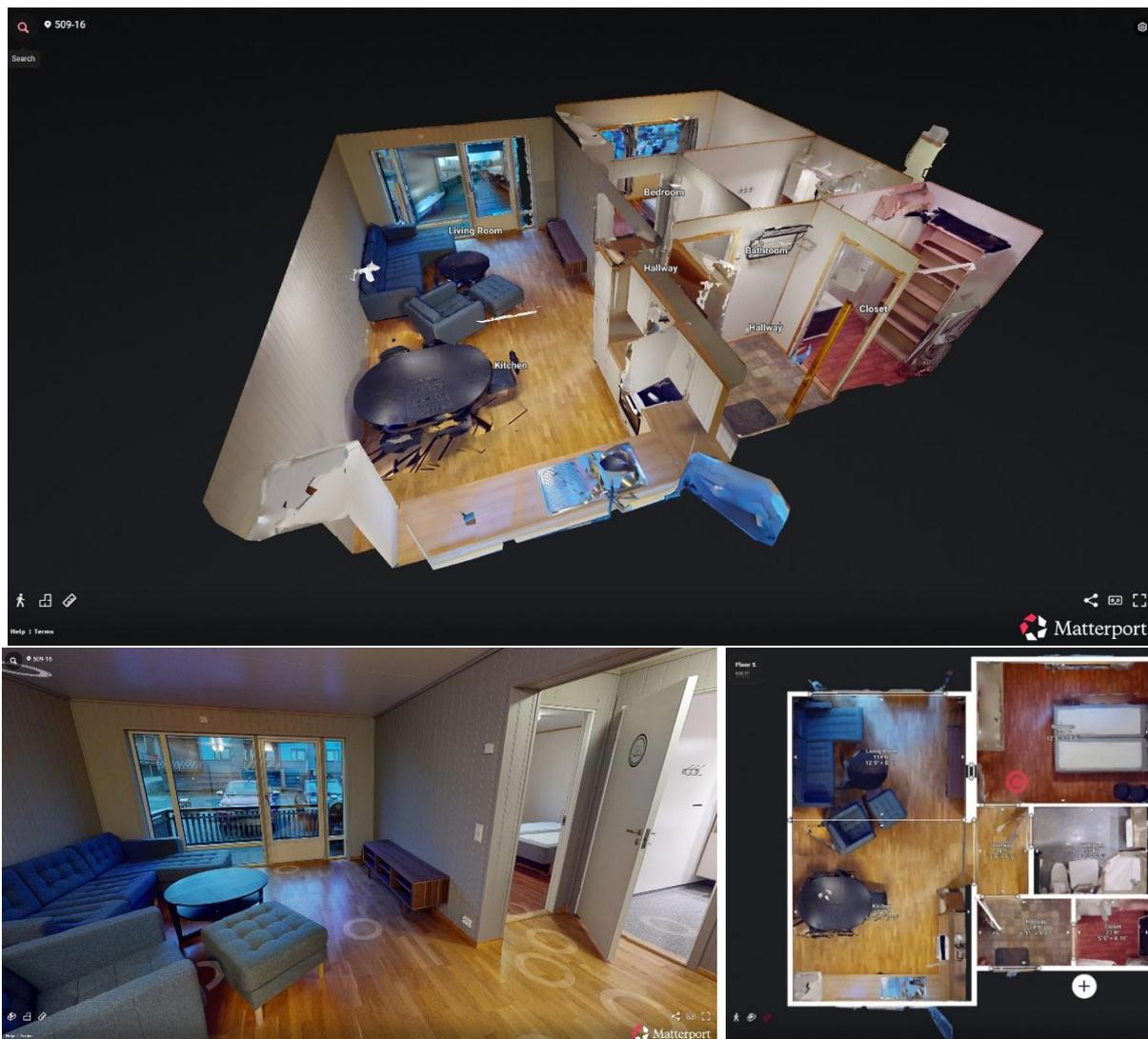


Figure 5-A. Screenshots of the photogrammetry scan of donor building on the Matterport platform.

The Matterport scan can be accessed here: [Matterport Scan](#)

Matterport provides API tools that enable integration with third-party software and direct connections to external back-end systems. These APIs support two-way data exchange and allow actions to be performed within the Matterport model space, including updates to its datastore. They can also be used to automate workflows, generate derived assets and services, and customize the functionality of the 3D player.

### 1.2.3 Norwegian Property Register

The Eiendomsregisteret is Norway’s official register of land and property, maintained by Kartverket (the Norwegian Mapping Authority). It combines data from the cadastral system (“Matrikkelen”) and the land registry (“Grunnboken”) to provide authoritative information about properties. Key data include:

- property boundaries
- area
- address and addresses if multiple units on site
- coordinates
- building presence
- ownership rights
- legal encumbrances

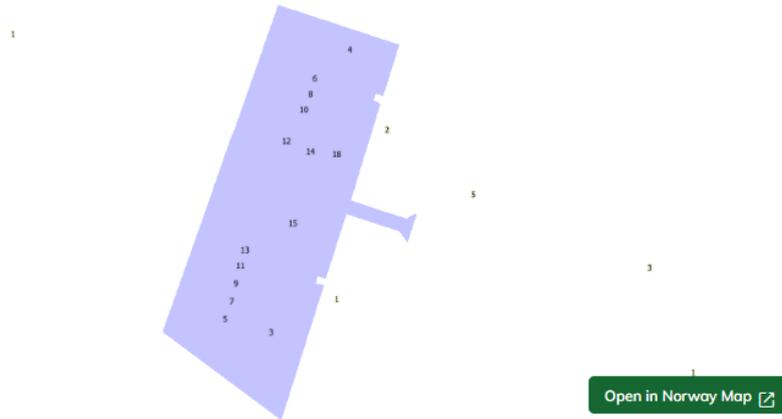
The property register can provide master IDs used to identify buildings in DMPs and DPPs, enhancing traceability and consistency.

The Kartverket system uses open data, accessible via API. It can be accessed here: [Kartverket](#)

**Property 2100-22/535**

The property has multiple addresses.  
SVALBARD MUNICIPALITY

Print Search again



**Information from the land register**

See what is registered on the property [Information](#)

[Show the basic book](#) [Order documents](#)

**More property information**

**Property**

Type <a href="#">Information</a>	Real estate	Coordinates <a href="#">Information</a>	<a href="#">8683133 514606 (32633)</a>
Municipality	2100 SVALBARD	Area <a href="#">Information</a>	10,407.2 m <sup>2</sup>
Farm number	22	Historically stated area <a href="#">Information</a>	15,742.3 m <sup>2</sup>
Usage number	535	Area note <a href="#">Information</a>	
Party reasons <a href="#">Information</a>	No	During merger	No
Sectioned <a href="#">Information</a>	No	Basic pollution <a href="#">Information</a>	No
Username <a href="#">Information</a>		Cultural monuments <a href="#">Information</a>	No
Registered <a href="#">Information</a>	Yes	MUF <a href="#">Information</a>	No
		Land acquisition <a href="#">Information</a>	No
		Land change required <a href="#">Information</a>	No

- Addresses (32)**
- Buildings (15)**
- Teiger (1)**

Figure 6-A. An excerpt of data pertaining to the donor building from the Kartverket platform.



Figure 7-A. An excerpt of data pertaining to the donor building from the Kartverket platform.

### 1.3 San Sebastian, Spain

There are two donor buildings for the pilot in San Sebastian.

#### 1.3.1 Donor Building 1

City: Donostia-San Sebastian

Address: Paseo de Errondo, 20011 Donostia-San Sebastián, Guipúzcoa

Building Name/ID: Vestíbulo de Anoeta

Pilot Manager: Jon Zubizarreta (Pilot manager for SUM4RE related tasks))

Year of Construction: 1993

*Table 3-A. Overview of auxiliary data and legacy systems for the first donor building in San Sebastian.*

Data Item	Available (Y/N)	Owner	Source/System	Format (PDF, DWG, CSV, ...)	Accessibility (Open, Private, Paywall, ...)	Quality
Historical use(s) of the building	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Original architectural drawings	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Asbestos and hazardous material reports	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Reusable material inventory	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Photos	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Main materials	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Amount of generated waste per LER code	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Demolition process	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable
Material Recycling Plan	<input checked="" type="checkbox"/>	Public Administration	Tender Dossier	PDF	Open	Usable

### 1.3.2 Donor Building 2

City: Donostia-San Sebastian

Address: Calle Jolastokieta 1, 20017 Donostia-San Sebastián, Guipúzcoa

Building Name/ID: Old Zardoya-Otis factory

Pilot Manager: Jon Zubizarreta (Pilot manager for SUM4RE related tasks))

Year of Construction: 1919

*Table 4-A. Overview of auxiliary data and legacy systems for the second donor building in San Sebastian.*

Data Item	Available (Y/N)	Owner	Source/System	Format (PDF, DWG, CSV, ...)	Accessibility (Open, Private, Paywall, ...)	Quality (Usable/Not Usable)
Historical use(s) of the building	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable
Original architectural drawings	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable
Asbestos and hazardous material reports	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable
Photos	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	
Building location (coordinates)	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Open	Usable
Main materials	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable
Estimated rubble (m3)	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable
Demolition process	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable
Material Recycling Plan	<input checked="" type="checkbox"/>	MOYUA HOMES	Demolition Project	PDF	Private	Usable

The pilot managers for this use case do not make use of any software applications or specific data management services. All data is stored on local servers (owned by and shared between employees of the company) and data is accessed and managed through standard local folder systems. Each department in the group has its own server or folder system.

The public administration of Spain has all building drawings, from where it can be requested.

### 1.3.3 Demolition Plans

Demolition plans for these buildings typically include the following information:

#### General Project Information

- Project purpose (demolition, waste management, safety requirements)
- Promoter / Owner details
- Project authors / engineering company
- Applicable laws and regulations

#### Location & Site Data

- Address and postal code
- UTM coordinates
- Site boundaries and adjacent streets
- Access routes for machinery and debris removal

#### Building Characteristics

- Number of floors and uses (industrial, residential, offices, garages, etc.)
- Structural system (concrete, masonry, wood, steel)
- Materials used (walls, floors, roofs, carpentry)
- Dimensions: footprint, total built area, volume, and height
- Internal layout (distribution of floors and spaces)
- Construction elements (roof type, facade, staircases, ramps, etc.)

#### Services and Utilities

- Electricity connections
- Water supply and sewer connections
- Gas lines
- Telecommunications and public lighting
- Notes on required disconnections and safety measures

#### Safety and Environmental Aspects

- Identification of hazardous materials (e.g., asbestos/fibrocement, fluorescent tubes)
- Safety regulations and risk prevention measures
- Traffic and pedestrian impact during demolition

#### Waste Management Data

- Estimated volume of debris (m<sup>3</sup> and tons)
- Breakdown of waste types (concrete, brick, wood, metals, plastics, gypsum, asphalt, asbestos, etc.)
- Waste classification (hazardous / non-hazardous)
- Destination of materials (recycling, reuse, landfill)
- Required documentation for waste handling

#### Execution Details

- Sequence of works (pre-demolition, selective removal, mechanical demolition)
- Methods and machinery to be used
- Estimated timeline for works
- Site closures and protective measures

#### Financial Data

- Cost estimation for demolition and waste management
- Breakdown of direct, indirect, and total costs

## Supporting Documentation

- Photographic report of the building and surroundings
- Plans (site layout, access routes, floor layouts, etc.)
- Annexes with legal compliance and waste management plans

### 1.3.4 Waste Management Plans

Waste management plans for construction and demolition are typically drawn up for buildings to be demolished. This plan includes, amongst others:

#### Materials and Waste Data

- Types of expected waste (concrete, brick, wood, metal, glass, plaster, plastics, soil, mixed waste, etc.)
- Hazardous waste identified (e.g., asbestos/fibrocement, oils, chemicals, fluorescent tubes)
- Estimated quantities per material/waste type (tons, m<sup>3</sup>)
- Classification (hazardous/non-hazardous, European Waste Catalogue codes)
- Potential for reuse, recycling, or disposal

#### Environmental and Legal Data

- Regulations referenced (national/regional waste management law)
- Obligations for sorting, documentation, and traceability of waste
- Authorized waste managers or facilities to receive materials

#### Management and Execution

- Handling procedures for waste collection, separation, storage, and transport
- Sequence of demolition / selective dismantling steps
- Required safety measures during waste handling
- Forecast of costs for waste management

This plan includes the estimated volume of waste of specific materials, as well as their classification. This aids in the identification and classification of materials in the DMP and DPP, and serves as input for several calculations. The existing material classifications can also serve as input to the IFC models converted from point clouds.

In the part of the project relating to the road network, the estimated waste is as follows:

LER code	Waste	m3 of CDW	Average density (tn/m3)	Tn of CDW
<b>CDW LEVEL I</b>				
170504	Soil and stones other than those specified in code 17 05 03	684.19	1.25	855.24
<b>RCD LEVEL II Non-rocky nature</b>				
170302	Bituminous mixtures containing coal tar <10%	316.83	1.3	411.88
170201	Wood	13.13	0.6	7.88
200201	Biodegradable waste	3.0	0.9	2.7
170407	Mixed metals	3.94	1.5	5.91
150101	Paper and cardboard	2.63	0.9	2.36
170203	Plastic	6.56	0.9	5.91
170202	Glass	1.31	1.5	1.97
170802	Gypsum	0.0	1.2	0.00
<b>RCD LEVEL II Stony nature</b>				
170101	Concrete	123.84	2.5	309.59
170103	Ceramics	31.88	1.5	47.81
170904	Other construction and demolition waste	10.50	1.25	13.13
<b>CDW LEVEL II Potentially hazardous and other</b>				
200301	Mixture of municipal waste	1.31	0.9	1.18
170903	Potentially hazardous	0.33	0.5	0.16
150202*	Absorbents, filter materials [including oil filters not specified in another category], cleaning rags and protective clothing contaminated with hazardous substances	2.3	0.5	1.15
150110	Containers containing residues of or contaminated by dangerous substances	1.51	1.25	1.89
160504	Gases in pressurised containers [including halons] containing dangerous substances.	1.31	0.5	0.66
080111	Paint and varnish waste containing organic solvents or other hazardous substances.	1.12	0.5	0.56
	<b>TOTAL</b>	<b>1,203.24</b>		<b>1,668.75</b>

This includes the demolition of materials included in the project budget.

Figure 8-A. An excerpt of data pertaining to the donor building from the demolition plan.

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