# BAMB
## BUILDINGS AS MATERIAL BANKS

# FRAMEWORK FOR MATERIALS PASSPORTS

## THIS EXTRACT IS FROM AN INTERNAL BAMB REPORT

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This extract of the original report was made for public viewing. Some changes were made as time passed since the original report was delivered, and to allow publication of the report. However the report is not fully revised.

# EXECUTIVE SUMMARY

The framework for materials passports (MP) described in this report provides a basis for BAMB MP and supports development, prototyping, and constant improvement of the passports and the enabling materials passports platform (MPP). The framework for materials passports includes contributions of BAMB partners and was mainly developed by EPEA and SundaHus.

**Components**

In order to understand how the framework fits together, brief descriptions of its main components are provided below:

*Materials passports (MP)* are (digital) sets of data describing defined characteristics of materials and components in products and systems that give them value for present use, recovery, and reuse.

*Materials passport platform (MPP)* is a software platform to create materials passports. The *proof of concept (PoC)* is the software platform developed as the first version of the MPP. It was developed in deliverable D6 and some aspects of it will be optimised as part of other tasks to aid the production of 300 MP mandated in deliverable D7.

**Development Process & Content Based on Value for Users**

The guiding objective of MP and the MPP is to provide value for users, a primary way this is reflected is in the data MP are developed to support. Value is described here as "value propositions."

Value propositions were created through a consultative process that included:

- Identifying a total of 21 stakeholder groups as potential users across the building cycle, including for example manufacturers, contractors, occupants, regulators, and recyclers.

- Surveying a selection of users about their preferences, or user requirements, and conducting an investigation into related platforms and tools in WP1 D1 Synthesis of the state-of-the-art.

- Crafting results into value propositions. A main learning was that priorities differ depending on the user, so the platform has to be adaptable for each user's preference.

- Integrating results into a MP input workbook with questions designed to identify those values, and then developing examples of how the system will be used, referred to here as system use cases. Tagging the input fields was started in order to connect value propositions to each input, so users see which input relates to which value.

- Using the workbook and system use cases as a basis for the D6 team to develop the PoC platform and for the D5 team to generate this report.

A priority identified by many users is that MP must deliver immediate and short-term value additional to providing tools to estimate long term value of materials. Value propositions like reduced construction waste disposal costs, improved environmental performance, quicker maintenance, more cost-effective data management, and healthier buildings rank alongside long-term recoverability of materials.

For example, as healthy buildings and productivity of occupants increase in importance, materials health ranks higher for owners and occupants. Materials health also contributes to improving residual value of those materials so they are not liabilities when recovered. Calculating materials health involves more than just totaling the contents of buildings.

Those types of values have basic impacts on the type of data gathered for MP and how the MPP is designed.

A main value question affecting the structure of the platform is: are MP designed to lead the market or to follow it? Do they reflect present values of the building industry or introduce new ones? The answer from investigations in this deliverable seems to be: MP are designed to lead the market because they are based on circularity, which is a new concept for the building industry. However, to achieve marketplace acceptance they will benefit from catering to conventional values like cost savings on replacement and maintenance, as well as improving property value. The mix of market leadership and catering to conventional value has basic impacts on the design of MP and the MPP. It is something being explored further in the work package 5 Action 2 focusing on business model.

**Development Tools Used**

The deliverable was developed using diverse tools brought by the team and developed during the project. Those include: the Cradle to Cradle® design protocol, the SundaHus system and methodology, an overview of marketplace initiatives related to materials passports, and an analysis of possible external data sources. In addition, the BAMB User Requirements deliverable D4, BAMB Software Platform deliverable D6 (PoC), input from BAMB members, as well as members of the Stakeholder Network were fundamental for this deliverable.

As with many research & development initiatives, considerable project-specific jargon was developed throughout the work. To clarify that, a glossary of terms is provided. However, this executive summary uses plain language wherever possible to make it easier for readers.

**MPP Characteristics Developed under this Deliverable**

For MP to be consistent, important characteristics have to be defined for the system that enables MP generation. Essential characteristics were defined and also used as input for the D6 Software Platform deliverable, including:

- Data sources: The system has to accommodate a range of data sources. Platform users, external sources (e.g. facility management and building design software), and materials assessment databases of BAMB members were identified as data sources for the MPP. Regarding external data sources, the team identified a series of obstacles for the connection with the MPP, much information is, e.g., not standardized, or available in different levels from the focus of the MP. Furthermore, even when the information is relevant to MP, it does not mean it will be available because it is optional. This means that information that is expected to be provided in some initiatives, such as BIM, are frequently not there;

- Data format: The system will accommodate structured and unstructured data. For example, structured data is a "yes"/ "no" answer or "15.2" to a question in the input form. Unstructured data would be maintenance instructions uploaded to the platform;

- Data standardization: How data requests can be described unambiguously and in line with existing standards where appropriate. This includes clear and usable definitions for materials, products, and systems. Also, decisions on what data should be supported by the MP; what data should be in a MP for a MP to be valid (both items completed); and what format should the data be stored in the MPP (work in progress);

- Data validation: Data provided by users in the MPP might be validated either automatically by the system or manually by a quality assurance body. The automatic validation is normally limited to verifying formats including check digits, for example, that values are within reasonable limits and relational requirements, such as if a certain answer is given to one question, then another answer is also required to another question. The MP do not itself assess the accuracy of data input or output and are not an evaluator of data. Instead, they provide information that supports assessments and certifications

by other parties. It also allows existing assessments and certifications to be entered into the passport as uploaded documents;

- Other services: Besides validation there is a selection of services to be offered through MP platforms which EPEA and SundaHus describe based on their own expertise and include material assessment, acting as a knowledge trustee between manufacturer and supplier, and supporting in the generation and updating of MPs.

- Access levels: MPP should enable confidential data to be provided, but only be accessible to specific authorized users. It necessarily involves the development of trustworthy software and database security;

- Interfaces: An Application Programming Interface (API) is a series of protocols, definitions, and tools to enable systems to communicate with the platform. It also allows the front end, called graphic user interface (GUI), to communicate with the back end. The API was already developed for the PoC and is essential for interactions planned between the MPP and the WP5A1 Building Level Decision Making Model and BIM Resource Productivity Prototype, WP2 task 8 relations to EPEA & SundaHus databases, and WP3 connection with reversible tools. Also, it will allow the MPP to connect with external data sources.

- Connection to building software: Software systems like Building Information Modelling (BIM) systems and databases such as the BIMobject® portal contain information relevant to the MP and vice versa. The MPP could import and export data from those, but retain full functionality in situations where BIM is not available or the MPP user is not familiar with it.

**Barriers and opportunities**

MP and the MPP are influenced by external barriers, cost factors, and perceptions:

- If MP are perceived to be limited to only inventorying raw materials, this will limit their value and practicality for users. For example, calculating economic value based only on raw materials inventory is limited without factors like extractability, reversibility, separability being included.

- If MP are not updated after generation, they will increasingly be outdated as buildings evolve. Quality assurance is a growing priority for credibility in the marketplace to reflect product version changes and building-specific context. The PoC structure supports this.

- Some stakeholders mention the problem of "certification fatigue" and "data input fatigue" due to the proliferation of certification and other inventory mechanisms and the costs of inputting the same data to different platforms. The trend might limit the readiness of stakeholders to enter data into the MPP.

- MP are developed to ask questions that are usually not present in initiatives related to building products. This differentiates the passports from other programs by not being directed into regulatory compliance, but focusing on how buildings and products can have positive impacts such as improving exterior and interior air quality (from a cradle to cradle perspective), and not on inventorying negative impacts or focusing on cradle to grave analysis. This is a major distinction of BAMB MP from programs such as EPD, for example.

- There is widespread confusion over what the term "circular economy" is and how it relates to traditional sustainability. Clear definitions are required to manage expectations and demonstrate value for users.

- As new products come into the marketplace constantly, and new chemistry is being developed with unknown effects on humans and the environment, there is an opportunity in working with positively defined healthy ingredients in product design and innovation.

- Insisting on full transparency might limit data collection. Experience shows there is a need to balance transparency with protecting data suppliers' IP. Mechanisms like the knowledge trustee function could address that.

**Significance of other Platforms**

Many initiatives related to MP are present in the marketplace (as inventoried in the WP1 D1 Synthesis of the state-of-the-art report). How this affects BAMB exploitation and credibility of MP and MPP, and whether those platforms will compete, co-operate, or consolidate remains to be seen and is beyond the scope of this report. However, from a brief D5 examination of those platforms, a few things are significant for the credibility of MP and MPP in BAMB:

- Credibility: A main risk for the MPP is transforming complexity into simplicity without being simplistic or misleading. A platform that simply totals the amount of materials in a building to assign value might mislead owners, unless the difficulty of extracting, separating, and processing those materials is described. For example, steel in reinforced concrete often oxidizes in old buildings and is expensive to extract. As a result, the accuracy and completeness of data is a significant consideration for credibility. The providers of those platforms, as well as BAMB, might consider how to develop quality assurance that maintains the reputations of this emerging group of platforms related to building materials and passports.

- Data gathering costs and duplication: The services in these platforms are only as good as the data entered. As described previously, estimating the residual value of materials in buildings depends on how those materials are designed, extracted and separated, and there is no guarantee that these platforms are gathering sufficient data to describe that accurately. For example, suppliers and sub-suppliers of building products are often 3 - 4 orders of separation from a building itself, making detailed data acquisition time-

consuming. There is also a risk of data gathering duplication and data incompatibility between platforms, creating "data fatigue" and alienation among users.

**MP Prototypes**

MP prototypes were developed based on the input workbook. The team worked with BAMB partner TUM to create the first MP prototypes for the NexusHaus[1] project. This case study is a modular residential green building that demonstrates transformative technologies in Zero Net Energy, and is carbon neutral in its use of sustainable building materials. This building was chosen to test the early results of the MP development, while the design and materialization of the BAMB pilot projects are being finalized. It is used as an example to initiate MP implementation with the WP4 pilot projects. One clear result from this prototyping was affirmation of the need for a user-friendly system interface and the option for users to filter which data is relevant for them to enter and extract according to the value propositions they want to focus on.

**Next steps**

As next steps after this deliverable, the WP2 team will be mainly working on the development of WP2 D7 Operational Materials Passports; WP2 Task 14 Continuous modification and updating MP framework and software; and further interactions with WP3 Reversible Design and WP5A1 Building Level Decision Making Model and BIM Resource Productivity Prototype such as for the alignment in data collection and standardization.

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[1] NexusHaus website: http://www.nexushaus.com/

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# 1. INTRODUCTION

## 1.1. Description of Deliverable 5 Framework for Materials Passports and Team

Deliverable 5 (D5) is the third deliverable to be developed by Work Package 2: Developing Materials Passports and corresponding database & platform, following D4 User Requirements and D6 Software Platform. The description and scope of deliverable 5 below is based on the BAMB Grant Agreement Annex 1 (EASME). Next to each item below the relevant report sections is mentioned so readers can refer to those.

Deliverable 5, the Framework for Materials Passports, goes a step beyond the user requirements analysis and lays down the vision of Materials Passports as they will be developed within the BAMB project. The user requirements analysis' primary focus is collecting information on what different stakeholders require from passports in order to be able to develop the passports and the software platform. The framework will cover more ground and will also be a tool to explain passports, and give them additional context. The development, testing and refining of materials passport prototypes will provide input to improve the Materials Passports framework throughout the project.

The Framework for Materials Passports will create an overview of the context of Materials Passports and their use by addressing the following:

1. What are Materials Passports? *See report section 1.2*
2. Who uses them? This includes suppliers of materials and products that deliver data as well as anticipated users of the information in the passports. *See report section 3.3*
3. How do they use them? This includes entering data and extracting information. *See report section 3.6 (under Guidance) and* **Fout! Verwijzingsbron niet gevonden.**
4. What is the desired structure for data input forms and output information? *See report section* **Fout! Verwijzingsbron niet gevonden.** *and 3.6*

5. What are the ways stakeholders interact with the information contained by Materials Passports? *See report sections 3.2, 3.5, and 4.1*

6. How do different stakeholders have different needs for information at different points in time, about different materials and products, and how does this influence the structure and the content of the passports? *See report sections 3.5 (for examples of different needs),* **Fout! Verwijzingsbron niet gevonden.** *& 7.2 (for structure) and 3.6(for MP content)*

7. How access levels can work, if they need to be used. *See report section 3.7.5*

8. What are current existing initiatives that touch on Materials Passports in (envisioned) concept, goal or marketing, and how do Materials Passports developed within the BAMB project differentiate from them? *See report section 2.3*

9. What information already exists on which the development of Materials Passports is based? This includes amongst other the description on how they are based on the Cradle to Cradle-approach, and will also include existing material databases which are used to perform compositional analysis. *See report section 2*

10. Encountered limitations or foreseen limitations for materials passports. *See report section 3.8*

11. What information will be stored in Materials Passports? (e.g. material composition, reuse or recycling scenario's, beneficial qualities, potential value, how to use value recovery potential, location, etc.). *See report section 3.6*

12. In what shape is this information stored, and how is this information organised? (i.e. what is the conceptual 'structure' of materials passports?) This includes a conceptual and or content description of different versions of passports as these are developed as outcomes of the user requirement analysis. Foreseen options to be investigated for this are:

a.  a structure in which passports can relate to each other (e.g. a system in which a passport can consist of components with passports), *See report section 1.4*

b.  a structure in which one general passport exists for a product and any number of specific passport instances can be made based on it, *See report section 1.4*

c.  a structure which describes customised passports for specific parties, as different information is of interest to different parties. *See report section 2.6*

13. What are ways in which this information is entered into or retrieved from Materials Passports? *See report section 3.7.6*

14. What are the identified sources of data for Materials Passports? *See report section 3.7.1*

15. A detailed description of what types of materials and/or products Materials Passports can and/or will be made for (BAMB, Consortium). *See report section 1.3*

**Deliverable 5 Main Team**

The deliverable contains contributions from WP2 partners and BAMB work package leaders, and it was mainly developed by EPEA and SundaHus. A brief description of these two companies is included in the annex section 7.1, as they are referenced several times in the body of the report.

## 1.2. Clarifying Terminology

This report contains a glossary (see section 6) to clarify terms used that might have diverse usage or interpretation outside the scope of this deliverable. This section lists only essential terminology for clear differentiation between key terms used thoroughly in this document. In this extract it is relevant to mention that this report contains references to 'deliverables', which are (in most cases) reports written in the frame of the BAMB project. These are numbered and referred to e.g. as D5, for this report. As well this extract contains references to 'work packages', or 'WPs', which are numbered working groups with different foci and partners involved. This report was written as a deliverable of WP2.

- **Materials Passport Framework (MPF)**

The content developed under the BAMB deliverable 5 to define and describe the BAMB materials passports and the software platform for their creation.

- **Materials Passports (MP)**

Materials passports are (digital) sets of data describing defined characteristics of materials and components in products and systems that give them value for present use, recovery, and reuse.

They are an information and education tool that asks questions often not covered by other documents or certifications related to building products, especially in relation to the circularity of products.

The MP do not itself assess the data output and are not an evaluator of data. Instead, they provide information that supports assessments and certifications by other parties and allows existing assessments and certifications to be entered into the passport as uploaded documents.

MP are outputs of the materials passport platform.

- **Materials Passport Platform (MPP)**

A Materials Passports Platform is the software and linked database to create MP. The main content of the platform is structured and unstructured data of buildings and building materials. This IT solution enables multiple stakeholders to fulfil two major purposes: 1. generate MP; 2. provide and see data during all the product and building usage phases.

The present report intends to describe the system features for MPP within the framework for MP for the long term. Some of these features will be developed within BAMB in a MPP prototype and others have to be continued afterwards.

**Materials Passport Platform Proof of Concept (PoC)**

A proof of concept is a realization of a certain method or idea to demonstrate its feasibility, or a demonstration in principle, whose purpose is to verify that some concept or theory has the potential of being used. In the present report, PoC refers to the software platform developed by BAMB work package 2 on deliverable 6, as the first version of the MPP. Some adjustments and updates of the PoC will occur during the remaining time of the BAMB project within WP2 task 14.

## 1.3. Subjects of Materials Passports

The MPP is intended to contain information about a broad range of materials, products, and systems present in the building industry. In this section, these terms are described in more detail to elaborate on what a MP can describe and contain.

These definitions should be understood in the frame of MP, and might be adapted if needed during the development of the project and other work packages.

**Material**

Material is used mainly to describe raw and/or generic materials such as metals (copper, aluminium, etc.), wood, earth, clay, stones (granite, marble, basalt, etc.) and substances that are content of products available in the market, such as additives, pigments, and polymers, but which are anonymous and not considered specific products themselves. In this sense of the term, materials can be represented in MP through the description of the composition of products and systems, but they do not have their own passports.

**Product**

Product refers to an item that is manufactured or refined for sale. A product is offered in the market by a responsible producer and has certain properties such as a commercial name, a producer ID, and a serial number. A product is not an anonymous material. Examples of products for which MP can be made are building related products such as; wall or floor tiles, flooring, gypsum wall panels, office furniture, wall paint, windows, connectors, steel or wooden beams, railing and framing, roof tiles, bricks, insulation, doors, coatings, piping, hardware, electronic equipment, and lighting.

**System**

A *System* is, in the context of MP, a complex product made out of multiple components/parts from different manufacturers which could also be used as independent products with their

individual passports. Examples are products used in mechanical, electrical, plumbing, facade, and wall systems containing a large range of other materials and products in their composition. For example, there could be a passport for an air duct and one for a whole air condition system, which includes the data from the air duct (see examples in the section below).

For readability, the set of materials, products, and systems is referred to throughout this report simply as *products*.

### MP Boundaries

In the context of BAMB, MP are created for something that is used/installed in a building, but the MP framework could also be applied e.g. to products that go into ships, vehicles or other systems. As well there is not limitation on which products MP can be made for based on their function, size, complexity, or supply tiers.

Different types of information are relevant for different types of products and usage situations. For a material to be added in the platform, there are certain mandatory input fields that should be provided by the user (see input workbook file section 3.6). Among these, product name and manufacturer identification are required for a product data set to be created. The completion of these two fields makes a material into a "product," rather than an anonymous material that does not merit MP.

One of the main objectives of the MPF is to facilitate that materials, products, and systems in the building industry be correctly used and maintained to enable them to be reused retaining their value for reuse. The intention of the MPF is to enable them to not only be reused in the building industry, but also in other sectors.

## 1.4. Relationships between Materials Passports

Passports can be compared to traditional Russian dolls (also known as Matryoshka dolls). They often consist of a product inside a product inside a product, or a component in a product in a system. The MP do this in order to reflect the way products are designed. The challenge of passports is to make this complexity understandable and easy to manage. Doing that involves two aspects: describing the relationship between the passports and describing how the product composition breakdown is organized.

**A. Relationship between passports**

Every level of passports can be regarded as a product, but also sometimes a component. For example, product X has a passport that includes components of that product, among them, component Y. If component Y has its own passport, then on its own it is a product. In one case, Y is a product, but in relation to X it is a component.



Figure 1 The Russian dolls. Source:
http://www.marktforschung.de/fileadmin/_processed_/c/b/csm_september-FA-Matroschka-650_1c83b4b55f.jpg

**B. How the breakdown for product composition is organized**

For systems and products, the respective data set and input lines are identical. However, when describing components and ingredients, the input items requested are different from what is requested for system and products. In the case of ingredients, for example, they are not individual parts anymore which are produced separately and then connected to each other, but uniquely identifiable chemicals.
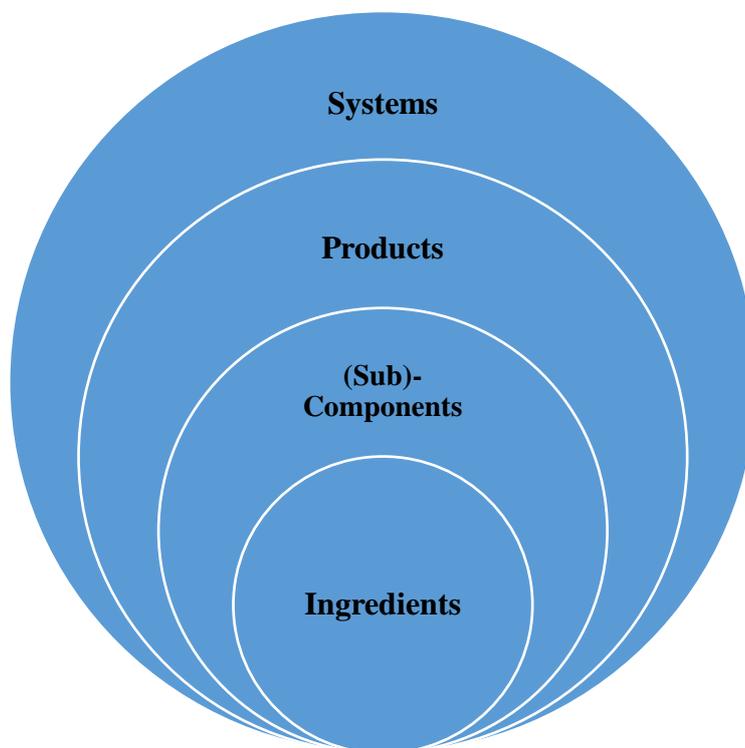


Figure 2 Product composition breakdown

The image above shows the product composition breakdown used by MP. Below, the description of the breakdown's organization:

- Systems and Products: refers to final systems and products (see definition in section 1.3).

- Components levels: parts that make the final product. They, and the other levels below, can also be final products available in the market. Levels of components are added as much as needed.
- Ingredients: items described on the chemical level, such as with CAS numbers. These definitions should be understood in the frame of MP, and might be adapted if needed during the development of the project and other work packages.

As mentioned in item A, an item that is considered a *component* in a product can also have a MP as a final and standalone product. This enables passports to relate to each other, as the data sets of many products can support creating the data set of a more complex one. A product does not need to contain all the levels above or describe them all in the platform, in order to have a passport.

The feasibility for a product to be added in the platform and have a passport depends if its data fulfils at least the mandatory input items in the platform, such as product name and manufacturer identification (for mandatory items for a passport to be valid see MP input workbook section 3.6).

Below there are examples of system and products with different levels of complexity to illustrate the product composition breakdown just mentioned (the red items are parts of the composition of the red item in the row right above them). These examples are for illustration only and do not intend to accurately describe a real world/existing product.

| Product composition breakdown | Example 1 | Example 2 | Example 3 |
|---|---|---|---|
| **System / Product** | **HVAC System[2]**  | **Office Chair [3]**  | **Granite Flooring polished, no seal[4]**  |
| **Components level 1** | • **Chiller**<br>• Boiler<br>• Fan<br>• Ducts<br>• Others | • **Wheels**<br>• Leg<br>• Upholstery<br>• Seat Frame<br>• Others | —————— |
| **Components level 2** (sub-component of level 1) | • **Condenser**<br>• Evaporator<br>• Pump<br>• Others | —————— | —————— |
| **Components level 3** (sub-component of level 2) | • **Valve**<br>• Copper Tubes<br>• Filter<br>• Others | • **Plastic type 1**<br>• Metal type 1<br>• Rubber type 1<br>• Others | —————— |
| **Ingredients** | • **Chemical 1**<br>• **Chemical 2**<br>• **Others** | • **Chemical 1**<br>• **Chemical 2**<br>• **Chemical 3** | • **Chemical 1**<br>• **Chemical 2**<br>• **Chemical 3**<br>• **Chemical 4** |
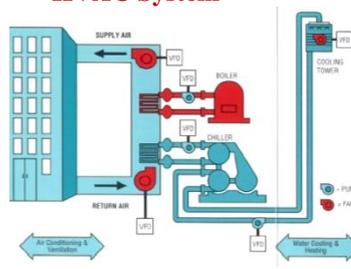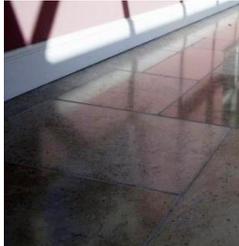
In the PoC, it is expected that a simplified model be implemented that just allows one level of components

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[2] Heating, ventilation, and air conditioning system (HVAC) to illustrate example 1 above. Source: (McKinnon Heating).

[3] Mirra Chair from Herman Miller to illustrate example 2 above. Source: (Herman Miller, Inc).

[4] Polished granite flooring to illustrate example 3 above. Source: (Tile Doctor).

# 2. BACKGROUND INFORMATION FOR THE FRAMEWORK FOR MATERIALS PASSPORTS

This section provides an introduction of the concepts and services that were used as basis and/or inspiration for the MPF, bringing general thoughts and principles to guide the team, including the Cradle to Cradle® design protocol and the SundaHus System and Methodology. Those concepts and services influenced the definitions, scope, team decisions, and content of the MP and MPP. Other initiatives and databases were also used, but it is not the intention of the section to fully describe them, as the annex of the WP1 D1 Synthesis of the state-of-the-art report provides an inventory of these.

## 2.1. The Cradle to Cradle® Design Protocol

The Cradle to Cradle (C2C) protocol was developed by William McDonough and Michael Braungart, two pioneers merging intentional design, chemistry, and products for industry. Its principles and cycles are based on a 1992 peer reviewed publication by EPEA scientists, which won the Oce van der Grinten prize for economics (Braungart and Engelfried).

Originally used loosely as a term with different meanings as contraindication to "cradle to grave," Cradle to Cradle is a beneficial design approach integrating multiple attributes based on quality, safe materials, continuous reclamation and re-use of materials, clean water, renewable energy, and social fairness.

The Cradle to Cradle design principles provide a positive agenda for continuous innovation around the economic, environmental, and social issues of human design and use of products and services. Specifically, the purpose of C2C is to improve the way we make, use, and re-use

things recognizing two cycles, the biological and the technical cycle, with a goal to leave a beneficial footprint for human society and the environment.

The aim is to set a positive course for product and process design and development in a way that will allow natural and technical systems, products, and processes to support the diverse living population on earth. Cradle to Cradle design mirrors the healthy, regenerative productivity of nature, and considers materials as assets, not liabilities.

To date, global efforts by businesses have been focused on becoming more efficient and reducing the (bad) environmental "footprint" by optimizing existing systems, which may be wrong designs. Cradle to Cradle design is about choosing the right thing to do and then doing that thing the right way to achieve positive outcomes. In other words, to become "more good," not just "less bad."

**Long-Term Goals, Short-Term Actions, and Transitions**

One starts by defining long-term Cradle to Cradle goals and then develops transitional strategies to achieve them. In the short term, it is possible to make successive design-based decisions that will move him to a more sustaining condition. The short-term actions for product development start with complete identification of the materials and chemicals that make up the product and process in order to assess them for human and ecological impacts.

In the medium term the goal is for designs that are positive or beneficial in terms of cost, performance, aesthetics, material health, and material (re)utilization potential with continuous use and reuse periods. Performance is a central consideration in C2C design. The protocol starts by asking 'what is the product intended to do for the user?' After that, and before materials are selected, ways of improving functionality and performance are explored. Materials are then selected based on that improved functionality. The use determines the selection of materials rather than the other way around. Additionally, moving renewable energy forward in a cost-

effective way, celebrating clean water as a human right, and honoring social systems are part of the holistic Cradle to Cradle approach.

The long-term goals can be wholly positive and intended to support 10 billion people and other species.

Cradle to Cradle provides a frame of thinking that is based on the precautionary principle and trust in the product supply chain. This is not a framework based on guilt or intended as an opportunity for taking legal actions. Rather it is the basis for building up a support system.

**The Cradle to Cradle® Principles**

In short, the design of goods and provision of services based on Cradle to Cradle can be achieved with three principles in mind:

**1. Eliminate the Concept of Waste**

• Nutrients become nutrients again. All materials are seen as potential nutrients in one of two cycles – technical and biological cycles.

• Design materials and products that are effectively "food" for other systems. This means designing materials and products to be used over and over in either technical or biological systems.

• Design materials and products that are safe. Design materials and products whose nutrient management system leaves a beneficial legacy economically, environmentally, and equitably.

• Create and participate in systems to collect and recover the value of these materials and products. This is especially important for the effective management of scarce materials.

• Clean water is vital for humans and all other organisms. Manage influent and effluent water streams responsibly, and consider local impacts of water use to promote healthy watersheds and ecosystems.

• Carbon dioxide ($CO_2$) should be sequestered in soil. Our current practice where carbon dioxide ends up in the oceans and in the atmosphere is a mismanagement of a material.

## 2. Use Renewable Energy

• The quality of energy matters. Energy from renewable sources is paramount to effective design.

• Aligning with Green-e's list of eligible sources, renewable energy sources are solar, wind, hydropower, biomass (when not in competition with food supplies), geothermal, gravitational, and hydrogen fuel cells.

## 3. Celebrate Diversity

• Use social fairness to guide a company's operations and stakeholder relationships.

• Encourage staff participation in creative design and research projects to enhance your Cradle to Cradle story.

• Technological diversity is key for innovation; explore different options in looking for creative solutions.

• Support local biodiversity to help your local ecosystem flourish; strive to have a beneficial social, cultural, and ecological footprint.

### Complementary Metabolisms

Cradle to Cradle is an innovative approach that models human industry on the processes of nature's biological nutrient metabolism integrated with an equally effective technical nutrient metabolism, in which the materials of human industry safely and productively flow within the two metabolisms in a fully characterized and assessed way.

Biological cycle                    Technical Cycle
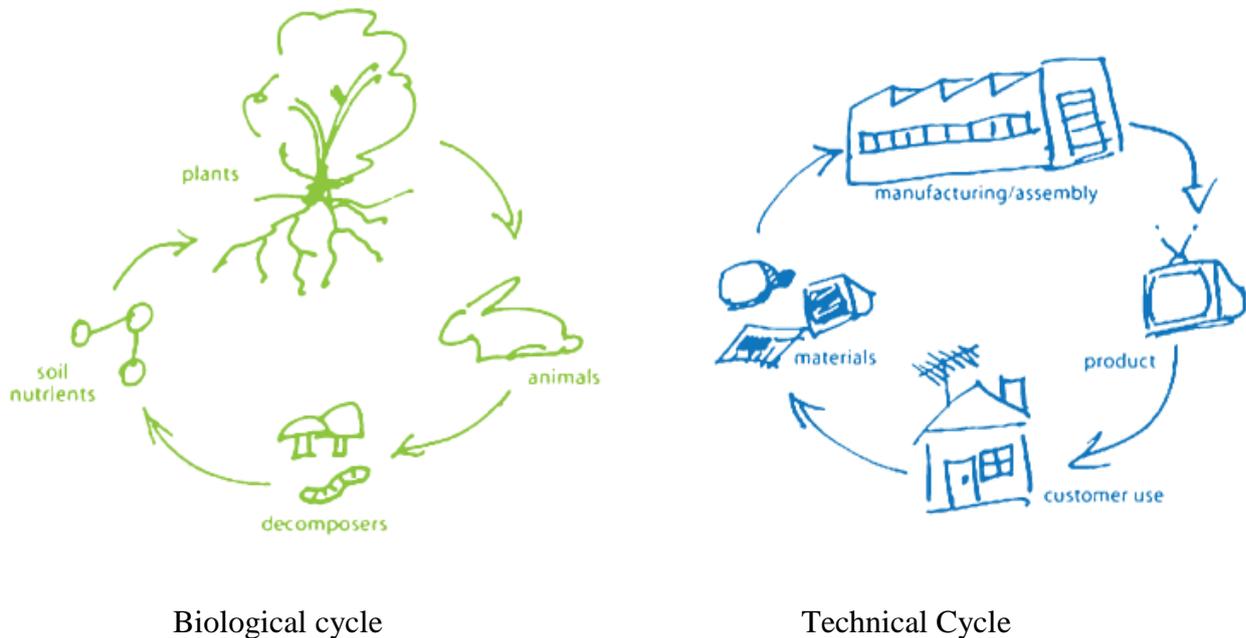
Figure 3 Depiction of Biological and Technical Nutrient Cycles

**Effective Material Cycles**

**1. Products of Consumption**

A product of consumption is a material or product that is typically changed biologically, chemically, or physically during use and therefore enters the biosphere either by natural processes or by human intention. As a result, products of consumption should consist of biological nutrient materials. The term "consumption" is used differently here from the traditional use of "consumer product," because consumers actually use both types of products: consumption and service.

**2. Products of Service**

A product of service, also known as service product, is a material or product designed to provide a service to the user without conveying ownership of the materials, or where a take-

back or other cyclical system is in place for manufacturers or other parties to take responsibility for re-using or recycle the product and its components. Products of service are ideally comprised of technical nutrients that are recovered at the end-of-use phase.

Technical nutrients (TNs) are products or materials that "feed" technical systems. While they may or may not be suitable to return to air, soil, or water, technical nutrients are never consumed but instead are catabolized (deconstructed) and anabolized (constructed) according to the following hierarchy:

• (Dismantle and) reuse.

• (Dismantle and) physical transformation (e.g., plastic remolding).

• (Dismantle and) chemical transformation (e.g., plastic depolymerization, pyrolysis, gasification) (MBDC in collaboration with Environmental Protection Encouragement Agency GmbH).

**Relevance of C2C for BAMB and the Circular Economy**

The 2012 Springer encyclopaedia publication *Resource Re-pletion: Role of Buildings*, by some of the EPEA team members, introduced the "Nutrient Certificates" based on C2C, which is part of the BAMB project proposal's and BAMB materials passports' foundation (Hansen, Braungart and Mulhall).

Moreover, the Cradle to Cradle concept was recognized by the World Economic Forum (WEF), in Davos 2014, as the basis for the circular economy. In the related WEF report *Towards the Circular Economy: Accelerating the scale-up across global supply chains*, prepared in collaboration with the Ellen MacArthur Foundation (EMF) and McKinsey & Company, the C2C principles and metabolisms are mentioned as the essential method for approaching and implementing circular economy (World Economic Forum). The EMF reports are also based on and cite the C2C methodology.

The BAMB project promotes the implementation of the circular economy in the building industry, in order to enable circular buildings through concepts such as reversible design and materials passports. The BAMB approach for circular economy is aligned with the EMF perspective and with the C2C concept.

The C2C two metabolisms and three principles, the way of thinking, the types of questions asked, and the re-thinking of product design, use, and reutilization are among the main foundations for the MPF and the development of the MP in BAMB. Cradle to Cradle influenced deeply the creation of this deliverable and other documents further described in the report, such as the use scenarios and the input workbook.

## 2.2.    The SundaHus System and Methodology

The SundaHus Material Data system was originally introduced under the name SundaHus Miljödata in 2003 as a web based online tool to help people within the construction and property management process to choose better products from a health and environmental perspective. It now contains information on over 36,000 construction products for almost every part of a building, ranging all the way from concrete delivered in bulk, to cable clips, and installation screws. The system has also been extended with a lot of helpful functionality, for example: assessments, customizable observation lists, a number of different reports, deviation handling, different access levels, project management, possibilities to link to BIM, and so on, which contribute to the time and cost effective use for all stakeholders in the entire construction and property management process.

The stakeholders are everyone who is involved in the construction and property management processes, from product suppliers, architects, contractors, and installers to facility managers. They access the system through a user-friendly web based interface. SundaHus' main focus and client is the property owner, even though there are many different stakeholders/users of the system. To give property owners full support and to make the work time -and cost-efficient, SundaHus also offers a proven methodology and consulting services.

From the beginning, the SundaHus system has been based on the fact that it is not possible to predict the future. Even though there is a good amount of knowledge today on which materials and chemical substances are safe to use and which are not, this knowledge is far from being complete. That is why SundaHus, since the introduction in 2003, always registers what is in a product, instead of what is not. This information is used to assess the products from an environmental and health perspective based on the industry's current knowledge. It is also stored together with information about location and quantity of a product used in a building. This enables SundaHus to update the assessments and inform its customers about potential risks

that were unknown at the time of construction. It also provides the customer with information about what is in their buildings for future reference, e.g. when it is time for reconstruction or for possible material harvesting.

**Guiding Principles**

- Detailed information – SundaHus is convinced that the only "future safe" way of handling construction product information from an environmental, health, and resource perspective is to have as complete information as possible about what it is made of. That is why it requires detailed compositional information.

- Promote openness – SundaHus believes that the only efficient way of improving the construction products is open communication between all parties involved. There is possibility of submitting information under NDAs, but that is discouraged, and the SundaHus rating system will also prevent products with non-disclosed information from reaching the highest rating.

- One size does not fit all – The SundaHus Material Data has a well-developed assessment system that is kept up-to-date with the findings and developments within the industry. However, some of its customers do have other needs and specific requirements. That is why the system supports customer specific requirements that can be automatically applied on all products in the database within minutes.

- Simple presentation of complex information – Even though SundaHus Material Data handles rather complex information and relationships, that information is of no interest to most of its daily users. They should not have to be an expert in chemistry or environmental science to make good product choices. That is why the assessments, but also the results of customer specific requirements, are displayed in a way that will give the user an instant answer if a product is compatible with the specific requirements for a given project (if the users do want the underlying information, it is possible to dig their way down to it, but they do not have to do it in order to use the system).

## 2.3.    Initiatives Related to Materials Passports

In D4 User Requirements and during the development of D5 and D6, initiatives related to the concepts and objectives of the MP and MPP were identified and analysed.

This section provides a brief analysis of these initiatives focused on identifying the similarities and differentiation of these with the MP and MPP, the unique benefits of these two, and areas of investigation and identified opportunities.

- **Similarities with MP and MPP:**

All of the initiatives analysed are used to collect data about products. Some are not exclusively to products used in buildings, but might include them. They have the common goal of providing product owners, users, and end users with selected data about products as possible, despite having different focuses on product usage phase and audience targets.

- **Differentiation from MP and MPP:**

As mentioned above, the initiatives have diversified audience targets and focus on different periods of product usage. They mostly range from product handling and use, such as MSDS, product end use, like DART, and cradle-to-grave such as LCA and EPD (for further information about databases and other data sources see section 2.4).

They are in general more focused on manufacturing, use, and disposal phases. Only a few focus on next use possibilities and material health. Some look into cradle-to-grave analyses of production systems, while others are focused on product's standards, regulation compliance, and product communication. A few are aligned with the Cradle to Cradle® concept.

- **MP and MPP unique benefits compared to other initiatives:**

MP are designed to ask questions and provide information about product use and reuse phases that are usually not available in other initiatives/documents /databases, by focusing on how buildings and products can have positive impacts from a cradle to cradle perspective. MP fill the data gap so circular buildings can become materials banks.

Products that have a passport can be reused in sectors beyond real estate and contain valuable information of their current conditions and previous uses.

A passport contains information about product use to enable the product to be correctly used to retain its values for reuse. It also provides guidance on next use possibilities to avoid premature or incorrect product disposal. As mentioned, there is a focus on the Cradle to Cradle® concept, so products are not waste in the end use, but instead nutrients for the environment or for other production systems.

It is not based on existing standards/ regulations or focused on regulatory compliance, but on voluntary data inputs from the users. It is not an assessment, although it contains data from and for assessments. This allows that more products can be listed and more information shared. The MPP has the potential to integrate the services of a Quality Assurance Body for data verification and validation (see section 3.9). Also, the MP can complement other data gathering systems such as design and facility management software (see section 2.4).

- **Areas of investigation and identified opportunities:**

Data collected in these initiatives can serve as input for the MPP and vice versa. The data exchange can occur through connection with the platform's Application Programming Interface (API). The MPP can provide valuable information for reports required by product manufactures and building owners. Documents generated from these programs can be uploaded in the platform as a complement for the product data set, adding technical information on product performance, and material composition, for example.

Note: in the WP1 D1 Synthesis of the state-of-the-art report, the investigation on MP contains a large inventory and overview of initiatives, including those here cited and many others. The ones mentioned in this document are the initiatives identified in D4 report and some that have special relevance for the content of D5. For a full overview of initiatives, refer to the Annex of the Synthesis of the State-of-the-art report.

## 2.4. MPP External Data Sources

Creating a capacity to export and import data from other sources is one aim of the MPP. This section provides an overview of the possibilities for this. For description of the function that enables this connection, see section 3.7.6. Important to note that it is not the scope of the MPP to design the connection with those sources, but to provide the capacity for them through the Application Programming Interface (API).

**Preventing duplicate data entry**

A general concern that has been raised by some potential users such as product manufacturers is the proliferation of systems where similar information needs to be entered. The MPP could of course be seen as yet another system. To meet this concern, one requirement for the MPP is a capacity to communicate with other systems.

In an ideal scenario, a manufacturer should be able to enter some basic information about a product into the MPP, and then the platform should contact all the other databases available and pull in, or create links to, all relevant information available there. As well, the MPP should present the user with a list of what has to be added to create a good MP.

In reality this is not as easily achieved as desired. In analysing possible existing data sources, the following obstacles that prevent easy synchronization between available systems were identified:

**Obstacles when synchronizing databases**

- Product identity: For automatic data transfer between different systems to be possible, it is important that there is a way to be reasonably sure that a specific product in one system can be safely identified in the other system. I.e. to ensure that product A in the first system actually is the same as product A in the second system. To do this

automatically, some form of unique identity for that product has to exist in both systems. That identity is usually an article number or even better, a Global Trade Item Number (GTIN). However, those types of unique identities are missing in most databases that hold information of interest for the MPP. This obstacle could partly be overcome by a semi-automatic approach. In this scenario, the transfer is triggered manually by a user who informs the system that a specific product in one system corresponds to a specific product in another system. Then, an automatic transfer of information between these two systems is initiated.

- Data format: Another requirement, if information is to be automatically transferred, is that the information is available in a well-defined machine-readable format. This is maybe most obvious in the several EPD databases available. An EPD contains some information that could be of use in the MPP. An EPD also has a standardized format on a high level, describing what has to go into it. But, there is no standard describing the exact format of the data in it, so there is no way of safely automatically extract that data.

- Product level: Most databases with the type of information that is of interest for the MPP tend to work on a level one or two steps above the specific product article. This makes sense in many cases since the information is usually similar for a complete line of products and by not specifying it on an article level you can enter one set of data instead of maybe 100 similar sets. But, this is also one of the reasons why there is usually not any unique identifiers, like article numbers, included in the information. The information is not specific to one article number, instead there should be a list of maybe 100 article numbers, which no one is interested in putting in and keep updated. For an easy data transfer between systems, the information should preferably be on the same or at least similar level.

- Relevant information: There are databases that do have information on a product article level and also have unique article numbers connected to it. Any system that handles any

form of purchasing will have this information since it is required to make sure that the buyer and the seller are "talking" about exactly the same article. However, these systems currently have almost no information that is of interest to the MPP except on a very general level. The same goes for the BIM object portals available, most noticeable BIMobject®. They do have information on a huge number of products and parts of the data are well structured, but there is very little that is of specific interest to the MPP. In addition, much of the information in BIM objects, for example, might be optional and there is no guarantee that they will be available in the object.

- Access to information: A lot of the information needed to create good MP is available in a database somewhere, probably at the manufacturer's internal production support systems. That information is not available to the MPP unless the manufacturer makes a decision to make it available. There are also other systems such as the SundaHus and EPEA databases that do have relevant information on article level together with article numbers that would be useful to the MPP. In these cases there are primarily two obstacles: the databases might contain confidential information, and even though the information in itself might be openly available, the way it is brought together and centrally accessible in a structured way represents a significant commercial value, which is why it is not publicly accessible and free to use. However, under the terms of the BAMB project, it has been analysed how these two databases can provide information to the MPP to contribute to the generation of the 300 MP in deliverable 7 (see section 3.7.1).

**Comparison of potential data sources**

For an overview of potential external data sources for the MPP, a comparison between different aspects of nine candidates is provided below:

- Name – Name of the potential data source.
  - SHMD – SundaHus Material Data https://www.sundahus.se/
  - EPEA – EPEA Database http://www.epea.com/
  - BIMobject® – BIMObject AB's database https://bimobject.com/
  - Quartz – The Quartz Common Product database http://quartzproject.org/
  - eBVD – Construction Product Declaration eBVD2015 http://www.byggmaterialindustrierna.se/index.php/construction-product-declaration-ebvd2015/
  - ECO – ECO Platform database http://www.eco-platform.org/
  - EPD – Environment Product Declaration (document based on ISO 14025 and EN 15804)
  - MSDS – Material Safety Data Sheet, required
  - CE – CE marking, the manufacturer's declaration that the product meets the requirements of the applicable EC directives.
  - ECHA – ECHA Registered Substances database https://echa.europa.eu/en/information-on-chemicals/registered-substances
- Db – Indicates if this actually is a database with information. If it says no, it is something else, such as a legally required document or a conformance marking.
- Products – How many products currently exists in the database. For the purpose of this document a product is considered unique sets of information about a products' properties.
- Articles – How many product articles the data sets described are known to be applicable to.
- Info level – On what level information is handled.
- Detailed comp – If the database or document contained detailed compositional information.

- Struct data – If the data in the system or document is available in structured standardized form that allows other systems to process it.
- Article no – If the database or document contain article numbers that could be used to automatically identify products between systems.
- Pub access – If the database or document is publicly accessible.

| Name | Db | Products | Articles | Info level | Detailed comp | Struct data | Article no | Pub access |
|------|----|----------|----------|-----------|---------------|-------------|------------|------------|
| SHMD | Yes | 37200 | 109000 | Article | Yes | Yes | Yes | Semi |
| EPEA | Yes | 2800[5] | 103000 | Article | Yes | Yes | Yes | No |
| BIMobject® | Yes | 262542 | 18131716 | Product | No | Partly | No | Yes |
| Quartz | Yes | 102 | N/A | Generic product | Yes | Yes | No | Yes |
| eBVD | Yes | Not public | Not public | Product or article | Yes | Yes | Yes | Semi |
| ECO | Yes | 500 | N/A | Varies | No | No | No | Yes |
| EPD | No | N/A | N/A | Varies | No | Partly | No | Yes |
| MSDS | No | N/A | N/A | Product | Semi | No | Semi | Yes |

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[5] Not only products used in the building sector.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CE | No | N/A | N/A | Product | No | No | N/A | N/A |
| ECHA | Yes | N/A | N/A | Substance | N/A | Yes | N/A | Yes |

As an example to illustrate the barriers being discussed, below is an extract from EPD International AB's website[6] (provider of EPD services) regarding the connection and transfer of information from EPD to other platforms:

"Is the EPD database available in a machine-readable format for import into my software/tool/database?

Incorporating data from EPDs into software platforms is <u>currently ongoing discussion</u> internationally. Unfortunately, there are some potential problems beyond the technical and formatting issues, including:
- the ownership (as well as liability) of the data lies with the manufacturer and not by the programme in which the EPD is registered. This is true for all programmes based on the standard EN 15804.


- the validity of the data is dependent not only on the stated validity in the EPD, but requires that the EPD owner monitors the environmental impact and updates the EPD if necessary. This process is ensured by the continued publication and registration of the EPD with the programme, which the EPD owner may choose to terminate before the end of the stated validity of the EPD.
- an EPD contains more information than the quantified environmental impacts. Some impacts are describes in a qualitative way, there is a content declaration, description of the product, description of system boundary, etc., to enable the proper use and interpretation of the EPD. If an EPD owner wishes, the International EPD® system allow the publication of a machine-

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[6] http://www.environdec.com/en/Contact/FAQ/#14297

readable LCI dataset in parallel to the EPD. Such data sets are available on the individual EPD page and may be produced in multiple of the available formats currently available on the market" (EPD International AB).

**Conclusion**

There is no straightforward route that by only technical means would allow the MPP to get substantial information from other systems automatically, possibly with the exception of the databases owned by EPEA and SundaHus, as well as the eBVD system. The databases owned by EPEA and SundaHus are planned to be used to provide information to the MPP. The eBVD system has a good data structure and a well-defined XML format for communicating it. However, the official owners of that format have chosen a business model (not making it free to use, but instead giving one party the exclusive right to use it in electronic tools) that currently prevents the format from becoming the de facto standard for this type of information, that it technically has the potential to become. There is currently no official API or any other way to access the data in the defined XML format. Even though progress is made in this area, the business model for access has yet to be presented.

The PoC is prepared for communication with other systems through its API and the software developed in WP5 Action 1 will be the first to use that functionality. For a more detailed description about how the PoC can connect to different data sources see section 3.7.6.

In addition to a system function for importing and exporting data from external sources, the MPP enables users to manually upload data sources in the platform (such as documents and images) that contain information relevant to the MPP.

### 2.4.1 EPD as a data source to MPP

Disclaimer: this section does not intend to explain EPD in detail, and it is only included as background to the analysis of EPD as a possible data source for MP and to serve as an example for the discussion above.

The focus of an EPD is to quantify the (negative) environmental impact of a product or system. On the other hand, MP focus on the positive impacts of a product, both in the short and long term and from a cradle to cradle (contrary to cradle to grave) perspective. MPP ask questions that are usually not asked by initiatives related to data collection of building materials and are not included in an EPD. For example, it asks how products contribute to the improvement of indoor and exterior air quality and the well-being of building occupants. That being said, there is still some information from EPD that can be used as source for the MPP.

The content of an EPD is controlled by a number of international and European standards where ISO 14025 and EN 15804 are the two central ones in Europe. There is also another EPD related standard that is of special interest for the future work on MP standardization, EN 15942. It describes a "Communication format business-to-business" for information within EPD. This standard is approximately on level 3 as described in Annex 7.3. It describes the items of data down to how it should be expressed including what units should be used, but it is still aiming for human readable reports in that it is not describing an XML schema or similar showing how the data technically could be sent in a machine readable form.

**EPD-MPP data overlap**

In an EPD, some sections are mandatory while most are optional. Then, even if a specific set of data could be available, there is no guarantee that it will be. Keeping that in mind, there are some general information in an EPD that would be useful for MP:

- Manufacturer contact information

- Construction product identification by name and any product code

- Description of construction product's use

- Declaration of material content. However it is important to note that the EPD's focus is on declaring hazardous substances, much like in an MSDS. The minimum requirements are that substances contained in the product that are listed in the "Candidate List of Substances of Very High Concern for authorisation" when their content exceeds the limits for registration with the European Chemicals Agency

- Links to other documentation such as MSDS.

The bulk of information in an EPD comes from LCA results such as environmental impacts at four stages together with a fifth more loosely defined section. They are: Product stage, Construction process stage, Use stage, End of life stage, and Benefits and loads beyond the system boundaries. For each of these five stages, and a number of sub sections under them, environmental impacts can be declared. Examples from the list of 20 different indicators are GWP, ODP, energy consumption, material consumption, use of fresh water, hazardous and not hazardous waste disposal. It is also possible to provide additional technical information for chosen scenarios linked to the stages described above. Among this information the following can be mapped to information needed in MP:

- Energy consumption

- Emissions

- Use of fresh water

- Use of recycled material

- Components for re-use

- Reference service life

**Conclusion**

There are some overlaps in data input between MPP and EPD (also identified in chapter 3.7.3 on data standardization), but they are in sections that do not constitute the core values of MP. It would still be useful if EPD could be used as a source of information for the MPP where the overlap exists. This can currently not be achieved automatically on a larger scale since the EPD databases that currently exists are databases of PDF documents, not structured data. Since accruing the data usually is a much larger part of the work than filling it in, it is still expected that EPD will be one of the MPP data sources that will require manual upload by the user.

## 2.5. BAMB Deliverable 4: Materials Passport User Requirements

The BAMB WP2 Deliverable 4 finalized in March 2016 collected user requirements from interviews and workshops with stakeholders identified as potential materials passport users (see section 3.3). It was accomplished by WP2 team with support of other BAMB partners.

The requirements are very broad containing needs for the system (MPP), for the data to be included in it, and requirements about exploitation and political support, for example.

The user requirements were the base for the MPF, providing the focus and background to generate the value propositions, use scenarios, and input workbook, detailed further in this document.

From the use scenarios based on the requirements, system use cases and other complementary documents to support the development of the MPP were created. These were used in D6 for the PoC development.

## 2.6. BAMB Deliverable 6: Software Platform

Deliverable 6 is presented as background for D5, despite both being created by the same team concomitantly soon after D4 was completed, because the discussions during the process, the expected results, and lessons learned from the PoC development had great importance and influence in shaping the BAMB MPF.

Documents generated under D6 were based on the team's discussions, experience, research, and decisions. These were valuable contributions to this report. For an overview of the MPP features presented in this deliverable and included in the PoC, refer to the D6 report and related documents.

The figure below demonstrates a high level MPP concept which enables in one side that multiple users input data, and in the other side multiple users are able to select information desired and retrieve customized materials passports.
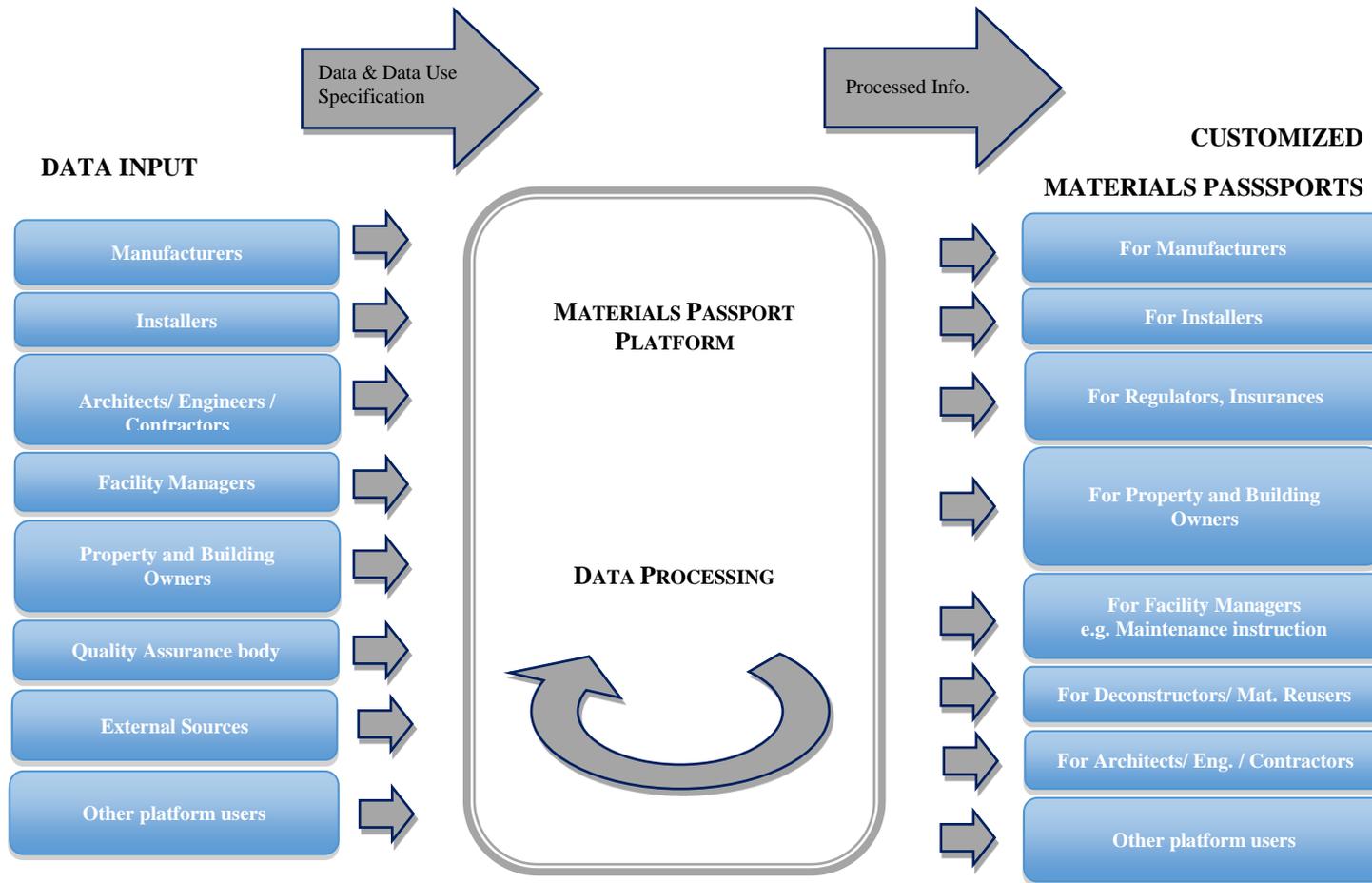
Figure 4 Concept for the materials passports platform, adapted from image presented in deliverable 4 report.

# 3. FRAMEWORK OF MATERIALS PASSPORTS

## 3.1. Deliverable 5 Methodology

The development of deliverable 5 started soon after deliverable 4 Materials Passports User Requirements was concluded in March 2016, and evolved together with deliverable 6 Software Platform. The WP2 team worked in both iteratively.

The methodology for developing the MPF started with refining of the user requirements collected in D4. The requirements list was the base for developing the MP *use scenarios,* and the MP *value propositions*. From these, *system use cases* were created, under D6 frame. Those system use cases generated the need for documents describing system demands mentioned in the uses cases, for team discussion and agreement.

In addition, the input workbook, describing the content of MP and criteria for the input lines implementation in the MPP, was developed reflecting not only the user requirements, but also the background information mentioned earlier and expertise of the team in the sector of material data collection, material assessment, circular economy, and Cradle to Cradle®.

These basic steps are shown in the diagram below and described in the following report sections. The use cases were created based on those and developed under the frame of deliverable 6 Software Platform and included here for reference only.

**DELIVERABLE 4**

**Materials Passports
User Requirements
(March 2016)**

**DELIVERABLE 5**

**Framework for
Materials Passports**

MP User Requirements
refinement through:

value propositions

MP use scenarios

input workbook

system use cases &
supplement documents
(input for Deliverable 6
until December 2016)

Update framework for MP based
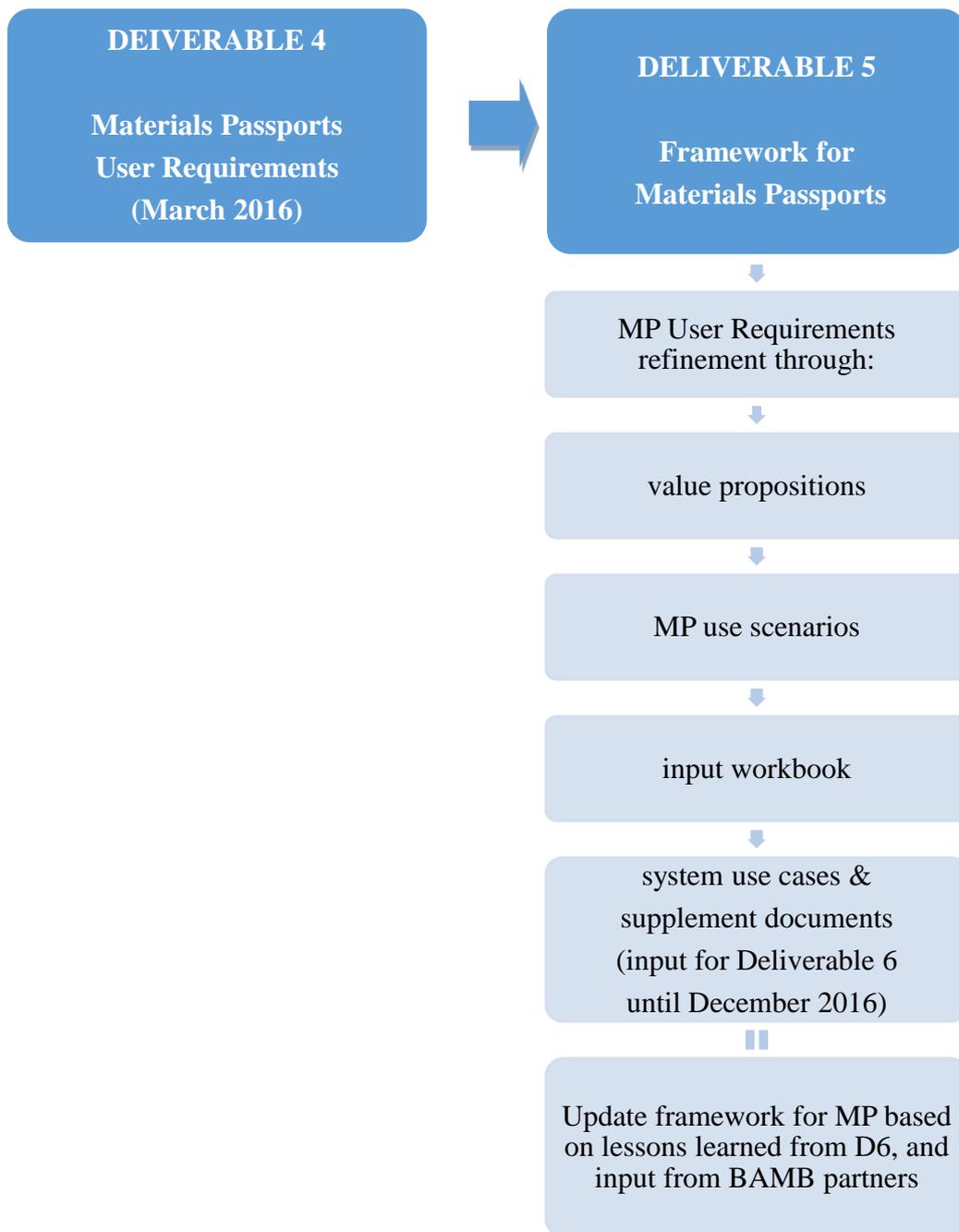on lessons learned from D6, and
input from BAMB partners

Figure 5 Deliverable 5 methodology steps

## 3.2. Materials Passport Value Propositions

Based on a definition from Investopedia (see glossary section 6), the value proposition for the MP and the MPP is defined as:

*Business or marketing statement(s) summarizing the reason(s) someone should use MP and the MPP. The statements aim to communicate to potential users that the passports and platform will add more value or better solve a challenge or opportunity than other offerings.*

Creating value for users is the basis for MP and the MPP. Everything in the MP and MPP structure is aimed at describing, facilitating and maximising that value. The purpose of this section is to provide a summary of the added values supported by the MP and MPP. It is also relevant to connect the users to the passports and platform.

It is important to note that the MP and MPP are designed to support the value propositions by users. They are not designed to provide all the value propositions themselves. As mentioned in section 1.2, MP are not an assessment or calculation tool, but used as a basis for assessments and calculations.

**Types of value stakeholders get when using materials passports**

Value is qualitative and quantitative: passports identify the circular qualities that add value to buildings and are used to quantify those qualities. For example, the qualitative value of a product might be designed for reversibility. The quantitative value might be time to disassemble, how many products are in the building, which components are re-usable, weight and volume of recoverable materials, and location. The main categories of qualitative and quantitative values include:

- Product content and design: For example, if the product components are re-usable or easily repaired.

- Operation & Functionality: For example, if a product actively contributes to a healthy indoor environment and has easy maintenance

- Data management: for example, all stakeholders being able to access the same information online.

- Potential for improvement: questions in the MPP input provide guidance on circular qualities expected. The guidance is especially valuable for shorter-cycle products that are replaced with new generations.

- Financial: tax revenues, savings in design and waste management, as well as value recovered from products in buildings are part of the MP content.

**Value propositions for materials passports**

Value propositions supported by the MP and MPP were identified and described below, combined with the identification of which users benefit from them. An overview is provided below:

- Passports support the transition from waste management costs to revenue-based materials recovery;

- Generate savings throughout the cycle by identifying prefabrication and modular designs;

- Generate data management efficiencies by describing location, quantity, type, content, and reuse potential of products, components, and materials;

- Identify products designed for disassembly to improve residual value, maintenance access, and upgrading;

- Identify value removed from building e.g. fully reusable components;

- Identify products' ownership to facilitate maintenance, removal, and recycling;

- Provide guidance for suppliers to define content and include instructions to safely disassemble components;
- Provide a basis to calculate carbon savings from using recycled materials compared to new;
- Provide a basis to develop a database of carbon trading credits that apply to the building;
- Showcase innovative examples to suppliers to accelerate best practices;
- Improve efficiencies by displaying products certifications in a single location;
- Improve productivity, compliance and reduce liability risk by describing defined healthy materials that contribute to healthy air quality and materials contact exposure;
- Identify products and systems most likely to generate benefits, for example, from leasing or take-back schemes;
- Inform about existing take back for packaging and products;
- Improve compliance and building certification processes by identifying when reused materials are utilized;
- Identify when tax incentives apply;
- Identify easy-to-disassemble products where unskilled, under-employed workers can safely and quickly perform the work;
- Reduce paperwork and data duplication, more reliable data on products, quicker fault correction, preservation of data integrity throughout the building use period;
- Reduce the risk of derelict property and degrading value of surrounding properties by providing information about reversible design;
- Support more accurate calculation of residual value of building components;
- Support transparency and validation of claims about products;
- Provide products' updates for users when entered by manufacturers;

- Save time communicating across the supplier chain with electronic feedback between product suppliers and platform users;

- Save time and cost when data only has to be entered once for products used across multiple buildings, or in many places in one building;

- Save duplication and maintenance costs with an API that enables connection with other software and databases, such as mobile apps that allow visualization of product location and features allowing on-site access to passports' data;

- Save time and improve valuation can be achieved by knowing how much of which materials are where in buildings;

- Save duplication of parts inventories by knowing exactly which building has which parts for which systems in real time, owners can save duplication of parts inventories.

**Priority values described by materials passports**

By consolidating the value propositions above, the following priorities for improved value were established. These priorities will be further evaluated within the WP5 business models work stream:

- Develop buildings as materials banks with high residual value at the maintenance, repurposing, renovation and end-of-use stages of the cycle;

- Improve flexible use and repurposing potential of buildings and products by including data on the portability of systems and products;

- Improve potential to re-use and recycle products & materials at each stage of the building cycle by providing data for defining and optimizing products;

- Improve regulatory compliance and reduce liability risks by providing transparent and convenient data;

- Allow product selection based on circular value propositions by communicating product Circular Economy characteristics;

- Increase operational value by improving working or living environment and productivity for occupants;

- Improve indoor air quality by defining and optimizing content of products (healthy materials);

- Fit for innovation in business model, by specifying e.g. product-service system (PSS), take back, reverse logistics, others;

- Improve trust between contracting parties by providing transparent data.

The WP1 D1 Synthesis of the state-of-the-art contains investigation on the opportunities for the MP and reversible design that relate to the value propositions here presented.

Reversible design is an example of an approach that integrates many of those values propositions, and it is among the main focuses of BAMB. It covers diverse aspects and a few of those are included in MP input items. WP2 and WP3 plan to further align the concepts of MP and reversible design even more during the development of the project in order to increase their complementarity.

Also, another relevant approach to the value propositions is data quality assurance. Section 3.9 discusses the possibility for the data provided by users in the platform to be checked for accuracy.

**Plans to optimise value propositions**

The development of value propositions is a work in progress. They will be revised, optimised and perhaps re-prioritised by WP2 together with the WP5 team focused on business

models. In an early business model meeting, it was pointed out that some value propositions might conflict with each other. This still requires exploration and examples, and will be done in the business model work stream. As well, the business models team is expected to consider the added value opportunities identified in the WP1 D1 Synthesis of the state-of-the-art.

## 3.3. Materials Passport and Platform Users

Continuing the work from deliverable 4 on the identification of potential passport and platform users, this section provides an update from D4 and broader description of them with the addition of the users *Subcontractor* (together with Construction Contractor and Builder) and *Product Installer*, both identified during D5 as potential users.

An overview of *how* users interact with the MP and MPP is found in sections 3.5 (use scenarios) and 3.6 (input workbook under guidance column). The main *reasons* for them to use the MP and MPP are presented in the value propositions section 3.2.

Description of MP and MPP users:

### 1   Regulator / Government / Municipality

Agencies and governing bodies of cities, states, countries, and regions with the power to establish regulations and guidelines related to development permits, land leasing, building products manufacturing and commercializing processes, construction sector, and resource management and reutilization.

### 2   Developer

Real estate developer investing in and improving land to create a supply of real estate that he anticipates will meet the needs of a population's commercial and residential endeavours, coming up with estimates of the time and money required to complete a development. He can oversee the entire process of developing and building a property, from buying the land and preparing it for development to hiring architects and sometimes even being part of the building materials selection process (Wetfeet, LLC).

### 3 Funder / Bank / Investor

Funders, banks and investors provide the possibility to investors, developers, and property owners to raise funds for application in the real estate sector, usually through a mortgage loan. Real estate investor usually purchases, improves, and later sells a property for profit. However, institutional and public agencies also make investments in the public interest and hold the property for extended periods.

### 4 Building Designer/Architect/Engineer

Professionals performing the design and technical specifications of urban areas, buildings, and interior spaces. These include architect, engineer, interior designer, design specialists (such as façade and MEP engineers), and draftsperson.

### 5 Building Permit Authority

Responsible for controlling and approving projects of built structures according to building standards and codes applicable in the project´s location, which are established by the user Regulator / Government / Municipality (see no. 1).

### 6 Construction Contractor/ Builder/Subcontractor

The construction contractor or builder manages the construction process working closely with and reporting to the owner, developer and/or architect, proving workforce, materials, machinery, and tools. He is responsible for the daily coordination of the project with subcontractors, product installers, product suppliers, and the overall workforce.

### 7 Research Institute

Institutions such as universities and companies' departments focused on the research, improvement, and the development of a specific topic or product.

## 8 Product Supplier/Manufacturer

Product manufacturer designs, produces, and assembles components and finished products. A single manufacturer is generally not responsible for all the manufacturing phases up to the point a finished product reaches the market. Suppliers provide to manufacturers supplier products (components) that contribute to the composition of finished products.

## 9 Building Valuator

The valuator analyses the real state property in order to set a value to it. This value is commonly used for mortgage, selling price definition, and juridical processes. He works for insurers, banks, investments and funds institutions, and lenders. Also, he can audit green building systems.

## 10 Land Owner

Person or institution in possession of a piece of land. The land owner might or might not be the owner of the property (building) sitting on the land. The land might be leased by a municipality, for example, for a university to build a campus and use the land through a long-term contract.

## 11 Property Owner

Person or institution in possession of a building. The property owner might differ or coincide with the developer, land owner, and property user.

## 12 Property User

Entities or individuals that use part or all of the property usually for commercial, residential, and industrial uses. When the property user is not the property owner, leasing contracts and relationship with facility managers are usually established.

## 13  Facility Manager

The facility manager oversees a property's everyday operations, whether commercial, industrial, or residential. The day-to-day duties include a broad spectrum of activities such as leasing or managing the leasing out of property to tenants, handling tenant complaints and relations, maintaining building occupancy levels, maintaining desired lease rates, preparing reports for property owners, preparing budgets, hiring service employees, collecting rents, paying bills, negotiating contracts, and maintaining and repairing the property (Wetfeet, LLC).

## 14  Product Installer (added in Deliverable 5)

The product installer has a variety of specializations, from generic hydraulic, electric, and mechanical installer, for example, up to specialized work force for complex systems such as facade, ceiling, and roofing system installation. The installer can coincide with the product manufacturer/supplier or be a subcontractor of him or of the construction contractor.

## 15  Maintenance Contractor

The maintenance contractor is usually hired by the property owner, property user or the facility manager to maintain and repair different parts and systems of the building which require specific skills, training, and permits. The role of maintenance contractor can coincide with subcontractor, product installer, and facility manager.

## 16  Insurer

Building insurer provides cover for loss or damage related to a broad range of property topics from environmental, structure and permanent fixtures up to demolition costs. Building insurance also varies according to building location, type, use, design, etc.

## 17  De-constructor

Professional or company in charge of disassembling parts or the whole building during refurbishment or building end of use phase. The de-constructor works on the building site taking products apart and might interact or coincide with the logistic manager and the material trader/reuser.

## 18  Logistics Manager

The logistics manager takes care of the transportation, distribution and storage of items discarded during product installation and generated from the disassembly of the whole building or parts of it. He interacts or might coincide with the de-constructor and the material trader/reuser. He also works on supply strategies and controls health and safety procedures for the handling of materials during transportation, distribution, and storage.

## 19     Material Trader / Reuser

The material trader/reuser is the person or company that recovers value from materials generated from the building disassembly process (possibly provided by the demolisher or logistics manager). He either sells or reuses the entire product or parts of it in diverse conditions such as "as-removed" or refurbished.

## 20  Platform Management Body

(Called Maintenance of Non-building Specific Information in D4)

This user refers to the professionals responsible for maintaining and managing inputs and outputs provided at the platform and updating the system according to the users' and the consortium's needs identified during platform testing and use phases. This user is further

described in section 3.7.8. A more complete definition of the scope of this user is linked to the platform governance and exploitation development, part of other BAMB work packages.

## 21  Quality Assurance and Standards Organisations

Quality assurance and standards organizations are in charge of verifying accuracy and analysing specific types of data inputs in the platform according to standards and protocols previously agreed between this body and the data provider, such as material assessment methods. This user type relates to possible service providers of services linked to the MPP. The platform users have the possibility, for example, of requesting this body to perform audit and verification of the data they provide in the system. See section **Fout! Verwijzingsbron niet gevonden.** for potential services linked to the platform, and section 3.9 for quality assurance. Both sections present suggestions to be discussed in the frame of the BAMB Work Package 5 within actions focused on Innovation and Exploitation, and Business Models.

Some stakeholders are described in groups as they might have similar interactions, benefits, and objectives when using the passports and the platform.

The users can be input providers and of output extractors. An overview of which user will most probably provide or extract data in the platform is found in the materials passport creation process, section 4.1. In addition, the identification of the users had an important role in the development of the use scenarios (see 3.5 and **Fout! Verwijzingsbron niet gevonden.**) and value propositions (see 3.2).

## 3.4. Possible Services Linked to the Materials Passport Platform

This section provides an overview of opportunities for services linked to the MPP, based on the work been done by the WP2 team in the development of the MPF and its experience working with building material manufacturers to promote healthy products and buildings. The services could be offered by the consortium, part of it, or external parties. The topic is related to the development in WP5 Action 2 and WP5 Action 4. In this report, it is intended to provide input to this WP based on the framework here presented.

Possible services to be offered linked to the MP and MPP to users are:

**A. Data Quality Assurance:**

- Description: MPP users will be able to provide a huge amount of data about products and buildings in the platform. Some automatic input data validation and standardization is possible to be in place in the system, but the quality, accuracy, and reliably of the data needs to be verified by a responsible body that has access to it and authorization to do so. This verification is not mandatory, but definitely adds value to passports that are verified.

- Benefits: MPP data is reliable and accurate, giving credibility to the platform and supporting the users' requirement of having "one version of the truth" when looking for information about products used in buildings.

**B. Material Assessment:**

- Description: Material health is one of the main focuses of the MP content. The goals are to promote and enhance the quality of building products included in the platform. Users can request materials assessment of the products added in the platform to assigned material assessors. The methods for sharing confidential data, defining methodologies,

performing the assessment, and the publication of the results in the platform will require agreement between platform users

- Benefits: User benefits by having an easy way to request material assessment, share data, and publish the results in the platform. The platform benefits by having an increasing number of assessed and defined products in the platform.

**C. Third-party Knowledge Trustee:**

- Description: Some products' data, especially about composition, can be sensitive for sharing due to confidentiality and market competitiveness. As a result, sharing of some data in or connected to the platform might be limited to certain users. This data can be verified and assessed by a third-party knowledge trustee, who holds the confidential information and only publishes assessment/verification of it.
- Benefits: Users do not need to publish confidential data in the platform is they are not conformable with it.

**D. Support on creating and updating platform's data sets:**

- Description: due to the large data amount that can be provided in the platform, some users that are interested in adding products and buildings in the platform might not have the capacity for the data gathering and/or transferring.
- Benefits: Users that desire to add data in the platform but for diverse reasons, such as products and buildings amount, staff capacity, budget for data transfer, etc., are not able to do it, can count with the support of assigned parties for it.

## 3.5. Materials Passport Use Scenarios

The materials passport use scenarios were generated by WP2 team as a refinement of D4 user requirements. These scenarios were the base for two main documents essential for deliverable D6 Software Platform: the input workbook (section 3.6) and the MP system use cases. They are also an important part in which the users are connected to the passports.

They provide examples (narratives) of passports and the MPP usage, identify the potential users involved, the benefits they have from using the passports and platform in the specific scenario, and the actions that should be taken to make the usage successful. The format and order of the scenarios do not follow any specific hierarchy.

The examples let the team to develop a common view of the MPF scope, the MPP usage, and drew the team's attention to aspects that required clarification as part of D5 and in co-operation with other WPs. This was one of the main values of it: to point out questions about the MP and the MPP usage, and to make decisions about them.

The following step after developing these scenarios was to list the system use cases under each narrative for validation of the use cases, as they were developed for D6 based on the present use scenarios.

Below the MP use scenarios are listed and summarized:

**A. The product is repurposable in the same building for the same use when the building configuration is changed**

Summary: this scenario mentions the possibility for a product data added in the MPP by its manufacturer to be linked to a building by the design team. The installation, maintenance, and products' conditions are retrieved and updated during the product use. When the building undergoes reconfiguration, data is extracted about the product disassembly and removal. The

product is then installed in another location in the building. Data about this new situation of the product is updated in the MPP under context and location data set.

**B. Material health assessment is a possible service linked to the MPP**

Summary: The MPP could have services linked to it such as material health assessment, performed by bodies formed by members of the BAMB consortium or external parties. This benefit especially product manufacturers and their suppliers to assess the products' composition. Due to the sensitive data and concerns of confidentially, the sharing of information from the manufacturer to the assessors can be done through the platform, by using data input filters, user access rights, or outside the platform on a case by case agreement. For further discussions on possible services linked to the MPP, see section **Fout! Verwijzingsbron niet gevonden.**.

**C. Manufacturer features a product in the platform**

Summary: Manufacturer creates a product data set for a product in the platform and contacts his suppliers to complement the data provided. He can use platform´s data filters to enable that the suppliers only access the information and interface formats chosen by him. In case these product suppliers are also suppliers of other products, they provide input in the platform just once.

**D. A product is specified for a particular building project**

Summary: The MPP could be able to import useful product information from a Building Information Modelling (BIM) project model. But, it should always retain full functionality by itself as there might be situations in which the model is stale or not available at all. A function to link generic objects used in the model to specific materials passports is necessary.

**E. Repairs: as part of repairs, a product replaces another already used in the building, before its expected use period expires**

Summary: A product has to be installed or replaced based on a product already used in the building. Users search in the MPP information about the product to be replaced regarding quantity, locations, identification codes, manufacturers and vendors' contacts, as well as instructions for installation, disassembly/removal manual and next use opportunities for the replaced item. After the repair is completed, users enter the product replacement information into the platform.

**F. Product is designed for flexible use and material reutilization**

Summary: in order to guarantee that a product designed for flexible use and material reutilization is used as planned, information sharing among different stakeholders of the building and material use is essential. This information is retrieved by the MPP users during the use phase of the product for maintenance and flexible use. At the end of product use phase, they access the platform to make decisions regarding product responsibility, ownership, and who recovers value from it. Stakeholders are able to reuse the material in the planned and optimal way.

**G. The product is removed from the building, refurbished, and then used into another building**

Summary: When the product is removed from the building, the product instance data set is updated and then terminated, available as read-only. When the product is refurbished, new conditions and characteristics are generated that require a new data set.

**H. Soil banking. Excavation soil is used to construct a green fence for landscaping**

Summary: The excavation soil produced during construction is reused in the building's landscape project. This information is included in the MPP. During the building use phase, the platform is updated on soil maintenance and status, such as runoff, nutrient depletion, fertiliser or compost inclusion. When the building is disassembled, this soil can be reused in another landscape project. The building becomes a soil bank for the future.

### I. Manufacturer receives feedback from product users

Summary: The MPP enables information sharing between product suppliers / manufactures and other platform users that want to specify or already use the product. When manufactures initiate a new product data set in the platform, this communication channel is enabled. By performing a product search in the platform, users access the product´s communication tool and can easily exchange information with other platform stakeholders and provide feedback to the manufacturer.

### J. The product is a feature submitted to a green building certification program

Summary: Green building certifications award credits/points to projects containing products meeting some of the certifications' criteria. The MPP informs users about the products listed on it that award credits for them. The passport is a tool to help product collection data, not the tool to do the report for initiates such as green building certifications.

### K. Aggregation of materials passports is done for different purposes, for example based on products, building, and ownership

Summary: Customized MP are generated based on the user`s value propositions and information he/she wants to see as an output. An aggregation of MP is also possible to be created based on pre-determined criteria in the platform. Instead of searching for a single product in the platform, the user can request an aggregation of MP based on the available criteria.

**L. An aggregation of materials assessments is done to guarantee that the site continues unpolluted after building disassembly (based on the scenario above)**

Summary: Due to the possibility of extracting passport aggregations based on pre-defined criteria, the Land or Property Owner access the MPP to have an overview of the products with MP installed in the building, and if any of them may be problematic during the building disassembly phase regarding site pollution.

**M. Manufacturer is guided in product innovation**

Summary: Manufacturers guided in innovation can use the platform to create opportunities for networking and sharing experience with other stakeholders. This generates collaboration among the value chain, from suppliers up to material reusers. In addition, the platform could contain linked services performed by consortium members or external parties that provide material assessment for product optimization.

**N. Research institute works with material innovation and looks for investors and manufacturers for R&D projects**

Summary: The MPP aims to promote quality and innovation in materials used in buildings. By connecting research intuitions with industry stakeholders, experiences can be shared and partnerships generated. These institutions are able to communicate their projects and intentions with platform users to be engaged or maybe also test prototypes and pioneer R&D projects.

**O. Product owner recovers material residual value at the after-use phase**

Summary: A product manufacturer can estimate the use period of the product based on the use (i.e. commercial and residential) and by the product type. As he intends to have the used product back, he is able to plan when the materials are coming back to the productions' material

stream. This information is included in the platform, as well as the ownership and take back agreements done with the real estate developer, property owner or user.

### P. Extracting product information from the platform to guide the design team (connected to WP3 and WP5A1 scopes)

Summary: The design team uses a design tool (preferably the tools developed in WP3 and WP5A1) which they feed with the basic design and construction product selections for the different design options they are considering. When it comes to assessment of different construction products' re-use potential, positive or negative impacts on the indoor and outdoor environment, estimated first use time frame, and residual value, the MPP provides important data that the tool accesses automatically through the API.

### Q. Building-specific data is updated from as-designed to as-built

Summary: Updating from construction to as-built is a high-priority, value-added activity, because it gives property owners and users, as well as facility managers, an accurate view of the current status of the building. Presently, BIM models are usually not updated partially because building owners and operators lack the BIM software and training for it. The MPP does not require software or training for updating building-specific information about products that contain passports installed in the building.

### R. Platform management body maintains and updates the system

Summary: The platform management body is able to maintain the system, perform updates, and implement some of the concepts from the MPF not included in the proof of concept (PoC). The main interest is to keep the system fully running with no errors and flexible to incorporate requirements and updates identified by the WP2 team, during the testing and use phases of BAMB project and after it is concluded and exploited. This body is further discussed in section 3.7.8.

## 3.6. Materials Passports Input Workbook

The MP input workbook presents the content of the MP and what information is able to be stored in the MPP, mainly based on the background sources mentioned in section 2, such as C2C and SundaHus methodologies. It provides an overview of the information that the MP can contain and decisions for input field's implementation in the MPP.

The first version of the workbook was created in June 2016 based on the input fields from the Circularity Passports® developed at EPEA and work done at Rotterdam School of Management. It was then amended and modified in a joint effort by the WP2 partners in a two-day session at IBM's premises in Amsterdam, also in June 2016. A second full review was performed by the team in November of the same year to address topics relevant for D6.

The workbook contains a collection of questions about characteristics of products and their contexts relevant for resource recovery and re-use. It also contains essential information and classifications for the field definitions in the MPP, such as guidance and examples for users, data entry type, prioritization for system inclusion, standardization of data, and mandatory data for a passport to be created. These criteria were used for building the PoC in D6.

Moreover, the input workbook is not intended to be seen by the MPP users, and rather is a work in progress document where questions relating to all value propositions are consolidated. Because of this, the list itself is extensive and is not made for users to see all at once or use it as an input form. Instead, the questions will be split according to value propositions in the web based graphic user interface (GUI).

## 3.7. Materials Passports Platform

This section provides an overview of system features and needs for the development of the MPP as part of the framework for MP in the long term, as the ideal situation we are heading to in the future. The chapter is a broad analysis to address the system requirements and also served as basis for the PoC, which contains some of the features here described.

### 3.7.1. Data Sources

The MPP contains a cloud-based database able to support data about products and buildings. The main data sources for this database are identified below. For discussion about data sources and their possible connection with the MPP, see section 2.4.

- **MPP users:** the users are the main source of data in the MPP. They have the roles of data providers and information retrievers. Users will access the platform to create new data sets for product, building, and instance, as well as be able to edit/update existing data sets. Data can be provided by filling in the input lines and by uploading documents.

- **External sources:** The MPP permits the communication with other systems through its API. Examples of other systems where this could be of interest are product databases, manufacturers' internal systems, design software, and facility management systems (see comparisons and obstacles in section 2.4). It is important to note that the MPP enables external software and databases to connect to it to provide and extract information. However it is not the scope of WP2 to develop these connectors, but to provide the API that enables these connections.

- **EPEA and SundaHus Databases**
  - o **EPEA Database:** from the EPEA database, the type of data that can be transferred to the MPP to support the MP creation is publicly available information on assessed and C2C certified products by EPEA with the following properties: name of the product, name of the manufacturer, overall certification level, detailed certification levels, certification date, and certificate as pdf.

    Also, with agreement of the manufacturer and/or their suppliers, further information can be provided on different levels such as: components of the product, ingredients of the components, toxicological assessment results of the components and/or ingredients, percentage of recycled content, percentage of renewable content, biological or technical nutrient, amount of energy used in production, $CO_2$ emitted in production, and contact details of manufacturer/suppliers.

    Important to note that some products' data in EPEA database are protected by a non-disclosure agreement (NDA) and will not be provided to the MPP without authorization of EPEA's clients. In the PoC, no data protected under NDA will be provided by EPEA, because the POC cannot handle confidential information. If the MPP is able to safely contain confidential data, manufacturers and suppliers will be invited to share this data or to commission EPEA to make it available.

  - o **SundaHus Database:** SundaHus Material Data contains a lot of detailed information about a large number of construction products. Examples of information that could be of interest and transferred to the MPP are energy classes, percent of virgin material from renewable sources, conformance to a number of different

certifications, expected service life, waste classifications, emission to indoor climate, and many other topics.

The system also contains compositional information on a substance level with chemical name, trade names, CAS registration no, possible hazard statements, other properties such as possible suspicion of endocrine disruption and quantity in weight. This information could be of use in a future MPP, but since it is not supported on that level in the current PoC, it is not of immediate use and the business model for future use is not yet clear. However the information will be used, when applicable, for the 300 MP being developed within BAMB in D7.

### 3.7.2. Data Format

Regarding data format in the MPP, the options identified are:

- Option 1: all data is structured and standardized
- Option 2: all data is in free form
- Option 3: a compromise

Annex 7.2 contains a more detailed description and discussion about the options above and how and when they are usually being used.

The options for data format and usage are essential for the MPF and were translated into the PoC. If the data to be handled is suitable to be structured, it is usually a good idea to handle it as such. If it contains large quantities of unstructured text, images, sound recordings, and similar, it is usually handled as unstructured data.

For the PoC, option 3 (a compromise) was chosen. The compromise approach has been developed and defined in the MP input workbook (session 3.6). The "Entry Type" column is intended to show how that data should be stored in a row in the database. The standardization comments relates to both how to standardize the meaning of that field, but also to how it might be formatted. The mandatory data relates to the fields that are required for the data set to be meeting the basic requirements of MP creation.

The data format for PoC will be tested through task 12 and WP5A1 which means that the data format for MPP will be further developed and refined. Probably some data need to be more standardized and structured to fulfill the requirements on these tasks. In this sense, decisions presented in the MP input workbook will be further developed throughout the project.

### 3.7.3. Data Standardization

What is standardization, why is it important for MP and what does it actually mean in that context? According to the International Organization for Standardization (ISO) "a standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose" (ISO).

When considering the impact of standardization within the scope of MP, there are a number of levels where standardization might mean different things although the overall goal remains more or less the same: to make sure that the input data (and the information gathered from it) is as easy as possible to understand correctly by human and machine alike. Below there are questions that exemplify how standardization on different levels can support MP creation.

Level 1: What data should be possible to include in a MP?

Level 2: What subset from level 1 above should be in a MP for it to be considered valid? I.e. what is mandatory/not mandatory?

Level 3: What pre-existing standards should data in level 1 adhere to?

Level 4: What format should the data in level1be stored in?

For a more detailed description and discussion about the different levels above see annex 7.3.

#### Current work in progress for data standardization

Level 1 is already implemented by defining the MP content in the input workbook and in the PoC. Level 2 is also completed in the workbook and PoC by defining which input lines are mandatory for a passport to be valid/created.

The level 3 is partially done in WP2 by defining which data has to be standardized. Decisions on definition of terms used in the context of MP, how data should be expressed, and the level of detail is a work in progress. It has been aligned with findings and feedback in this topic from WP3 and WP5A1, so data collected within BAMB, when possible, is provided in the same way to be easily exchanged.

In summary, levels 3 and 4 are planned to be partly implemented in an ongoing process based on input and experience from using the PoC, especially from WP2 task 12 and WP5 A1. For example on level 3, the PoC itself could be used for standardisation. Through analytics on the standards that are mostly used by the users when inputting data in the MPP, it is possible to improve the system and its standardisation with the use, enabling maximum flexibility for the users.

Examples of level 4 standardization that will be of interest during this process are the JSON format defined in the Quartz project and the XML format defined for eBVD in SBUF project 13045 "En uppdaterad byggvarudeklaration."

Some input lines are present or similar in more than one data set because they relate to different phases of the product or the building. For example, the same question can be asked for a generic product (as it is sold in the market) and an instance (an specific product unit installed in a building) and generate different responses needed for the product reuse.

Items identified for further development regarding data standardization within BAMB tools between work packages 2, 3 and 5 are:

- There are links with data requested in the MP on product level that relate to assessment of reuse potential done within WP3 of system, component, and element on building level, and system and component on assembly level.

- Reuse potential within WP3 is further being characterized by (1) direct reuse, (2) reparation, (3) reconfiguration (as for example addition and extraction and includes upgradability of element, component or system as well) and (4) remanufacturing. Those are different reuse options to be aligned with MP.

There are also links to economic and environmental impact of different reuse options, a part of what is being investigated with WP5A1, that also relate to MP.

General alignment with WP5A1 in data standardization for areas, such as:

- Product information which is necessary for environmental assessment – material composition, recycled content, end-o-life options etc.;
- Product information which is necessary for economic assessment – cost of removal/processing vs. value as product/material; any specific valuations linked to business model, such as leasing;
- Building information which is necessary for the outcomes of the reversible building design assessment, whole life environmental and economic assessment;
- Maintenance information which is necessary for whole life environmental and economic assessment;
- Other related aspects that will be in the WP5A1 BIM prototype to link data/algorithms/assumptions together.

The next steps for alignment on data standardization will be accomplished by WP2 on task 14 *Continuous modification and updating MP framework and software.*

### 3.7.4. Data Validation

The data in the MPP would ideally be validated at some point, if the stakeholders will use it to make informed decisions about products. The data validation could be done manually by a quality assurance body, as described in section 3.9, or automatically by the system when entering data. The automatic validation is normally limited to verifying formats including check digits, for example, that values are within reasonable limits and relational requirements, such as if a certain answer is given to one question, then another answer is also required to another question.

Since the data will most likely be entered much less frequently than it will be used, either displayed to a user or as input to any number of automated processes, it makes sense to validate the data when it enters the system. If it is known that the data in the system is already validated, it will reduce the requirement for anyone using that data to implement manual or automatic validation on everything retrieved from the system.

However, data validation is not implemented in the PoC. That does not remove the relevance of the arguments for doing this, and it is an important factor for a future commercial version of the MPP. For MPP it should be done automatically when feasible and reasonable according to good practice within software development. Also the MPP should allow and offer manually data validation by a quality assurance body. Some automatic data validation can be further developed during future updates of the PoC.

### 3.7.5. Access Levels

The MPP is intended to be accessed by diverse stakeholders who have diverse objectives, such as adding data for a specific product or retrieving MP for a product installed in a building to have information about the next use phase.

This diversity requires managing the flow of information from multiple sources and levels of specificity with sometimes conflicting requirements. Especially there is a need to balance product user requirements for transparent product data with confidentiality from the manufacturers' side to protect data that reveals IP. This was discussed in the D4 report.

The MPP should allow confidential data to only be accessible to specific users in the platform. The provider of confidential data should be able to define who could access it. This requires defining the types of users via registrations and log in/out in the platform.

In the PoC developed in D6, no confidential information is included in the platform due to lack of resources to complete that feature.

However, personal accounts are supported in the PoC, i.e. every user can have their own username and password that have to be provided for access to the system. There is also support for a limited set of access rights described below. These access rights would be modified in a fully operational system and are for demonstration only;

A. **Read only**: this is the default for any user that is authenticated, i.e. has logged in by providing correct username and password. It means that in the PoC the user can read any information within the system except the list of users.

B. **Write access to one or more manufacturers**: a user can be given write access to data from one or more manufacturers. This gives the user the right to create and modify product data related to those manufacturers.

C. **Write access to one or more buildings**: a user can be given write access to one or more buildings. This gives the user the right to modify data about those buildings, the right to create instances of any product, edit those instances, and link them to any of the buildings the user has write access to. The aim here is to demonstrate how the owners of a building would have privileged access to data about their building.

D. **Administrative access**: a user can be flagged as administrative user. This gives him the right to create and modify anything within the system.

### 3.7.6. Interfaces

This section refers to how users can access the MPP, to provide and extract data, and generate MP. An Application Programming Interface (API) has been developed within deliverable 6 for the development of the PoC. The API is important for the PoC and further versions of the MPP, because it serves as the basic foundation on which to accomplish a number of possible requirements identified in project, as discussion below.

The graphic user interface (GUI) of the PoC also gives access to all basic functionality. However, the PoC's GUI does not focus on a user friendly interface and that is why a more user friendly interface is described for the MPP under section B below.

#### A. Application Programming Interface (API)

An API is a set of routine definitions, protocols, and tools for building software and applications. In the MPP context, the API is the interface that allows other systems to programmatically communicate with the platform. It also allows the front end (web based user interface) to communicate with the back end (data base/store and business logic).

The main reason for an API is to serve as the basic foundation on which to accomplish a number of possible requirements identified in project, such as:

- Input from external data sources.
- WP5: Input / output / Connection to BIM
- WP3: Input / output / Connection to WP3 tools
- WP5: Input / output / Connection to WP5A1 decision making tool
- Input / output content to and from SundaHus and EPEA databases

A possible analogy for an API is of a power socket that allows plugging in as long as the socket and plug comply with the same standard. The WP2 team provided this standard, a

specification of the API that a developer can implement directly. The implementation and testing of the API in the MPP is done within deliverable 6.

A central part of designing an API is how the data is organized and represented. It is a trivial task to decide whether to use JSON, XML or maybe both, compared to saying that a document should be printed on A4 or letter size paper. The more complex part, targeted within the standardization section above, is to decide what should be in the JSON or XML objects, i.e. the content of the A4 or Letter paper.

### B. Web Based Graphic User Interface (GUI)

The API mentioned previously is also used for implementing the web based graphic user interface (GUI), allowing *the front end (GUI) to communicate with the back end (data base/store and business logic).*

**Websites whose user interfaces were references for the project:**

- Initiatives related to MP:

European Chemicals Agency (ECHA): https://echa.europa.eu/de/registration-dossier/-/registered-dossier/15858/1

Quartz Project: http://quartzproject.org/p/CP152-a02

Designer Pages: https://www.designerpages.com/categories/flooring

UL Spot: https://spot.ulprospector.com/en/na/BuiltEnvironment

Cradle to Cradle Product Innovation Institute: http://www.c2ccertified.org/products/registry

Circular IQ: http://www.circular-iq.com/

- Other examples:

Dashboard: https://themes.getbootstrap.com/products/dashboard

Limitless: http://demo.interface.club/amsterdam/1/forms.html

Wolfram Alpha: https://www.wolframalpha.com/

**Data filtering**

Filtering of input fields is a way to make the GUI user friendly. Users would then see a subset of input fields relating to e.g. the type of user they are and which value propositions they are interested in. As information priority varies among the stakeholders and at specific building and product use phases, this facilitates the system usage and access to information.

Relevant for filtering is that it supports entering data by only showing relevant fields to be filled in based on the filter, and not only retrieving data from the system. This is especially valuable in early versions of the MPP until more sophisticated queries or cognitive analytics are in place.

In the GUI filters can be selected by the user. If the GUI becomes user specific, it can display only data relevant to the type of stakeholder they are, value propositions connected to them, or to the relevant product and building phase.

**General remarks on UI**

The GUI is for all users that have no capacity to develop their own GUI and users who want to try out the platform before investing time and budget to connect their own systems, GUIs and apps with the MPP thorough the API. The GUI is a website and could be compared in functionality to an online store. When the user is interested in more than just looking what is available in the website, he creates a user account. Then, he has access to further functions, such as add products to a building (similar to an online store shopping cart), add products, add buildings, get suggestions what other users looked at, see private statistics for his products/buildings, book further services (such as assessment of products, contacting suppliers), sharing/collaboration functions (invite suppliers or colleagues to provide data), etc. In addition, the user could be able to edit the data, the interface and the dashboard, and adjust the pages to better suit him and his stakeholders.

### 3.7.7. Materials Passports and BIM

Usually when MP are described, the question about how it relates to BIM is raised. This is logical since one thing the acronym BIM stands for is Building Information Management and the MP are data sets related to management of construction products found in buildings. Also, BIM is an investigation topic under WP5. However, it is not as straightforward to integrate BIM and MP as one would expect.

Building Information Modelling (BIM), as a concept, relates rather well to MP. A BIM Model could potentially contain all available information about every single component of a building. Information contained in, or needed by, a MP could also be a part of this set of information.

In deliverable 4, the approach to the relationship between the MPP and BIM was pointed out. A main characteristic is that the MPP is BIM enabled, but not dependent. The present section provides further and updated information about the topic.

#### A. The difference between BIM objects and BIMobject®

In order to avoid confusion between *BIM objects* and *BIMobject*®, a brief overview is provided below:

BIM objects

A Building Information Model actually consists of a large number of "objects" representing both physical components (like a door) and areas in three dimensions (like the shape of a room). These objects contain information about their geometry, their location within the building space, their relation to other objects and a number of different other attributes that describes the object. These objects are generally referred to as BIM objects and every BIM tool

comes with a library of pre-created generic BIM objects. It is also possible to import BIM objects from other sources like a manufacturer's website or a central portal, such as BIMobject®.

<u>BIMobject®</u>

BIMobject AB is a Swedish company which define itself as:

"... Europe's largest and fastest growing digital content management system for BIM objects. Our unique solutions for manufacturers provide development, hosting, maintenance, syndication and publication of the digital replicas of manufactured products – BIM objects" (BIMobject® ).

BIMobject® helps manufacturers to develop, host, maintain, syndicate and publish BIM objects representing the manufacturers' specific products. These objects will usually contain a bit more data than can be expected from a generic BIM object, like manufacturer's name, primary material, secondary material, IFC classification, Uniclass2 codes, and similar. Then, instead of just knowing it is a door, one might know that it is a door blade made out of wood and glass. But, it is usually not more detailed than that.

### *B. What can be expected from BIM?*

There are a number of factors that influence the type of information from building projects using BIM that can be useful to MP. Some of them are discussed here:

<u>Pragmatic</u>

The usage of BIM tends to be rather pragmatic. Even though it is possible to add much information to the data set, what users will actually add is usually dictated by either the direct gain it will result or what is required from a contractual standpoint. Currently, much of the

information that potentially could be added to the different objects has not been used in any significant way, i.e. there has been no real significant need for them.

### Not standardized

Some information will almost always be available for BIM objects. That is their geometry, their location and usually also their relation to other objects. The reason for this is that the BIM tools would simply not work without this information. But almost all other potentially useful information is optional. Even though there are a number of properties that sound promising, like *Manufacturer, Model* and *Material*, they are just free text fields with no standardized format, making whatever information that might be there rather tricky to use in an automated manner.

On the other hand, the problem with lack of standardization is recognized within the industry and a number of partly overlapping initiatives exists to address it. However, none of them are, by themselves, the solution that solves the problem once and for all.

### Usually not one model

The holy grail of BIM is currently a single shared project model in which everyone works concomitantly (sometimes referred to as Level 3 BIM or Open BIM), but very few projects are using this approach. The current level for a good BIM project tends to be that each party have their own internal model and then send the design information between them in a standardized format, like IFC files. That enables them to combine selected models into what is called a federated model for, among other things, collision detection. This is usually referred to as Level 2 BIM.

### Usually not as-built

Even though BIM is much more than 3D CAD, actual real world BIM use has been most frequent where CAD is traditionally used, like for architectural design, structural engineering, HVAC planning and similar. BIM use for facility management, sometimes referred to as 6D BIM or AIM (Asset Information Model), is so far rather unusual. Hence the only argument for updating the project model to include all on-site modifications is to have a good model as base for future re-configuration of the building. In general this has not been a strong argument for setting up the feedback loop needed from the construction site to the project model manager. I.e. the project model is left as-designed and not updated to as-built.

<u>Not updated during facility management</u>

Many points mentioned above also apply to this topic. In addition, the majority of the organizations' facility management department (or sub-contractor) does not have the resources to properly maintain a BIM project model. The way BIM tools are designed at the moment, a simple task of updating the model when a product is replaced in the building is not a task one would do correctly without a rather good understanding of the BIM tool and the methodology. If the changes done by facility management staff should go into the model, usually extra personnel would be required, increasing the facility management cost, as exemplified below:

A broken washbasin is replaced with a new model, since the original is not available any more. A common process for handling this is:

1. The tenant is creating a fault report either online or through a telephone call.
2. The fault report is reviewed, accepted and assigned to a technician by a customer service coordinator.
3. The technician either contacts the tenant to check the broken basin and then gets a new one from a supplier or, if they have good knowledge of what is out there, gets a new basin directly and returns to the tenant.

4. The technician replaces the basin.
5. The technician flags the work order as completed which sends a status message to the tenant and possibly an invoice to whoever should pay for it.

If the BIM model is to be updated to reflect the new washbasin, someone already involved in the process could do it, assuming they have the skill set to use currently available BIM tools to do it correctly, or someone else would have to be brought in. In most day-to-day facility management organizations, neither the customer service coordinator nor the service technician will have that skill set so someone else would have to do it. That extra person updating the BIM model is also just doing work that is not replacing anything currently being done in the normal process, i.e. he is incurring additional cost. In the long run this could definitely be worth it, but in the short run it will be more expensive to replace the washbasin.

There is no doubt that in the long run an accurate model could be of help for the facility management. However, currently there are very few projects that have this. One of the rare examples is the Swedish hospital New Karolinska Solna, in Stockholm. There, the plan is to actively use BIM in facility management. To make this possible, it was originally planned to have several BIM technicians working full time updating the model.

### C. Consequences

MP and BIM have a number of similar objectives and there is an obvious bilateral advantage of communication between them. A logical scenario would be that the BIM project model is the authority when it comes to the data that is available there and that the MPP links to that data. Examples of such data would be quantity and location of construction products. This leads to two requirements:

1. The model has to be available as long as the MP for the products in the building are used (which for some products are several decades). On the contrary, the MP will not be complete.
2. The model needs to be updated as soon as anything contained in it that has a MP is moved, replaced or taken out of the building.

Even though these two requirements are desirable, not only from a MP perspective, it is not the way BIM is in general used today, and probably not in the near future, according to the team's experience in the topic. As pointed out earlier, what is included within BIM is usually dictated by what is required by contracts or is of direct use. So far, information linking the often generic BIM objects to specific products has been of little real world use in BIM. The most common approach has been using BIM as an input to the product selection and purchasing process, mostly for calculating product quantities. But the actual choice of products is not brought back into BIM, since there is no real advantage of doing that.

However, the work that is being done within the BAMB project in order to support a transition towards a circular built environment also aims to support a transition into the way how BIM will be used. The developments within WP5A1 will help demonstrate the advantages of having information identifying specific products within BIM and the opportunities BIM provides with regards to a circular economy in the built environment. The tool developed in this WP will require not only information that is native to BIM, such as product's location, dimensions, and quantities, but also specific product information, such as if the product is designed for disassembly and/or re-use.

The following table describes what could currently be expected from BIM:

| Feature | Available? | Explanation |
|---|---|---|
| **Product identification** | Mostly not | Usually generic objects are used. If specific objects are used most of the times useful identifiers as GTIN are left empty since the object could correctly represent a number of products having different GTINs. |
|  |  |  |
| **Location** | Yes | Always as coordinates in the model space, often also floor and room. |
| **Quantity** | Yes | Always number of instances (if they are included in the model), usually volume and sometimes weight. But, even if the number of instances is available, they might represent different products if generic objects are used. |
| **Material** | Mostly not | There are usually properties for information about material. In some cases the data in them can be useful, but many times they are empty or too vague such as "Wood" or "Glass". |
| **Up-to-date information** | Sometimes | If it is a high profile BIM project the model might have as-built status and also being updated during facility management, but this is rare. |

In one sense this looks like a paradoxical situation with contradictory rules (also known as Catch-22), in which on one hand information is not entered into BIM because no one is using it, and on the other hand, applications that would use it are not feasible on a large scale because the information is not available. To get around this, the MPP should be able to import useful

information from a BIM project model, but always retain full functionality by itself even in situations where the model is stale or not available. A function to link generic objects used in the model to specific MP is necessary. This will enable the MPP, for example, to access in the model the product's location and quantity information and possibly other useful information. When these links are established, data from the MPP could be imported into the model to be presented there or used as a basis for further assessment or modelling. In addition, even if a set of information is usually part of BIM, it does not necessarily mean that it will be available for use, as some are optional or not standardized.

### 3.7.8. Materials Passport Platform Management Body

The MPP management body is defined in section 3.3 under potential platform users, as the body responsible for maintaining and managing the platform, as well as updating the system when possible.

The identification of this platform user is aligned with the deliverable 6 Software Platform, in which a PoC for the MPP is provided. The creation of the planned 300 passports within deliverable 7 will demand that many users, not only the BAMB partners, but manufacturers, designers, facility managers, building owners, among others, will interact with the system to provide and extract unstructured and structured data about buildings and products, which are the core of the passports' content.

These interactions and the management of the data provided will demand that a management body be defined within the consortium, to make sure the system runs correctly and does not contain problems that interfere in the passports creation in deliverable 7.

This section is intended to address the management body for the period within the BAMB project, from the time the PoC is delivered, further updated, up to the project conclusion.

The WP2 addresses the MP topic. It has delivered the user requirements and has been developing the software platform, together with this MPF. EPEA and SundaHus are the partners with the majority of work planned in the WP. Due to this intensive and close involvement in all aspects related to MP, the suggestion is that EPEA and SundaHus be the MPP management body until the conclusion of BAMB project. This is aligned with the creation of the 300 passports in D7, in which EPEA is the deliverable leader and SundaHus the largest contributor.

The interaction with the system as management body is also essential for WP2 task 14 *Continuous modification and updating of framework, software and Materials Passports based*

*on pilot projects and lessons learned,* in which EPEA and SundaHus have the majority of time allocated to it among the other partners involved.

After the BAMB project is finished, this management body also will have an essential role to ensure that the system is kept running, updated, stable, secured, and supportive of users for trouble shooting. The management body after BAMB is also linked to governance and ownership of the platform. These items are to be defined and implemented in the WP5A4 focused on exploitation.

## 3.8. Encountered and Foreseen Limitations & Challenges for Materials Passports

The development of deliverables 4, 5 and 6 provided important input to WP2 team about limitations and challenges for the MP and MPP. The team also contributed with the identification of barriers in the WP1 D1 Synthesis of the state-of-the-art. The summarized information below, mainly collected during research and workshops with the stakeholders, is based and complements the D1 analysis:

- Stakeholders are beginning to suffer from "certification fatigue" due to the proliferation of certification programs. Moreover, there is also a rapid proliferation of passport-type mechanisms, which on one hand is good because it reflects demand, as well as provides diverse insights. How this affects BAMB exploitation and credibility of MP and MPP, and whether those platforms will compete, co-operate, or consolidate BAMB remains to be seen. However, a few things are significant for the credibility of the BAMB MP and MPP, as well other initiatives, such as data credibility, data gathering costs and data duplication. In order to avoid data duplication, synchronization between databases could be an alternative, but is proven to have many obstacles (see 2.4).

- As pointed out by WP5A1 during the work on data standardization, it is necessary to identify (and communicate) the additionality of a MP above and beyond initiatives that already collect information on building materials – what is it that makes it a unique dataset –.

- In addition, if there is no consistency in standards and passport mechanisms, the risk of discrediting the overall approach is high.

- Due to this proliferation of passport types, quality assurance is a growing priority for credibility in the marketplace to reflect product version changes and building-specific context (for discussion on quality assurance, see 3.9).

- Authorization for data providing i.e. who fills in which parts of a passport is central to a credible passport, and also, for validating data across multiple platforms Moreover, insisting on full transparency might limit data collection. There is need to balance transparency with protecting data suppliers' IP. Mechanisms like the knowledge trustee function could address that.

- There is confusion over what circular economy (CE) means and how it relates or differs to traditional sustainability. Clear definitions are required in order to manage expectations and demonstrate value for users. Users are not certain about the scope of CE platforms and how those relate to their own priorities such as Corporate Social Responsibility. In marketing the MPP it will be important to describe how it integrates into the value propositions elements from sustainability and the CE.

- Shorter term value seems to be a priority for users, more than raw materials value at end-of-building-use. Initiatives about passports identify scarcity as a driver for MP e.g. secondary raw materials recoverable from a building at the end of its use. These are based largely on the European Commission focus on strategic raw materials. However, the marketplace looks at shorter-term value. If MP are perceived to be limited to only inventorying raw materials, this will limit their value and practicality for users. For example, calculating economic value based only on raw materials inventory is limited without factors like extractability, reversibility, separability being included.

- Building owners are increasingly looking for healthy buildings, also as a competitive advantage to attract personnel. However, "healthy" does not just mean "less toxic." The great majority of databases today focus on keeping out toxic ingredients, but this is a losing enterprise as hundreds of thousands of new products come into the marketplace. A more manageable approach seems to be to develop lists of healthy ingredients.

## 3.9. Materials Passport Platform Quality Assurance

According to the Business Dictionary, quality Assurance (QA) "often used interchangeably with quality control … is a wider concept that covers all policies and systematic activities implemented within a quality system" ( WebFinance Inc.).

Quality of data is usually a concern of databases and information sources. As the saying goes, "garbage in, garbage out." In order to check MP for data accuracy or "fake news," data quality assurance has to be performed as a distinct step.

MP contain some questions that ask if the data was quality assured, so users can see if it was done. If it was not done, then after data is entered into the MPP, the input can be used as basis for quality assurance.

In the case of MP and MPP, the priority is to assure *data* accuracy (possibly performed by the consortium members or external parties as services linked to the MPP). However, there is also a requirement for wider QA on policies and system activities that govern how the platform functions (this being part of the MPP governance).

QA falls into the following categories:

- on accuracy of data provided (as a possible service linked to the MPP);
- on formatting of data (as part of the MPP governance). See standardization section 3.7.3;
- on avoiding duplication of data (as part of the MPP governance);
- on policies for displaying and organizing the data, input and output (as part of the MPP governance).

**Structure**

The definition of the body's scope, according to the categories mentioned above, and members is as fundamental as the definition of the policies and systematic activities implemented by it.

The QA body can consist of one or more organisations from the consortium or be open for others outside it. Regarding *data* quality assurance, different assessments and methodologies can be performed depending on who is involved on it. For example, EPEA does a certain level of data QA when it does assessments and SundaHus on its own QA methodology.

The variety of QA is wide, and the question of which procedure to use that allows for flexibility but also system consistency remains to be defined. For example, for some data users could have the possibility to choose and be transparent about which quality assurance methodology they use for the input data. In other more universal cases like formatting, the platform's quality assurance body would determine which methodology to use. In any case, QA structuring will require substantial attention.

Because quality assurance mechanisms have costs and benefits, their implementation should be considered as part of the WP5 exploitation and business model tasks. This means that after defining the QA body members for the categories above, the methodologies need to be clearly specified and agreed on. In this report, D5 team intends only to point out this identified demand as an initial input for further discussions with the project partners.

# 4. MATERIALS PASSPORTS PROTOTYPES

## 4.1. Materials Passports Creation Process

As mentioned previously, the MP are outputs of the MPP. They can be customized so the user is able to filter which information about a building, product, or instance he wants to retrieve from the system. This avoids that users be overloaded with more information than needed.

The information that is able to be extracted with a passport is a result of data sharing from many platform users during the product and building use phases. This is the core of the passports' creation. Some users are data providers and also retrievers. The time in which they provide and retrieve data varies. As the platform is the place for data sharing about products, the data sets will be continuously updated and adapted by the users, to reflect the latest knowledge available about them in the market and when installed in a building. This is the advantage of having a dynamic system that offers the opportunity for data to be updated and checked. A passport is not a fixed set of information, but the reflexion of the latest knowledge of a product to date.

## 4.2. Materials Passport Prototypes

The team worked with the BAMB partner Technical University of Munich (TUM) to create MP prototypes for the NexusHaus building.

The University of Texas at Austin and the Technical University of Munich designed and built the NexusHaus for the U.S. Solar Decathlon 2015 competition. Combining the efforts of UT Austin and TUM students, an affordable, modular residential green building was designed and constructed. The NexusHaus demonstrates transformative technologies in Zero Net Energy, Zero Net Water, and is carbon neutral in its use of sustainable building materials s (The University of Texas at Austin and The Technical University of Munich).

In WP2, TUM has the role of supporting the WP4 pilot projects in the platform usage and MP creation. The NexusHaus was used as a testing and prototyping opportunity, in order to understand the concept and the process of generating MP. The prototype passports were then used to optimize the MPP and the data collection process.

During the development of the D5 report, the PoC of deliverable 6 was not yet available for testing and prototyping. The prototypes developed for this report are based on the input workbook (section 3.6). They contain data about the building, five generic products, and one instance for each product as an example. When the PoC becomes available, the inputs will be transferred to the system.

## 4.3. Lessons Learned from the Prototypes

The prototypes for the NexusHaus by TUM provided important insights in the data gathering process. It was possible to identify the required data inputs that are easily available and the data that needs to be provided by specific user groups (e.g. products' suppliers/manufacturers). It was also a useful test for understanding the input fields (e.g. common terminology and definitions), which was helpful for future reviews.

The process confirmed the need for a user-friendly system interface and the option for users to filter data that is relevant for them (e.g. enter and extract according to the value propositions they want to focus on).

In addition, the prototypes demonstrated the need for further development in data standardization and definition clarity of used terms in the context of MP. This will be accomplished in combination with the other WPs that focus on data collection.

The data was collected by TUM, with support of the D5 team, because the PoC was not available for sharing with platform users such as the product manufacturers and building designers. When this is possible, many lessons will be learned from the feedback from the platform users. This knowledge will be incorporated into D7, for the creation of 300 passports.

Important to note: it is not expected that the PoC will handle confidential information. The data collected for the prototypes is openly available and does not include confidential information at this stage.

# 5. CONCLUSION & OUTLOOK

Deliverable 5 Framework for Materials Passports is the foundation for the development of the materials passports and the materials passports platform in BAMB project. Further deliverables already completed, such as WP2 D4 User Requirements, and under development, WP2 D6 Software Platform, had great influence in the progress of this report. It consists of research, discussions, contributions from BAMB partners, and work based on the team's expertise, which brought a rich background to the framework.

The content of this report, including the attached files in the annexes, has been fundamental for the development of D6 and will form the base for the further development of the platform and passports' creation. D5 cites the main topics to be addressed in the creation of the MPP and briefly points out what is expected to be implemented in the PoC.

Moreover, limitations and challenges for passports were identified based on and complementing the analysis from D1 State-of-the-art report, for the development of the next project steps. It is not only relevant to WP2, but also as input to other work packages such as WP5A2 developing business models and WP5A4 focused on exploitation.

Last, over the course of the project, the MPF will be refined through the lessons learned in the creation of passports in D7 and the software developed in D6. The list below identifies areas where further development related to D5 is expected:

A. WP2 D7 *Operational Materials Passports*

- Insights gained in D5 will impact the implementation of the 300 passports to be made as part of D7.

B. WP2 Task 14 *Continuous modification and updating MP framework and software*

- Adaptations of input lines: adding, removing, and adjusting input fields;
- Improving guidance and examples for each input field;
- Standardization of data (continuation of work done to the moment of report delivery);
- Adaptations to the software to reflect the changes above;
- Adding functionality to software such as data filtering and presenting a summarised and customised output. There is significant potential for added functionality.

C. Interactions with WP3 Reversible Design, WP5A1 Decision Making Model Tool, and other BAMB partners such as BAM and Drees & Sommer.

- Contributions on:
  1. data standardization
  2. input lines review relating to reversible building design and circularity indicators.

Both contributions will impact the adaptations of the input fields in the MPP mentioned in item B.

# 6. GLOSSARY

Many terms and concepts mentioned in this report need to be further described and clarified, as some might bring different interpretations or not be aligned with the focus of this deliverable and the intentions of using these terms in the present report.

1. **API**

The MP platform's Application Programming Interface (API) is a series of definitions and protocols which enable other systems to communicate with the MPP and connect the platform's database with the *user interface* (see below).

2. **Building Data Set**

Mentioned in the input workbook and used for data structure and organization in the platform. This data set contains the data related to a specific building that is included in the platform.

3. **Building Information Modelling (BIM)**

Building Information Modelling is the process of designing, constructing or operating a building or infrastructure asset using electronic object-orientated information.

4. **Cascade**

It is the process of having materials cascading through other applications following the initial use, in order to benefit from the materials' values as much as possible. For example, avoiding that timber be incinerated after its first use, by planning that between these two extreme phases composite wood and paper be produced from it.

Technical cascade potential: Repurposing/Flexible use, Reparability, Refurbishing, Remanufacturing, Disassemblability, Recycling.

Biological cascade potential: Recycling, Decomposition, Composting, Biodigestion

**5. Component (of product)**

Part of a finished product that can also be an individual finished product and subject of a MP. A product can be made of many components, for example, an office chair contains components such as legs and wheels.

**6. Context and Location Data Set**

Mentioned in the input workbook and used for data structure and organization in the platform. This data set contains the data related to a (product) instance in relation to its surrounding environment, such as its geographic location and connection to the building (see *Instance* below).

**7. Disassembly**

Disassembly refers to the act of taking apart the product or system on site or in another facility creating the possibility of replacing some parts of the product (e.g. during maintenance or renovation), without the necessity of removing it as a whole.

**8. Generic Product**

It refers to a product as it is available in the market. The collected information for it is true no matter the locations and the manner it is used.

**9. Impact (positive/beneficial) of a product**

Positive/beneficial impacts relate to the values brought by a product to the environment and humans during its manufacturing, use and reuse phases, such as cleaning the air, water or soil, and producing energy. This is beyond impact minimization, such as using less fossil fuel; it is about bringing more good that if this product was not used.

**10. Ingredient**

A level of product composition breakdown. It is a chemical element, chemical compound, ion, or alloy (see product composition).

**11. Input Data (=Data Input)**

Content provided by MPP users when adding, editing or updating new or existing product, building, or instance data sets in the MPP through defined forms and formats.

**12. Instance**

An individual of a product. From one generic product it is possible to have many instances. Contrary to a generic product, it refers to a single/unique real world product used in a specific situation. Example: one building contains 10 doors, and in the MP platform these doors are identified as 10 individual instances of the generic product door.

**13. Instance Data Set**

Mentioned in the input workbook and used for data structure and organization in the platform. This data set contains the data related to a specific instance (see instance above).

**14. Material**

Material is used mainly to describe raw and/or generic materials such as metals (copper, aluminium, etc.), wood, earth, clay, stones (granite, marble, basalt, etc.) and substances that are content of products available in the market, such as additives, pigments, and polymers, but which are anonymous and not considered specific products themselves. In this sense of the term, materials can be represented in MP through the description of the composition of products and systems, but they do not have their own passports.

**15. Material Input**

Substance part of the product manufacturing process, but not present in the final product composition.

**16. Materials Passport**

Materials Passports (MP) are (digital) sets of data describing defined characteristics of materials and components in products and systems that give them value for present use, recovery and reuse.

### 17. Materials Passport Framework

The content developed under the deliverable 5 to define and describe the MP for BAMB and the software platform for their creation.

### 18. Materials Passport Platform (MPP)

It is the software platform to create MP. The main content of the platform is structured and unstructured data of buildings and building materials. This IT solution enables two major purposes for multiple stakeholders: 1. generate MP; 2. provide and see data during all the product and building usage phases (see *Proof of Concept* below).

### 19. Output data (=Data Output)

Content retrieved from the materials passport platform. The materials passport itself is a MPP output.

### 20. Ownership (referred in the MPP input fields)

Ownership referred in the input workbook of the MPP refers to the ownership of the materials used in a building.

### 21. Product

Product refers to an item that is manufactured or refined for sale. A product is offered in the market by a responsible producer and has certain properties such as a commercial name, a producer ID and a serial number. A product is not an anonymous material. Examples of products for which MP can be made are building related products such as; wall or floor tiles, flooring, gypsum walls, office furniture, paint, windows, connectors, steel or wooden beams, railing and framing, roof tiles, bricks, insulation, doors, coatings, piping, hardware, electronic equipment, and lighting.

### 22. Product Composition

Definition of product content breakdown: system/product $\rightarrow$ the components $\rightarrow$ ingredients (chemical level). The level of information available in the platform for material

composition varies among the products. Material composition might be available up to the component level, for example.

### 23. Product Data Set

Mentioned in the input workbook and used for data structure and organization in the platform. This data set contains the data related to a generic product that is included in the platform. This data set describes the product as it is available in the market and is relevant to the product no matter if it is installed or not in a specific location.

### 24. Proof of Concept (PoC)

A proof of concept is a realization of a certain method or idea to demonstrate its feasibility, or a demonstration in principle, whose purpose is to verify that some concept or theory has the potential of being used. In the present report, PoC refers to the software platform developed by BAMB work package 2 on deliverable 6, as the first version of the MPP (see *Materials Passport Platform* above).

### 25. Quality Assurance

"Often used interchangeably with quality control (QC), it is a wider concept that covers all policies and systematic activities implemented within a quality system. QA frameworks include (1) determination of adequate technical requirement of inputs and outputs, (2) certification and rating of suppliers, (3) testing of procured material for its conformance to established quality, performance, safety, and reliability standards, (4) proper receipt, storage, and issue of material, (5) audit of the process quality, (6) evaluation of the process to establish required corrective response, and (7) audit of the final output for conformance to (a) technical (b) reliability, (c) maintainability, and (d) performance requirements" ( WebFinance Inc.).

**26. Removal (material)**

Material removal in the context of material passports means the extraction of the product or system as a whole from the building after its end use, and no remaining parts of it stays in the site.

**27. System (as an object subject of MP)**

A system is an assemblage or combination of things/parts forming a complex or unitary whole. System as an object subject to MP is a complex product made of many components/parts from different manufacturers which could also be used as independent products or subject of individual passports, such as products used in plumbing, electrical and mechanical systems.

**28. System Use Case**

Describing the behavioural portion/ interactions between user and the system, based on the use scenarios and created for the development of the MPP.

**29. Use Phase**

The use phase is the period the product is performing its intended use and, most of the time, it coincides with the period it is installed in or around the building. The use phase has the following purposes: to guarantee safe use in the building; to reasonably estimate when the product will come back for its next use.

**30. Use scenarios**

Narratives of platform uses to identify the potential users involved in the situation described, the values they have from using the platform in the specific scenario, and the actions that should be taken to make the example successful. The scenarios are made based on the D4 user requirements.

**31. User Interface (UI)**

The user friendly web based interface for accessing the MPP without the need for the user to connect his system with the platform's API (see API above).

**32. User Requirements**

Requirements for the MP collected from possible users through interviews and workshops in deliverable 4 User Requirements, concluded by WP2 in March 2016.

**33. Value Proposition**

A value proposition is a business or marketing statement that a company uses to summarize why a consumer should buy a product or use a service. This statement convinces a potential consumer that one particular product or service will add more value or better solve a problem than other similar offerings. Companies use this statement to target customers who will benefit most from using the company's products, and this helps maintain an economic moat (Investopedia, LLC).

# 7. ANNEXES

## 7.1. Deliverable 5 Main Team

A brief description of the two partners mainly involved in D5 is included below:

**EPEA Nederland BV:** EPEA supports companies, institutions and local authorities to analyze and optimize materials, products, and systems so that they are of human, environmental, and economic benefit based on the Cradle to Cradle® design concept. By material flow management, it is possible to identify and positively define beneficial resources for biological and technical nutrient cycles. Examples of previous EPEA projects related to the topic of this report include, but are not limited to:

- o Mid-1990s. Dow Chemicals starts Safechem based on the EPEA concept of leasing chemicals. Safechem uses criteria from EPEA for identifying high quality safe chemicals which can be effectively recovered and reused.
- o 2011. Turntoo, a C2C-based concept for products leasing is launched. EPEA NL is a founding member of the group.
- o 2012 Delta Developments and Park 2020 request EPEA NL to describe criteria for MP in Buildings.
- o 2013 The first Maersk Triple E ship piloting C2C MP is launched.
- o 2013 Rijkswaterstaat requests and receives from EPEA NL a study on the potential for designs for disassembly relating to MP in ships (EASME).
- o 2014 EPEA launches the Environmental and Health Statement (EHS). It is based on the positive Cradle to Cradle® approach and integrates statements on product safety during use, material productiveness after use, post-use management, good raw materials, and progress planning.

**SundaHus i Linköping AB:** SundaHus i Linköping AB (publ) is an SME registered in Sweden as a public limited liability company. SundaHus has an extensive experience from over a decade of structuring, normalizing, and providing easy access to information similar to the one in the BAMB project and for the same context that the project is targeting. The company has been doing that in well over 1,700 real-world construction projects which have resulted in a system with documentation, assessment, and in depth information about products, chemical content and other quantifiable and environmental properties of over 37,000 unique construction products available in just short of 110,000 "flavors", i.e. sizes, colors and so on. The "easy access" provided includes web interfaces, but also Application Programming Interfaces (APIs) for linking to external systems, such as other database and BIM tools. SundaHus' services, projects and experience that relate but are not limited to the report topic:

o   SundaHus Miljödata (SundaHus Material Data) - The main, web-accessible information platform that handles construction product and project information. Used by all stakeholders in design- and construction phase as well as in property management.

o   BlackList - The customizable automatic assessment system that allows customer's specific environmental requirements to be encoded into the system and automatically applied to every product in the database.

o   An assessment service that consists of an in-house staff of qualified chemists with an extensive experience of assessing construction materials on a daily basis.

o   A Revit plugin that allows easy access to information in SundaHus Miljödata from within a BIM model.

o   Methodology for conscious material choices who does what and when, based on the concept of "plan, do, check, act".

o   Counselling services about the methodology and system SundaHus Material Data.
Knowledge and experience in structuring and standardising data and to develop tools, software platforms and functions to make data easy accessible for all users.

## 7.2. MPP Data Format Options

This is a complement to the discussion in section 3.7.2 on MPP data format options.

### A. Option 1: all data is structured and standardized

This is the traditional way and still the way most critical businesses are run. This is how the bank handle accounts, how the taxation authority handles tax returns, how e-commerce sites handle orders, how the stock exchanges handle trading, and how almost all electronic business transactions work, for example.

**Advantages**

It is easy to get the information from the system, since you know what is available. If a specific field should tell if a product complies with the *E1 norm*, for example, it can contain "Yes", "No" or "No information available" i.e. null. If a computer program needs to locate all products compliant with the E1 norm it simply searches for all products that have a "Yes" in the "Complies with E1" field. It is also rather straight forward to produce a relevant summary with just the highlights automatically.

**Disadvantages**

Structured data puts a larger responsibility on the users that have to input the information, either manually or automatically. All information has to be provided to the system in a well-defined way. If there is a field called "Complies with E1" that only accepts "Yes", "No" or "No information available" the user has to make sure he actually has the proper answer. If the answer is "Well, I think so, but the test has not been completed yet," he won't be able to enter that. On the other hand, if he were allowed to type in "Well, I think so, but the tests has

not been completed yet," it would put the responsibility on how to value that statement on the user (either human or machine) that get the information from the system.

### B. Option 2: all data is in free form

This is essentially how Google[7] (and its competitors) works. It is also how a lot of advanced analytics tools partly work. They will use structured and organized data when it is available, but also use the unstructured data both when there is nothing else available and to supplement the structured data.

**Advantages**

It is easy to enter information by simply uploading what is wanted. The user will not be limited to the fields currently available in the form, so if there is something new he wants to communicate, he can add that information into one of the documents uploaded.

**Disadvantages**

The general disadvantage of using unstructured data is that user tends to retrieve much more inexact results from such data than with a structured format. Since the unstructured data can be entered in almost any form without any real validation or standard, it is very sensitive to "garbage in – garbage out." It is however possible to standardize what to add to the system and start to tag the different data items in a uniform way, but then it is not unstructured data anymore. It is more complex to use the information, especially if the user needs to use it automatically. So if he wants to create a summary of the information available, advanced analysis tools are required to analyze what has been uploaded. Those tools need to be extensively tuned to make the right analysis of it.

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[7] www.google.com

## C. When these options are used

Users that utilize large quantity of data to make any form of calculations, decisions or summaries tend to prefer structured data. It is simply much easier and much safer. So why then is the other alternative used? It is pragmatism: "Even though we would prefer to know the exact figure, if that isn't available, we will have to do as good as possible with what is available." This approach has been used before, but what really made it take off was the popularization of the World Wide Web. There is a great amount of information available there that is unorganized and unstructured (as well as organized information). The only way of making any good use of that mass of data is to accept it *as it is* and try to develop methods of extracting insights from it. These tools have developed rapidly over the years and will undoubtedly continue to do so. However, the "definition" of when these tools have reached complete maturity is when they can assess and value the unstructured data to give the exact answer a user could now get instantly with structured data.

## D. Option 3: The compromise

A common way of handling the topic of structured and unstructured data is to decide what data is worth the effort to have structured and well defined, and let the rest to be stored unstructured. In the example above with the "Complies with E1" field, it might result in another field called "Complies with E1, comment". Then the absolute "Yes" or "No" is still available, but there might be some extra information about this that cannot be foreseen and therefore not standardized. This information goes into the *comment* field.

Another example would be one standardized field that tells if a product is designed for disassembly with the answer options: "Yes", "No" or "No information available". However, the user inputting data may also have a document describing how to disassemble the product.

Then, the system can allow the user to upload files, and it is decided that the disassembly instruction will be stored as an unstructured document.

The questions that needed to be answered to make the right choice between the different strategies were:

1. Which type of information is required from the MP? Is it a list of texts where a human might find the answer sufficient, or is there a need of an exact answer? Is there a need for aggregated information and, if that is the case, which type of in data then is needed for that type of aggregation?

2. Is the data in the system suitable to be structured? Is the data from providers currently structured? If not, which is the best solution: to enter it in structured form or to set up a system that deducts all needed information from unstructured data to the level of certainty that is required for the needed functionality?

### E. Materials Passports Input Workbook

The compromise approach above is what has been used throughout the MP input workbook (session 3.6). The "Entry Type" column has been intended to show how that data should be stored in a row in the database, the *standardization comments* relates to how to standardize the meaning of that field and also to how it might be formatted. The *mandatory data* relates to the fields that are required for the data set to be meeting the basic requirements of a MP creation.

### 7.3. Data Standardization Levels

To exemplify the levels of data standardization mentioned in section 3.7.3, material composition information is used to illustrate the possible different levels of standardization within MP.

**A. Level 1 - What data should be possible to include in a materials passport?**

To enable a MP to fill some of the functions identified within the D4 User Requirement gathering, it was decided that it should be possible to include materials composition information in it. This is one example of standardizing, on a high level, what data should be handled by a MP.

**B. Level 2 - What subset from level 1 above should be in a materials passport for it to be considered valid?**

As an example, if the user requirements that prompted the need for composition information, and the use scenarios connected to them are central to the success of the materials passport, composition data should be mandatory. If not, it can be optional. It is also possible to choose a middle road and make it mandatory for certain types of products. Here it is also standardizing, on a high level, what data is required to make up a valid MP. This is important to make sure the MP actually will deliver the required functionality.

**C. Level 3 - What pre-existing standards should data in level 1 adhere to?**

How the composition data should look like or consist of within MP to be usable for providing the functionality that triggered its existence, is the focus of this level.

To continue with the previous example of composition information, the following four examples could all be seen as composition information:

1. Metal, plastic, oil
2. Steel (26.5 %), Aluminum alloy (11 %), cast iron (54 %), brass (0.25 %), oil (2.25%), thermoplastic (0.75 %)
3. A more detailed list like this:

| Substance name | CAS reg. no | Percentage |
|---|---|---|
| aluminum alloy (EN AW 5049, 3.3527) | | 11 % |
| cast iron ENJL 1030 (0.6020) | | 54 % |
| white mineral oil (petroleum) | 8042-47-5 | 2.25 % |
| steel (1.0718, 11SMnPb28) | | 9 % |

4. A list that also contains the composition of the substance and optionally, information about identified hazards:

| Substance name | CAS reg. no | Weight % | Hazard Statements |
|---|---|---|---|
| aluminum alloy (EN AW 5049, 3.3527) | | 11 % | |
| Aluminum | 7429-90-5 | | |
| Iron | 7439-89-6 | 0.055 % | |
| Silicon | 7440-21-3 | 0.044 % | |
| manganese | 7439-96-5 | ≤0.54 % | |
| Sulfur | 7704-34-9 | 0.081 % | |
| POM-H hostaform | | 0.75 % | |
| (1,3,5-trioxane) | 110-88-3 | | H228, H335, H361d |
| brass (CuZn39Pb3F51) | | 0.25 % | |

| lead | 7439-92-1 | ≤0.009 % | H360Df, H372, H373, H400, H410 |

All alternatives above can be considered as composition information.

While alternative 1 probably would be considered way to crude to be of any real use, alternative 2 gives at least some basic information of what is in the product.

Alternative 3 is more detailed, but still poses some problems, such as that it is not standardized how the percentage is calculated (weight or volume). Another problem is that the names of the different alloys, although recognizable for a person well versed in metallurgy, is not standardized enough to be safely machine readable.

Alternative 4 without the last column is easier for a machine to understand, since it specifies the composition of the alloys and uses CAS registry numbers (a de facto standard) to identify the different substances. It is also clear that it is weight percentage that is used (another de facto standard).

The last column of alternative 4 adds the internationally standardized hazard codes (an official standard) for some of the substances. This gives a hint about possible problems with the substance, which could be of use. But, this information reflects how a substance is classified at the time when the document was created. The assessment of the hazards for a particular substance might change at any given time if new findings are presented. In comparison, the other information in the table will not change unless the product is modified.

For the example above, it is possible to conclude that it is necessary to standardize what is considered proper composition information (clear definition of terms and concepts), what should be included, how it should be expressed, and to what level of detail.

**D. Level 4 - What format should the data in level 1 be stored in?**

We standardize a "document format" for expressing everything that is listed in item 1. The users of this format are machines, i.e. different software packages and APIs. Besides defining how the data should be communicated, the format also gives a general description about how it will be organized. This step is essential to make the system interoperable and is more a matter of good engineering than tough decisions. How the data is expressed to a human is not the focus of this level.

SundaHus has an extensive experience in structuring and organizing this type of data. When it comes to composition information SundaHus' data structure could, somewhat simplified, be expressed in XML as shown below. This is part of the IP contributed by SundaHus to BAMB.

```xml
<compositionInformation>
  <substance>
    <name locale="en-UK">aluminum alloy (EN AW 5049, 3.3527)</name>
    <casno>N/A</casno>
    <fraction>
      <ceiling included="true">0.11</ceiling>
      <floor included="true">0.11</floor>
    </fraction>
    <substance>
      <name locale="en-UK">aluminum</name>
      <casno>7429-90-5</casno>
    </substance>
    <substance>
      <name locale="en-UK">iron</name>
      <casno>7439-89-6</casno>
      <fraction>
        <ceiling included="true">0.005</ceiling>
        <floor included="true">0.005</floor>
```

(The structure continues and only a segment is demonstrated here)

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