BUILDINGS AS MATERIAL BANKS AND THE NEED FOR INNOVATIVE BUSINESS MODELS

THIS EXTRACT IS FROM AN INTERNAL BAMB REPORT

October 2017

Authors: M. Peters (IBM), A. Ribeiro (IBM), J. Oseyran (IBM), K. Wang (VITO)

Co-funded by the Horizon 2020 Framework Programme of the European Union

Table of Content

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

1. Building as Material Banks and the need for innovative Business Models

'Building as Material Banks' is the wider concept where corresponding business models reside. In its essence, a business model is describing the way 'how we actually make money' by defining the value proposition and build up an understanding if the model is economically viable. This is done by providing insights on how we create value, and market and deliver the offerings to the target customers segments, including potential revenues generated.

When using the analogy of 'banking', or within this project's framework of 'materials banking', we recognise different mechanisms to extract the value of these products, components or materials, or rather building assets. For example, in the world of Finance, banks (as a role) have many different business models to 'make money': e.g. (Capital) Investment banks have their own corporate customer segments, value propositions and product portfolio. They make money via different mechanisms and offerings than a traditional consumer bank that enable consumers to have savings and lend for mortgages, etc.

Also, within the same company, you can have different business models. For example, when looking at IBM different models are applied like professional services (via business unit Global Business Services), IT services (via Global Technology Services), cloud pay-by-use services (via Cloud Business Solutions), and selling of new products (via Systems & Technology Group) and remanufactured/ refurbished products (via Global Asset Recovery Services). All have their own offerings and customer segments. Especially with GARS, being part of IBM Global Financing (i.e. IBM's internal bank), the IT assets are assessed for reuse and resell value, based on condition, rework effort and market demand.

As for the many different assets in a building, we need to understand the reuse potential by design and how we would assess the value of these assets in present use and when these assets become available for reuse or recycling. For multi-cycle products, do we adhere still to the different accounting depreciation rules or will the (residual) value be prescribed by the market via supply and demand mechanisms that are fed by the relevant information on these assets? And what will be the effect on the residual value assessment of assets if other factors become more important in the value assessment, like with products and materials that improve indoor air quality and directly impacts the productivity of building occupants?

When we link this all to the BAMB project, the material bank on its own will not generate money. We need to understand who owns the material and data (and makes the decision to reuse), who will need this for re-purpose, etc. So, the concept of material banks contains many different business opportunities, that have a value for the different roles in the industry. How to capitalize on this, we first build an understanding what type of mechanisms are to be considered to successfully extract the value out of the BAMB outputs and have a way to assess the value and reuse options to the industry. These mechanisms, or business models, enables the concept of material banks.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Work package 5 Action 2 focuses on the recommended business models and associated Operating Model that are applicable to the outputs being generated in the BAMB project. These recommended business models are a conceptual structure on how to extract value from the work products of this project but do not constitute a full commercial proposition. The business models to be designed pertain to the application of this innovation project's main outputs: material passports and reversible building design (depicted in 1.1).

1.1 BAMB Recommended Business Model Scope

These applications will have implications on the different participants in the construction value chain and the different stages of the lifecycle of a building and installation. Therefore, this report will include an assessment on which parties are most impacted and what type of impact is expected.

For each of the project outputs, some main questions need to be answered:

- What functionality will the *Material Passport* cover, and how will it service the different stakeholder groups in the industry?
- How will *Reversible Building Design* help reuse of buildings, products, components and structures?
- What will be viable Business and Operating Model designs, that can leverage the potential of both the Material Passport and Reversible Building Design, that will enable a *technically feasible and economical viable Building as Material Banks*?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Global and local trends and/ or facts

Already there are global and regional trends that indicate a changing landscape for businesses to start adopting circular economy principles. An overview is provided in 1.2 below.

Political	Legal & Regulatory	Societal & Demographic	Environmental
• European Commission with stated ambitions and targets as part of the Circular Economy package December 2015, triggering many cities and municipalities to start initiatives • World Economic Forum (WEF): also focuses on construction industry to introduce and expand circular economy principles to tackle environmental problems and capture new economic opportunities • Climate Change Summit 2015 (COP21) in Paris, with Circular Economy high on the agenda as a lever to achieve the environmental goals • Cities embracing ambitious circular goals: London, Amsterdam, Utrecht, Copenhagen, …	• Changing legislation for demolition (pre-audits), stricter waste regulations on European and country level • More focus on excluding toxic or harmful materials from further reuse (all industries)	• Urbanization trend, with 70-80% of world population thought to move to cities by 2050, with increasing demand for city planning and reuse or transformation of existing building stock • Worldwide awareness of circular economy with northern European countries leading in initiatives	• Increasing societal awareness on waste, pollution, environment and climate and our species' role as ambassadors of this planet • Depletion of natural resources and impact on environment and our habitat, e.g. forest destroyed for mining, etc.

Economic	Technology
• Overall there is limited growth potential in construction in Europe with today's traditional (or linear) business models – this growth potential refers to new and more traditional or linear building projects, renovation has the largest market potential, but is currently limited by the reuse potential of current products and materials, and many buildings are unfortunately more a demolition liability on a balance sheet because of lack of building transformation capacity • Increasing scarcity of part of available construction materials; not limited to precious metals/ materials but also increasing costs of mining or extraction of virgin materials • Lost value of 'waste' where the vast stock of one-purpose buildings is considered a demolition liability at end of their performance cycle • New circular ways of working where businesses are moving away from traditional 'product and additional service' models to more performance driven models • Many public and private tenders are already embedding circular economy targets (e.g. CO_2 avoidance, % reuse materials and products, etc.) • The traditional organization of the economies is changing, and the boundaries between functional areas and industries are fading away, which is leading to value chains will decompose (i.e. clear separating of functional areas leading to specialized parties), industries will converge (value is created by leveraging knowledge across completely different industries), and ecosystems will emerge (with continued collaboration between the different players circular ecosystems will be accelerated and solidified)	• Currently there are already many existing resell and trade platforms for used products and materials targeting the construction industry, however much information on product characteristics, specifications, condition and availability are missing • For design & build project teams there is an extensive data and information gap on product, components and (toxicity or health of) materials in existing and new buildings, blocking potential reuse and re-purpose options • Change of construction methods every 6-9 years will accelerate modularity and standardization in the industry, but demands access to properties and reuse potential of existing products and components; the change of these methods will impact businesses with a product portfolio of limited reuse potential

1.2 Macro-level global and local trends/ facts

These trends show that mind-set and willingness to change practices is being widely adopted on all levels in society, political landscape and businesses, and has found its way into the built environment too.

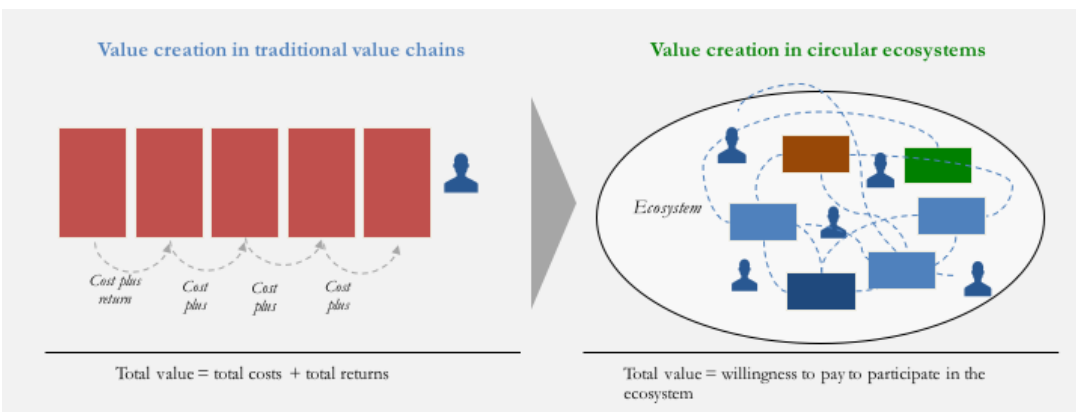
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Changing ways to capture value

The way that value is created and allocated across society is changing. This process is starting to differ from traditional linear value chain environments. Where traditional models are based on a cost-plus value calculation, new ecosystem based models are more based on the 'willingness' to pay to participate in the value network (as depicted in 1.3).

In a traditional value chain, value is in general added to a given product and service every time it moves from one player to the following one. Chains are in general rigid and participants have clearly defined roles that are not changing overtime. Additionally, these chains are organised for one way flows (usually the production/distribution/sale processes).

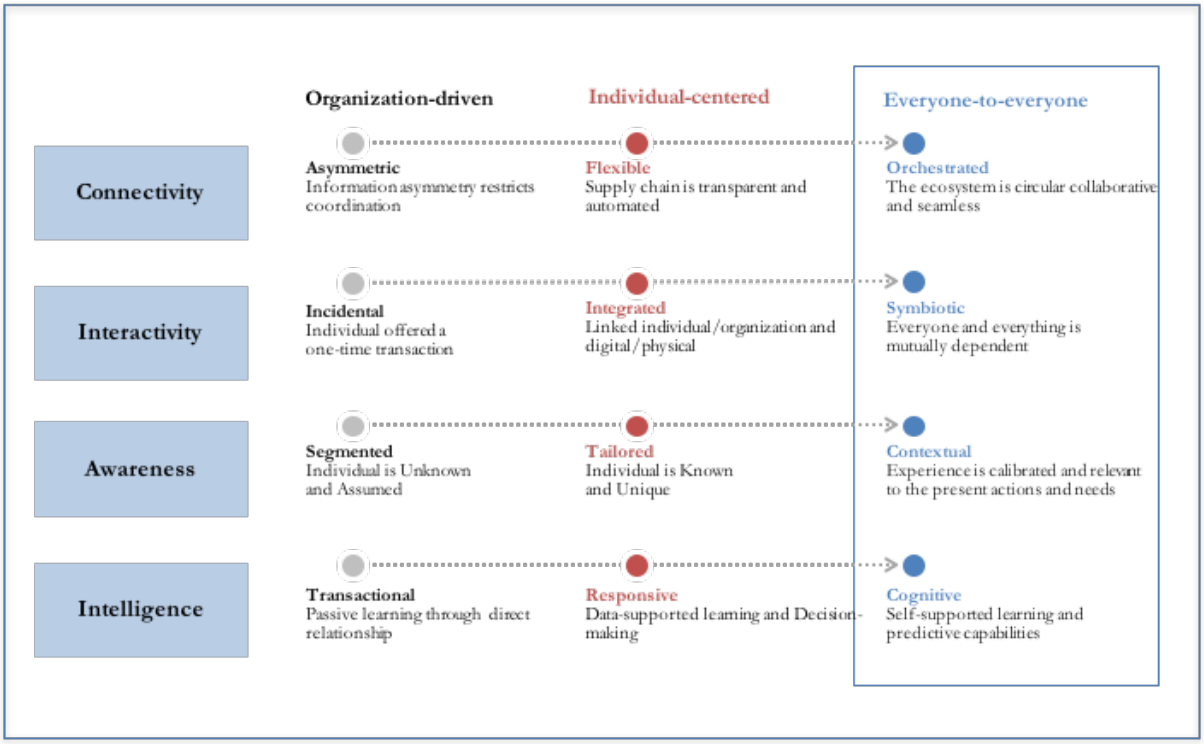
A circular ecosystem is significantly different than a linear value chain. The different players are more flexible, individually and as a group. The flows are multidirectional in the different dimensions (leading to much more intense collaboration and sharing of information). Finally, the value creation is also much more complex and group based. These ecosystems will have a way of allocating value to all participants in a more proportional way than linear models (due to much more data availability and transparency in the system).



1.3 Ecosystem based value determination shift

Therefore, successful circular ecosystems will act as the enabler and the vehicle to accelerate value creation, and the end integrator of experiences for consumers. These circular ecosystems will increase the interdependence between participants to deliver new value propositions to all participants, both suppliers and users/consumers (see 1.4 below).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.



1.4 Shift partner collaboration needs and dependency trend

Information as the main ecosystem enabler

Currently, one of the major gaps in the construction industry that hinders an acceleration of circular practices is the lack of high quality shared information. This information gap, where professionals (designers, builders, recyclers, etc.) have no or limited access to product specifications, condition, availability, is to a very large extent limiting the reuse potential at different levels. New ways of working and interaction between parties increases demand and dependency for storing and sharing of data and insights.

Current approaches and technologies focus on the integration of building models captured in data (like BIM – Building Information Modelling/ Management) to provide the base information, but do not tackle yet the information gap of existing building stock. Furthermore, BIM systems are relatively complex and are in general still only accessed by experts to manage, (re)work data, and extract data to be used by other systems; many roles in the construction industry still lack specialist knowledge of these complex information systems, like BIM. However, application of BIM in new build and the larger renovation projects is increasing, including application for facility management and maintenance.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

A set of important changes is expected in the construction industry

Main drivers that will contribute to the uptake of circular building practices in the European union ecosystems:

- Urbanization
- Legislation
- Resource scarcity
- Land scarcity
- Shift to modular construction
- Tight margin industry
- Corporate Social Responsibility
- Improved Recycling Technology
- Construction Process Optimization (using technologies like BIM)
- Improved Asset Lifecycle Management

Current and available solutions in the industry

In the construction industry, many initiatives have been started and there are solutions available to support both the understanding of material composition of installed products and the exchange (or trade) of these materials and products between parties. Many of these available solutions are built for one purpose and are not aiming to integrate multiple data sources and functionalities to serve the multiple roles in the industry.

Roughly we can group them into 2 solution approaches:

1. Solutions for trade of used products, components and materials

This type of solutions supports the exchange or trade of excess or used construction products and materials. The products and materials on these websites have the basic information on the product and condition, but lack details on product specification, detailed condition and only report what is published and made available now.

A selection of sites (non-exhaustive):

- Resource efficient Scotland (http://cme.resourceefficientscotland.com/)
- Enviromate (https://www.enviromate.co.uk/)
- Globechain (https://www.globechain.com/)
- Planet Reuse (http://planetreuse.com/)
- Harvest Map/ Oogstkaart (https://www.oogstkaart.nl/)
- Used building materials/ Gebruikte bouwmaterialen (http://gebruiktebouwmaterialen.com/)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

- Resource Limburg (http://www.resourcestore.nl)
- Bouwmarktplaats (http://www.bouwmarktplaats.nl/)

2. Solutions for building and material passports, database oriented

This type of solutions focuses on the provisioning of product or material compositions, with some passports aiming to describe an entire building, and others including passports for individual component products.

A selection of building focused passports (non-exhaustive):

- Electronic Building Passport Queensland
- Finland Green Building Council Building Passport
- Materieller Gebäudepass Austria (https://nachhaltigwirtschaften.at/de/sdz/projekte/bimaterial-process-design-fuer-bim-basierten-materiellen-gebaeudepass.php)
- Building Passports from Green Deal (includes some product descriptions, http://www.greendeal-circulairegebouwen.nl/index.php)
- Madaster (http://www.madasterfoundation.org/)
- CIE.Archicten (http://www.cie.nl/newsitems/154)
- Circular Building Platform (developed by Royal BAM and IBM)

A selection of material/product/recycling focused passports or product composition listing:

- C-passport Cirmar
- Circularity passports EPEA
- Cradle to Cradle Passport Sustainable Shipping Initiative
- Declaration of Performance (DoP) EC Product Directives
- Environmental Product Declaration EPD® ISO
- Health Product Declaration (HPD) (Health Product Declaration Consortium)
- Material Safety Data Sheet (MSDS) & Safety Data Sheets (SDS) The Hazard Communication Standard, OSHA
- Raw Materials Passport Turntoo & Double Effect
- Recycling Passport based on WEEE Agfa model
- Tool Groene Zaak/Metabolic/Fairmeter.org
- Technical passport for equipment Kazakhstan & Russia
- Workwear Passport Dutch Awareness

Note: Many of above passport examples were already listed and described more detail in 'D1 State-of-the-Art Report'[10], 'D4 Materials Passports User Requirements Report'[5], and 'D5 Framework for Material Passport Report'[11]. This report is not intended to cover a comprehensive market study of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

available solutions, which would include details on targeted customer segments/ stakeholders, etc. The list is non-exhaustive and is here to provide an overview of the many initiatives out there.

For many of above mentioned solutions and initiatives (on 1. and 2.) an assessment was done by reviewing the structure of the solution (or website), terms & conditions, and for some we also became a member to test the solution as potential customer. The vast majority of these passports are still mostly databases. In order for buildings to act as material banks, implies that reuse decisions need to be taken at one point in time. These reuse decisions are made based on a comprehensive view on product, its journey data like transformations, maintenance record, condition/ health status, change of ownership, etc. and requires integration of these different data pockets to build this comprehensive view.

The above mentioned solutions and initiatives are developed with a specific application in mind, and only offer part of the information to a limited set of targeted stakeholders and not directly targeting the many other users in the construction industry that need specific information on buildings and its embedded products and materials throughout the lifecycle of a building: whether they are considered and applied in design and engineering phase, build phase, use (or operate) phase and repurpose/ end of performance phase. To support these roles, the relevant information on building, product, component and material need to be integrated, made available to all industry roles and should be enriched with use data (repair, maintenance, replacement, etc.) to understand reuse potential at any given time to the professionals in the industry. The passports mostly cover the technical feasibility of reuse (most of them static), while for understanding the economic viability of reuse more information is required as this is more subject to market conditions, regulations, cost of rework, cost of extraction, etc., thus reuse potential is dynamic by nature.

Especially in the design phase of a building (either being a new build, transformation or renovation project), the architects, designers and engineers lack the information on availability of the potential supply for their projects. Most solutions are focusing on project managers, realizing the build, but most decisions are made at design (new/ renovation) phase where availability is off-synch, and inventory rules limit product reservations for longer periods. This is a particular challenge as the build phase always starts weeks or months after the design has been completed, by which time the materials are no longer available on the market.

This calls for new and integrated solutions, supported with innovative business models, that assist these professionals with ample information when they are interacting with a building.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

2. Construction industry based Business Models

For the Building as Material Banks project the business model and value proposition is based on the complementarity and synergies of Material Passports and Reversible Building Design protocols, enabling and unlocking value for multiple roles in the construction industry.

To understand how these project outputs or deliverables support the different roles in the industry, we need to evaluate the common and new business models used by the different roles. The project's outputs could then be structured into value propositions that serve the multiple roles, and be the accelerator of adoption of circular practices in the changing construction landscape. These business model strategies can be applicable for one or more of the business model innovation framework, and are not directly related. The strategies are aimed to describe how industry roles are organized in general so to link the business model output to the information needs associated to their business model approach. This in turn is then linked to fulfilling the information needs from the project's output.

For the construction industry four business model strategies are highlighted:

A. **Product/ Component/ Material driven**: focusing on providing the product or material with additional (take-back/re-use) services.
B. **Product Performance Driven**: focusing on providing a complete performance package (including product, financing, maintenance, etc.) with products as part of the proposition.
C. **Building Performance Driven**: focusing on providing a complete performance package on building level, basically being the main partner for building owners.
D. **Value Network and Collaboration Driven**: focusing on providing services to connect roles, value propositions and provide access to new and existing ecosystems in- or outside the construction industry

For each of these business model strategies we can link various business model approaches with industry roles and provide an understanding what the needs and requirements are to embed circular economy principles. Ultimately, all business models must be aligned with the objective of making buildings function as true material banks. With materials flowing easily in an out of the bank structure.

Below the four strategies are described to better understand the needs of different industry roles:

A. Product/ Component/ Material driven

The following set of business model approaches can be structured under this model strategy:

- <u>non-toxic ingredients/ nutrients/ materials</u>: supplying materials to the industry to make products or building with a minimal or no to low impact on health by taking out toxic or harmful materials out of the reuse loop; in some cases, the choice of materials can have a

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

positive contribution as health and productivity of occupants in buildings is increasingly recognized as a leading economic benefit

- product/ component substitution: supplying new products and components to replace or substitute when a product's end-of-life or performance is being reached; a traditional model but relevant in a circular economy context if these new products and components are constructed using reused or secondary raw materials
- product lifetime extension: providing specialized services for certain building products (building installation systems, HVAC, lifts, elevators, etc.) to increase value during use by extending the performance of a products; this can be achieved by using the other approaches mentioned in this overview
- component reuse: providing services for components as spare or replacement parts for building product that wear and tear during use
- refurbish/ remanufacture: providing refurbishment (to original product or component specification) and remanufacturing (including upgrading) services; this will not only lower procurement costs, but also will reduce the environmental impact by using less materials, energy and water compared to new products and components
- material recovery and reuse: providing services to provide materials or nutrients back to the industry or manufacturers by recovering secondary raw materials from deconstruction or demolition (for non-reversible old building stock) and renovation projects; the technology and process improvements in this area is expanding each time and provide a compelling case to more materials to be recovered at the same (or better) quality (i.e. upcycling)

These approaches typically apply for roles, such as:

- manufacturers or suppliers of new and reused products, components (including spare parts providers) and materials
- refurbishment and remanufacturing companies
- recycling companies and refiners

The information needs and requirements these roles would need to successfully implement and run these business model approaches are among others:

- material composition, contamination and recovery profiles
- product specifications
- condition or health status of used products and components
- construction and deconstruction profiles of building systems, products and components
- cost effective extraction, handling and reworking of reclaimed products and components

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

B. Product Performance Driven

The following set of business model approaches can be structured under this model strategy:

- product as a service: focusing on extension of services around the product
- product access as a service: providing more financial services (like renting or leasing) where building owners have access to the products, without having the concerns of financing (OPEX instead of CAPEX) or maintaining the assets
- product performance as a service: providing a complete performance package (product, repair, maintenance, replacement, etc.) of the product (e.g. a lift) or a set of products (e.g. light fittings, and pay-per-lux) where building owners pay-by-use with the performance carefully linked to either the life of the building or the building ownership (i.e. usership versus ownership); this includes products that actively clean the air or are safe for indoor air as health and productivity of occupants in buildings is increasingly recognized as a leading economic benefit, e.g. improved air quality is a distinct output of the performance of products and materials (through choice of material design) and could be used in performance pricing schemes
- shared use: providing services of reducing idle time and increasing efficiency of certain building products (or the whole building), by offering use of assets in a sharing model (i.e. the sharing economy)

These approaches typically apply for roles, such as:

- product manufacturers and suppliers
- asset owners (building or product owners)

The information needs and requirements these roles would need to successfully implement and run these business model approaches are among others:

- product specifications
- refurbishment and remanufacturing capability (includes upgrading to latest technology)
- condition or health status of the products and components in the field
- construction and deconstruction profiles of products and components
- cost effective extraction, handling and reworking of reclaimed products and components

For many traditional suppliers, without an existing portfolio of new and reused products and materials the transition to performance based business model approaches poses a financial challenge, as the immediate revenue upon sale (including cost recovery) of products change into a pay-by-use frequency payment scheme, that could heavily impact a company's financial position. Such transition will take time and a complete overhaul of how business is conducted today.
The availability of information on their products in the field would provide more knowledge to build usage- and maintenance profiles. This understanding would help in improving circular design, as up-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

time/ performance is key to reduce the costs of operation. Having the relevant (usage) data available, would help price these performance services and understand revenue and cash flow implications. These insights will help in accelerating the implementation of the required competencies and capabilities.

C. Building Performance Driven

The following set of business model approaches can be structured under this model strategy:

- design-build-operate: on behalf of the owner, financing the project, providing a complete service where design, build and operating the building is managed by one or a consortium of parties (also known as public-private-partnership); this includes the requirement on health and productivity of occupants which relates to the performance of the users of the building
- finance-design-build-operate-circulate: providing a full pay-by-use performance model, where the difference with above mentioned approach is that other parties are included in the consortium to deal with financing the project and taking care of the asset at end of life or end-of-performance

These approaches typically apply for roles, such as:

- developers
- architects
- engineers
- designers
- builders or main contractors
- facility management companies
- urban miners/ deconstruction companies
- demolition companies

The information needs and requirements these roles would need to successfully implement and run these business model approaches are among others:

- building energy profile
- building condition or health status
- specifications of products, components and materials
- refurbishment and remanufacturing capability (includes upgrading to latest technology)
- condition or health status of the products and components
- construction and deconstruction profiles of products and components
- cost effective extraction, handling and reworking of reclaimed products and components

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

D. Value Network and Collaboration Driven

The following set of business model approaches can be structured under this model strategy:

- platform as a service: providing an environment where businesses can share data (data repositories), share knowledge (education and forums to exchange experiences), build and integrate specific application, and/ or other based on pay-by-use schemes
- software as a service: providing specific applications with specific functionality (build on integrated data sets), on a pay-by-use scheme, and part of a collaboration platform
- insights as a service: provide insights as a service for businesses (e.g. product performance benchmarks, reusability comparison), to cities or (local) governments on environmental impact, regulatory compliance, building profiles, building stock and material resource consumption, etc.

These approaches typically apply for roles outside the traditional model, such as:

- (Digital) Services companies (targeting construction)
- Professional Services (such as strategy, business model innovation, circular economy advisory)
- Research and/ or Innovation Institutes (providing specialized services)

The information needs and requirements for these roles are based on the direct need of the other (more traditional) roles that use the data, applications and insights in order to execute their business models.

Common information needs shared across business model approaches

There is definitely common ground on information needs and requirements for all those roles, and boils down to information on different levels:

1. Building level: understand the performance of the building (e.g. energy consumption, positive contribution to the environment, reuse potential), build a profile of embedded products and materials to understand residual value and repurpose options, understand the condition of the building (via internet-of-things type data gathering, or traditionally with inspection reports), understand and assess the capacity to transform a building into a different function (e.g. from office to residential), understand the capacity to deconstruct (part of) a building into valuable and reusable components and materials; understand a building's ease of maintenance and refurbishment
2. Product or system level: understand the product's specifications, and understand the product's upgrade or reuse potential (i.e. next best reuse loop)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

3. Component or material level: understand the material composition of the products, components and materials as used in the building for all building product categories, and understand material recovery (upcycling versus down-cycling) and reuse potential in construction or across industries
4. Condition or health status: understand the condition of the products, components and materials implemented for the building to assess reuse potential and determine the best next reuse loop (to reuse on product, component or back to material level)
5. De- or reconstruction effort and instruction: understand easiness of deconstruct and reconstruct of products and components to determine a reuse effort profile and understand resources, equipment, time and costs involved to make a reuse decision

This information needs across different roles links into the main outputs or deliverables from the BAMB project:

- Material Passport: The Software Platform will be a functional proof of technology based on the Materials Passports User Requirements gathered in the early stages of the project. Ultimately, the software platform will be able to support the generation of - and access to Materials Passports. The software platform is aimed to manage and store information items that will shape the concept of Materials Passports, the exact combination and format of these information items and their representation will be based on the collection of business and functional requirements.
- Reuse Potential Tool: The Reuse potential tool will enable the assessment of the reuse potential of building structures - at the system and component level - in order to preserve the buildings and its components' and materials' residual value and foster high quality reuse.
- Transformation Capacity Tool: The Transformation capacity tool will enable the assessment of the transformation capacity of buildings, as well as building structures at the system and component levels.
- Design protocol for dynamic & circular building: The Design Protocol for dynamic & circular buildings will inform designers and decision makers about the transformation capacity and reuse potential of the design and the impacts of design solutions during the conceptual design phase. It aims to support the design of reversible buildings - and more specifically offices, apartments and public (socio/cultural) buildings with high transformation and reuse potential.
- Building Level Integrated Decision-Making Methodology: The Building Level Integrated Decision-Making model will be a methodology whereby new buildings and existing buildings can be assessed for resource productivity, based upon material selection and design decisions. This will build upon the data being collated and interpreted in the Material Passports and Reversible Building Design outputs, but will also include data and information from other sources, such as a Building Information Model and datasets created in the WP5 A1 work package. The reporting metrics of the nature and level of reuse are being developed currently and will align to the user requirements analysis undertaken with expected 'users' of this methodology and the associated BIM Resource Productivity Prototype. These results will be related to an indication of environmental, economic and

social value performance to assist decision makers in various system/ building level scenario evaluation, both in new and existing buildings.

- BIM Resource Productivity Prototype: The deliverable is expected to be a BIM compliant resource productivity prototype that supports a selected subset of the features of the Building Level Integrated Decision-Making Methodology. The ambition is to provide a useful prototype as a proof of concept of how the assessment and decision-making model could aid real world BIM users in making better choices and designs to enhance reuse potential and transformation capacity through the different phases of the life cycle of the building (design, construction, management & maintenance, refurbishing, dismantling).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

3. Determination of business model innovation needs

Today, industry professionals that are focusing on reuse of products, components and materials in the build and renovation project, identify three key issues that prevent additional re-use:

1. There is little to no information on **what is in our buildings**
2. There is little to no information on the **reuse potential and ease/ options of re-construct** for the architects, engineers and designers
3. There is no connection between the **supply** (the products, components, materials that will become available in time) **and demand** (for design inspiration or direct project use) of reusable products and materials

And even when the above issues are addressed, there are still issues to be solved to enable reuse at the higher product level or higher value level:

For example:

- The liability issue for load bearing structures: what is the condition and/ or health status of the used products, and are there guarantees or warranties applied by the manufacturer or supplier?
- Or legislation around waste: when is something considered waste versus used, and which product categories in construction are affected by these types of laws and regulations? For more background, see also a European Commission published checklist on 'preparing for reuse' (http://ec.europa.eu/environment/waste/framework/pdf/Checklists/4.%20Checklist%20_Preparing%20for%20reuse.pdf)

The major question for many players to move to circular ways of working is the balance between technical feasibility (potential of reuse from a functional perspective) versus the economic viability (does the effort for deconstruct, rework and handling way up to costs of new, with tax schemes and legislation not fully supporting circular business constructs yet).

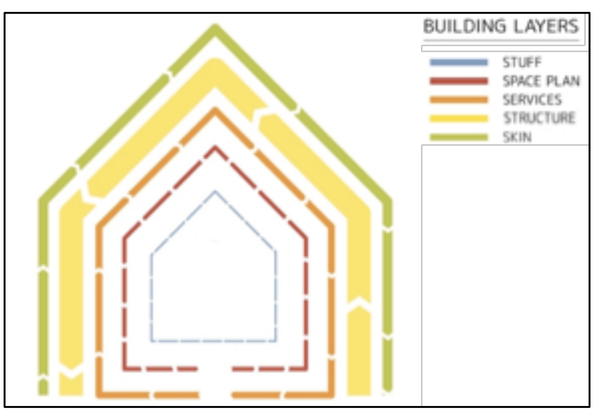
Also, when considering the different building types (see 3.1 below), we observe building regulations change over time. This impacts a building's performance requirement and what type of materials cannot be used anymore for specific applications), decreasing reuse potential of these materials and products (e.g. reusability of windows or facades with changing building energy requirements). Also, like with building regulation, with each type of building there are also different requirements evolving from e.g. emergency services, and health or hygiene requirements (e.g. for hospitals, food process industry, including requirements on durability, comfort). All of this put different requirements on construction methods, materials and products to be used, and in turn the reuse potential of these materials and products.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

3.1 Main building types

To address the information needs in the industry in order to accelerate reuse, the relevant information of a building needs to be captured to create a so-called 'digital twin' by using a variety of category structures. This will then provide base information to develop the different reuse opportunities. Category structures could be organised by:

- <u>building type</u>: e.g. residential, office, industrial, retail, health, sport, education and hospitality (as shown in 3.1)
- <u>building category</u>: e.g. by using the 6S from *Stewart Brand* [3] (see 3.2) and allocate the different products and materials used to either
  Site – location and infrastructure
  Structure – load bearing
  Skin – facades and roofing
  Services – building installations
  Space – interior spatial set-up)
  Stuff – furniture, etc.



3.2 Stewart Brands 6S framework

- <u>product category</u>: the different product that can be allocated to a building category like wooden, steel or glass beams to (load bearing) Structure category

The categorization, as a layer over the specific digital profile of a building, will contribute in understanding inventory by building type, year of build, location that can be used by the different

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

roles in the industry. For municipalities and cities, the view could be on a more aggregated level than for building owners, or for product/ material manufacturers or suppliers.

Capturing the relevant building, product and material information even with today's technology developments is still very challenging. In recent years BIM models are being put forward as the main mechanism to start describing what is in a building according to the architectural design. But the maturity of many of these BIM models, for example, not meeting even the basic level of populating the key properties for each product or material used. With the example in the Netherlands, where the largest construction companies have put forward a standard for BIM ('*BIM basis informatieleveringsspecificatie'* [4]), to ease transferability of building data across industry roles and facility uniformity in updating this data through time, these standards should also first be adopted and applied in current build and renovation projects.

The frequency of when different product categories become available for potential reuse is also dependent on four main building event types (see 3.3). Using the 6S approach again as a conceptual structure, we can conclude that most of the products and materials that become available are in the right 3 categories. Many of the building products that become available at a lower frequency can be found in the left 3 categories, where the building and product regulations on waste and reuse is limiting reuse options.

Supply of used products and materials

Event type	Site	Structure	Skin	Services	Space	Stuff
Small upgrades/ replacements/ repair/ maintenance				x	X	X
Refurbish (interior)			x	X	X	X
Renovation (all)		x	X	X	X	X
Deconstruction/ demolition	X	X	X	X	X	X

← increasing building and product regulations adds to the complexity of reuse potential

3.3 Frequency of availability of building/ product supply by event

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Questions and hypotheses to be answered

There are many questions and hypotheses that needs to be tested and/ or answered to understand the needs in the construction industry and what is required to capture the intrinsic value of circularity for each role or stakeholder in the construction industry's value network, and meet the building as material banks concept. Some of these questions and hypotheses we can include when answering how the BAMB output would help the different roles in the construction industry. Others are still to be proven over time when the wider industry adopts the circular principles through exploring the business opportunities or adhering to the changing legislation and regulatory rules.

- Even with supply information available in materials passports and reuse potential available for secondary products and materials, is there a demand in the market and how does this demand look like now and in the (near) future?
- How will the members of the design team use the information (when available) for inspiration or embed into their design? (Design team being the architects, designers, engineers (structural/ civil/ mechanical/ …), and extended team members like suppliers that design and build parts of the buildings.)
- How willing are suppliers and manufacturers to share detailed product and material information? Will this be driven by demand?
- How will supplier of secondary products and materials use the information to grow their current business opportunities?
- How will owners (including financers and investors) use the information to understand residual value on building, product and material level?
- How will recovery specialists, like urban miners, reclamation specialists, demolition companies and waste management companies, use the information to optimize reuse at the building, product and material level?
- How will cities, (local) government and regulatory bodies understand the resource profile of a city, region or country and assess reuse potential of the building stock and support city planning and changing needs of us, humans? How we live, work and use the buildings available to us, has a great impact on future demand city development.

This section drills into determining the innovation needs of the project's main outputs to understand which business models could be applied that meet the project's objective, help answer the questions and hypotheses, and support the different roles in the industry on executing their own business models and accelerate reuse in the construction industry.

Industry Value Network Analysis

To better understand the dynamics in the industry, we analyze the network on how the different roles in the industry link and do business with each other. This value network approach is intended to describe a given industry ecosystem and analyze the value creation mechanism that emerge from the interactions between the different participants. Networks are characterized by the dynamic nature of relationships and flows between the participants.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Participants in the network, in the broader sense are described as physical entities (businesses, individuals, public bodies), that can take different roles in the network, depending on the interactions that occur. The interaction between the different participants are described as links, these can also have different characteristics (ranging from information and financial flows to material and services flows).

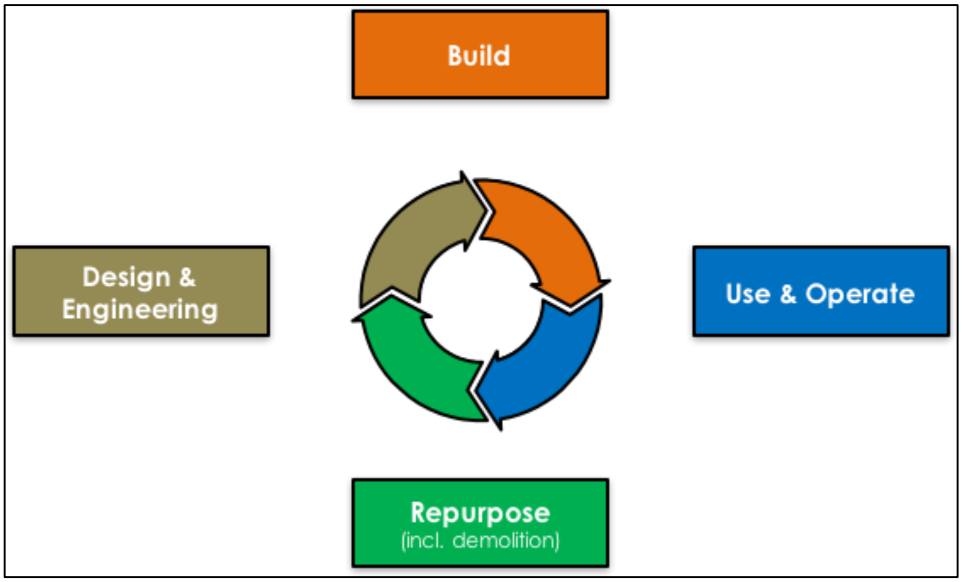
The value creation is considered as the mechanism whereby usability of goods and services is developed and a matching of supply and demand is realized. The value can be found and defined in different areas such as societal value, financial value, environmental value and others. In this analysis, we have focused only on the systemic value creation, therefore not describing the specific value creation mechanisms that can be found in specific links.

In the construction industry, many companies are involved in various roles: how these different roles relate to each other is also depended on the phase of the building. In this input document, we have used an industry model framework to highlight the interaction between the different partners in the construction network.

Although there are many possible ways of analyzing the complex construction ecosystem, for simplicity we have started by considering 4 building phases (see also 3.4 below):

1. Design & Engineering: the phase where all the financing, designing, planning is done.
2. Build: the phase where the building or infrastructure is realised
3. Use & Operate: the phase where residents/ users/ occupants, etc. are using the building and the building is operated to maintain the service levels required to the occupants
4. Repurpose: the phase where reuse is planned, and products and materials are extracted

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.



3.4 Main phases of a building

Within each of the phases we have defined the main roles (groups of roles that are necessary to perform a certain set of activities) and described the links between the different roles (or groups of roles). In overall analysis, we focus on a more dynamic and certainly not linear analysis of the ecosystem (iterative and loop links already exist between the different network participants).

The roles in this value network analysis are described on the level they interact in the industry. This means that suppliers of new and reused products have to adhere to their respective industry legislation and regulatory compliance rules, and basically have a value network or sub-ecosystem of their own. This is not considered in this value network for construction as in this value network we consider each (re)used product to comply to all available and/or mandatory legislation and compliance rules. It cannot be denied that industry specific rules and legislation could either hinder or support the reuse of products, components and/ or material in the context of the construction industry.

Also, only the main roles have been described in the value network analysis. All other roles, that are not depicted or described as part of this value network, are either:

- Too far from the value network to influence the business model (e.g. real estate agents, acting on behalf of the owner)
- Limited to no value addition to the business model (e.g. a notary is mandatory to use in process with handover of ownership)
- Could be considered as part of other roles (e.g. tax authorities to be considered as part of the public authorities)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Each link is described from an industry model perspective, so any description is **not a process or activity**, but represents a *business* link (an exchange) between the participants:

- information exchange: e.g. regulatory bodies supply information in the form of regulatory rules, standards to be applied, and/ or laws
- financial exchange: contracts, payments
- resource exchange: being product, material, and/ or labour
- or a combination of these 3 exchange types

The links are assessed individually to determine, based on our research, what is the observed current state of the business exchange between the roles. The scope of research is limited to current and previous client experience (from IBM), interviews with our internal experts and literature review. In the framework, we do not describe specific situations but instead we provide a generalization of links based on multiple observations.

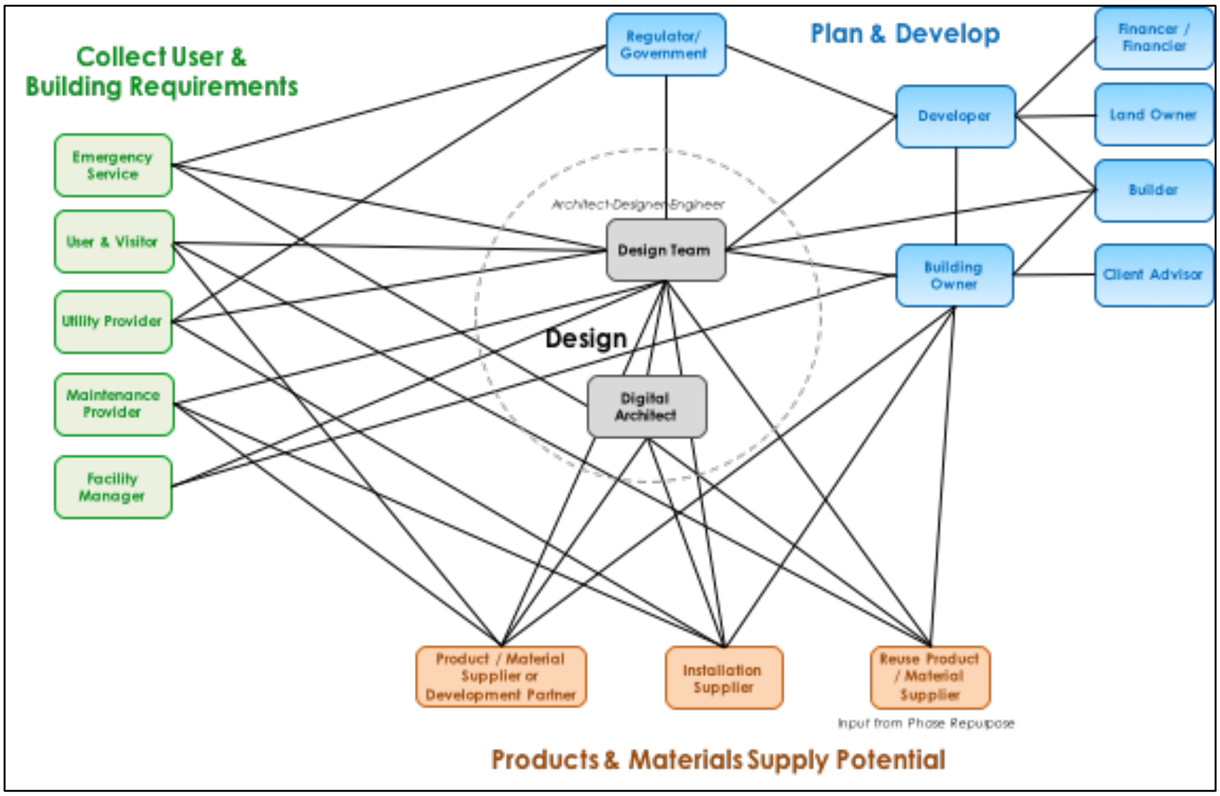
PHASE 1 - Design and Engineering phase

The design phase is a defining and critical initial stage in the lifecycle of a building. It should capture and integrate the various requirements from usage and operations of the building. These requirements should reflect the key benefits for the various stakeholders, including maximizing the potential for repurposing and reusing the building and its content.
Viewing the variety of profiles of the stakeholders and the capabilities of the enablers, the collection of the key relevant requirements and its matching with the right capabilities is not a trivial task. There is a key role and a focal point around the Architect to be the spider in the web in this crucial phase. Though complex, if done properly, the design phase will provide the right direction for building and embedding various services, with lasting positive impact throughout the lifecycle and lower total cost of ownership or lower total cost of usage.

We have aimed to represent hereunder the design phase of the value network in the construction industry. The maturity of the links and the roles involved can differ by country and company involved. During the design phase, we consider 4 major grouping of roles:

1. Collect User & Building Requirements: Key set of requirement from various stakeholders. Not limited to future users and providers
2. Plan & Develop: Initiate the idea of the building project, define the concept and plan for development, including funding.
3. Products & Material Supply Potential: the supply market of new or reuse products, components and/ or material to realise the building
4. Design: the design team that take into account information and direction from all connected partners in the eco-system, led by the Lead Designer or Architect. This is the spider in the web/value network.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.



3.5 Industry Value Network overview – Design & Engineering Phase

The main outputs of this phase are:

- Requirements understood, from all relevant roles
- Building and (embedded) products designed (includes performance/ as a service based contracts)
- Financing, permits and construction planned
- Update to infrastructure designed, when building is being renovated/ expanded in mid-use

What can we conclude and observe when analysing the links between these roles?

- Changing roles and partnerships: New roles emerge, like what we call 'the Digital Architect' who focuses on all technology aspects of a building or supporting the realization of the building; these technology aspects are spanning everything around IT infrastructure, data

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

storage/ - access/ -security/ -privacy, (integration) protocols and standards, and the use and integration of correct use of enabling technologies like BIM, Asset Management systems, Material Passport, 3D-tooling, Building Automation Systems, HVAC, Access and Security Systems, etc. The role of the Digital Architect should be part at start of any design activity, so the relevant data can be modelled, captured and used throughout the lifecycle of the building and its embedded products, components and materials.
Also, new relationships between roles are established, as suppliers and manufacturers are becoming an integral part of the design team by design/ build and sometime maintain part of the building (e.g. facades, building installation systems, etc.). This is also true for material scientist, as the use of non-toxic or healthy materials are promoted in applying new products and materials. Or data scientist, that specifically target the data needs for building operations, and capturing the relevant product journey data to build a product's passport.
Regarding public tendering and procurement processes, currently the rules prohibit public procurement specialists to work directly with design teams and/ or suppliers of products and materials until the tendering process has been completed. This flags a need for reconsidering the public tendering processes and support the transition to circular economy practices in the public space.

- Building and user requirements, together with adaptable building functionality become centric: The requirements of users, including providers of different services, are becoming more centric in the design process. Focusing on how users actually are using the building, and the contribution the building and its embedded products have on comfort (natural versus artificial light/ natural ventilation/ comfortable temperature/ acoustics (noise or vibrations)/ link with nature (biophilia). How maintenance providers and facility managers would like ease of asset management, or the different emergency providers to access and respond during calamities. Furthermore, as humans have changing requirements in time, how adaptable and flexible is the design to change functionality, expand or change part of the building (interior and exterior), etc. Especially the need for more residential space in cities highlight the fact that the building stock consists of too many one-purpose buildings that can only be transformed at very high costs.
- Suppliers of secondary products and materials struggle to grow business: Already the industry professionals say that the lack of data on what is in our buildings, is hindering the reuse potential of products and materials (e.g. what is the building and embedded products and materials made of, and what the condition or health status).
  Volatile supply patterns and not having information when, and how much comes available in time also limits broad adoption by design team and project managers to consider reused products and materials as viable design and purchasing option.
- Legislation and regulatory compliance rules moving towards resource efficiency: Waste regulations in construction and other connecting industries (like electronic waste for building installations), bans on landfill and changing circular economy targets to increase reuse and decrease environmental footprint (resource / energy/ water consumption) is found in many countries in Europe already. The interaction of business and governmental/ regulatory bodies is important to increase effectiveness of these rules, by taking a proactive role, to support achieving the circular goals and meet the building as material bank objective.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

- For utility type buildings, the role of facility managers is increasing: Facility managers have vast experience in running and managing a building. Every day they deal with repair and maintenance providers, cleaning, suppliers of consumables (restaurant, printers, etc.), reception services, moving events, hospitality events, etc. This knowledge base is essential to understand the main principles to be applied to build an efficient and effective building during its use and operation.

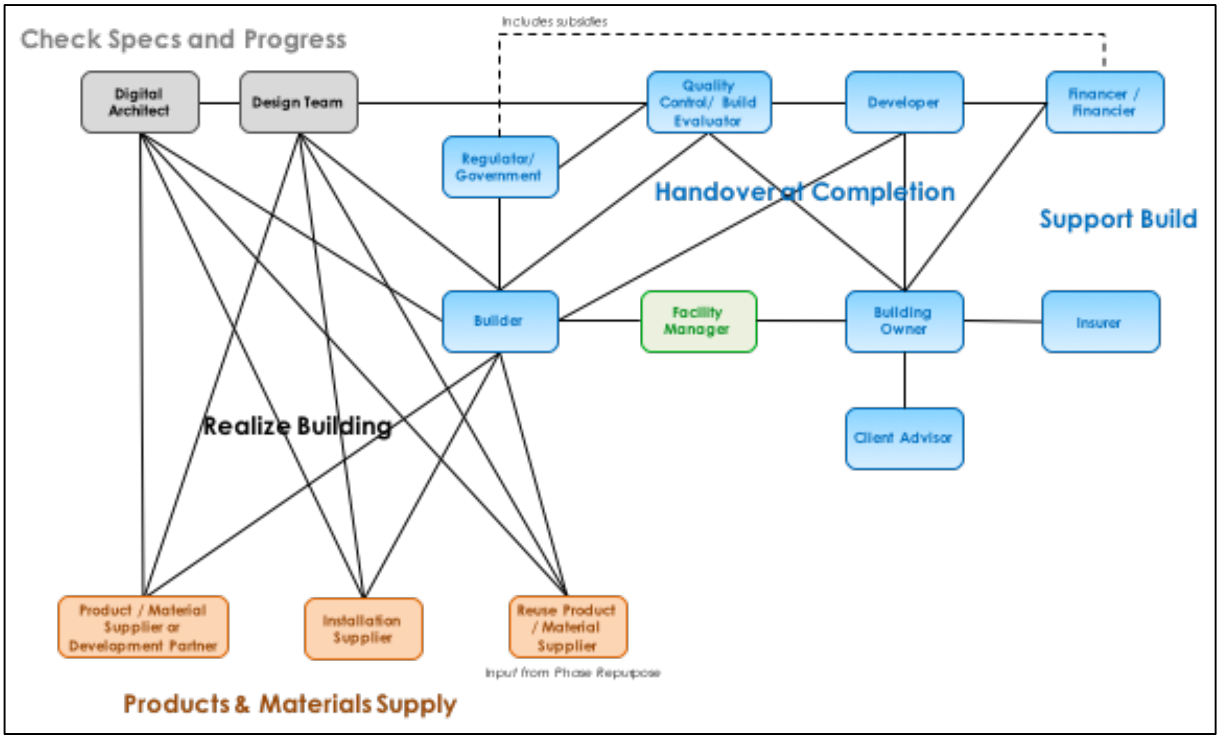
PHASE 2 - Build phase

The build phase aims for delivering the building according to specs, in time and on budget. It is the translation of the design requirements to the physical product. The focal point at this point shifts from the Design Team/Architect to the Civil engineer/Contractor that will ensure that the blue print embedding all design requirements are correctly built and delivered.

In the build phase, we consider 3 major grouping of roles:

1. Check Specs and Progress: the members of the design team that oversee the technical implementation and check progress against the technical design
2. Realize Building: engineers, main contractor, subcontractors, design team and the different suppliers and providers working together to realise the build.
3. Products & Material Supply: the suppliers of new or reuse products, building modules, components and/ or material
4. Handover at Completion: after realisation and quality control of the build, formal handover of ownership to the property owner
5. Support Build: roles that support the owner and/ or developer during the build by financing, financing advice, insurances (and advice) and general client advisors as specialist in the construction industry

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.



3.6 Industry Value Network overview – Build Phase

The main outputs of this phase are:

- Construction partner network managed to realise the build
- Actual build of the infrastructure
- Functionality repurposed, when (parts of) existing buildings are repurposed for other means than initial design

What can we conclude and observe when analysing the links between these roles?

- Partnering with suppliers and manufacturers change build logistics: the traditional role of the builder or main contractor and the supplier community is fading away fast. Already trends are visible in recent years where suppliers are designing, building and maintaining their products (or build system). The builder becomes even more the coordinator of integrating the different building blocks, helped by the fact that many of these suppliers build their building components off-site in their own quality controlled production environment (leading to higher quality products, while reducing installation time on-site).
- Move to performance models: Not happening for all building products yet, but more and more product suppliers are introducing performance based product portfolio, where the owner will have access to the product (pay-by-use), but where maintenance, repair and

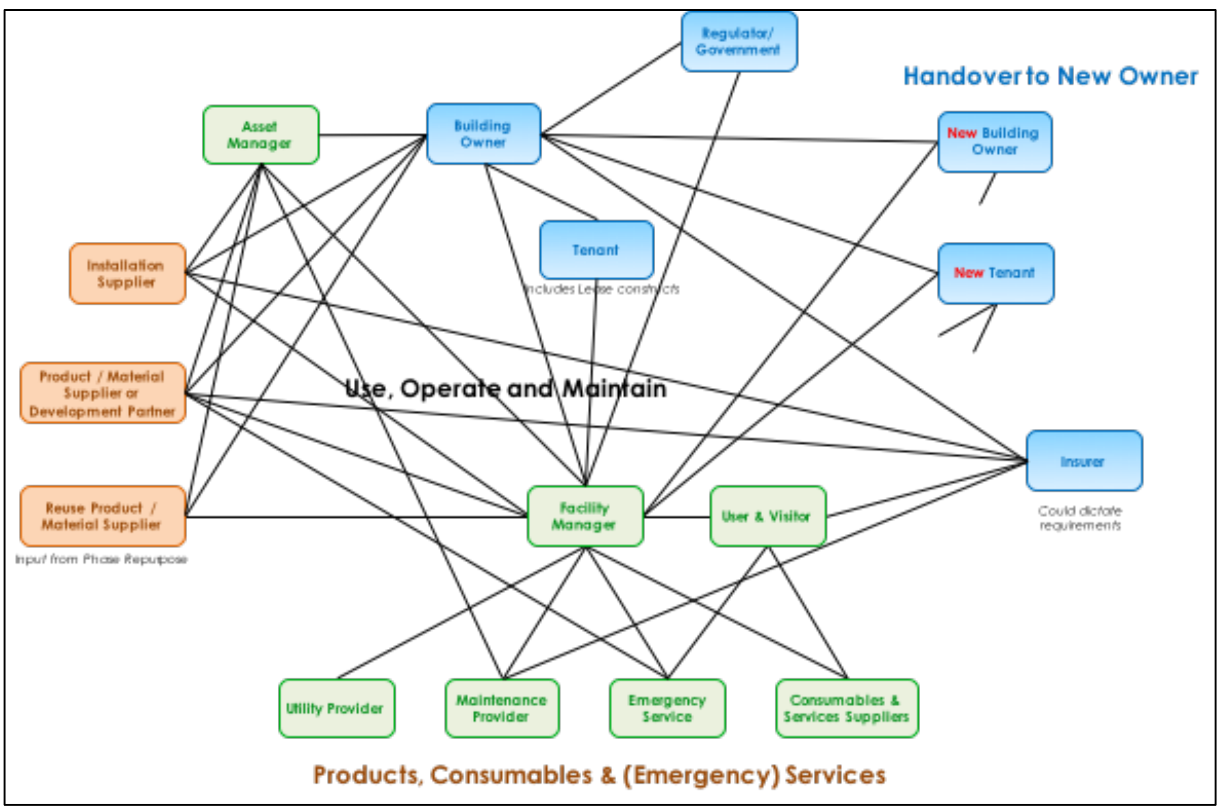
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

replacement (performance cycle management) and ownership resides with the supplier or manufacturer. Examples in the industry are a.o. Desso leasing carpets and floor tiles, Philips Lighting with light-as-a service, Mitsubishi Elevators with M-Use, façade suppliers introducing façade-as-a-service, etc.

PHASE 3 - Use and Operate phase

The Use & Operate phase has the longest duration in the lifecycle of a building. This phase has 2 perspectives: a user and operator perspective. In this phase, we consider 3 major grouping of roles:

1. Use-Operate-Maintain: actual use and associated maintenance and operating activities related to the building
2. Products, Consumables & (Emergency) Services: all suppliers of different services and products needed to operate the building (e.g. consumables for catering/ printers, emergency services, maintenance providers and product suppliers when maintaining/ replacing products, etc.)
3. Handover to New Owner: initiating a potential redesign of (parts of) the building



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

The main outputs of this phase are:

- Infrastructure and ecosystem operated, incl. partner network managed
- Building used by all user types against (changed) use requirements; users like residents/ occupants, visitors, emergency services, operators
- Building ownership transferred (when relevant)

What can we conclude and observe when analysing the links between these roles?

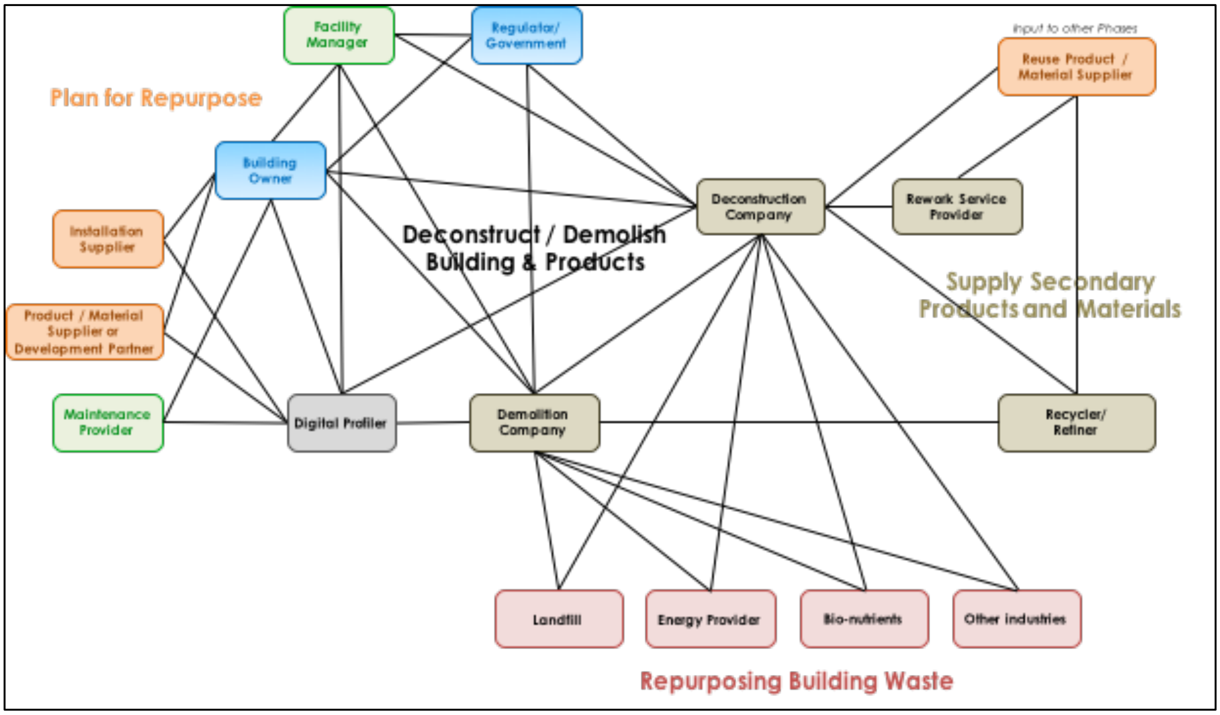
- Change way how services are being planned or procured: More and more the facility managers are coordinating and managing the contracts with the different suppliers or services providers, on behalf of the building owner. With performance contracts, the product owners (the suppliers or manufacturers) are maintaining their own product.

PHASE 4 - Repurpose phase

The repurpose phase is relatively new for the construction industry, as today most of the building's resources end up as waste or a demolition liability. A full and optimized repurposing plan when planning to deconstruct a building, or part of a building, requires a full (data) view on all products in the building and its usage status. In this phase, we consider 3 major grouping of roles:

1. Plan for Repurpose: using all available information to understand product status and reuse options to plan for repurpose (as product, component or material)
2. Deconstruct / Demolish Building & Products: actual extraction of products, components and materials out of the building, according to plan; although in this project the Reversible Building Design protocols will accelerate the transformation capacity of a building (including the deconstruction or reconstruction potential), still for existing building stock, that have limited to no options to transform, demolition and harvest the material is still a viable option
3. Supply Secondary Product & Materials: channelling the (refurbished/ remanufactured) products, components and material back into designed/ redesigned buildings
4. Repurposing Building Waste: building materials that have no reuse potential in the construction industry could find a way to new applications (in other industries and products), or eventually end up in a landfill (less desired option)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.



3.8 Industry Value Network overview – Repurpose Phase

The main outputs of this phase are:

- Insights obtained for repurpose/ reuse options
- Products, components and materials repurposed

What can we conclude and observe when analysing the links between these roles?

- Emerging and changing roles to support the growth potential of secondary products and raw materials: There is a vast stock of existing buildings without a digital profile (being a BIM model, (simple) material passport or other), where building digital profiles or digitization companies could fill that gap and start building and expanding on these building profiles by integrating the different available technology components: using spatial scanning technologies, visual image recognition technology for products, linking to supplier product catalogues and material composition databases, etc.
  Also, demolition companies are moving towards urban miner profiles, to deconstruct and trade products and components before turning the remaining building components into demolition waste (recycling of materials).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

- Next to what is actually in a building, there is also a lack of information on how to deconstruct and extract (without damage) the products, components and materials for potential reuse: Today the reuse potential of a building and its products and materials is down to the assessment of industry or product experts, building on their knowledge and experience. This is mainly tacit knowledge, and not available (digitally) to others to determine reuse options. Also, there is no info on deconstruction sequence of the individual product as well as how that particular product is connected to its environment, i.e. other products.
- Recycling techniques are evolving: The development of new material harvesting and recovery techniques is opening more opportunities to include more material for recovery as secondary (high quality) raw materials. Examples are material harvesting of concrete (e.g. https://www.slimbreker.nl/smartcrusher.html), carpets (Desso), etc. Another Horizon2020 project, HISER is looking into innovative solutions for an efficient recycling and recovery of valuable raw materials from construction and demolition waste (see also: http://www.hiserproject.eu/).
- Refurbishment and remanufacturing (including upgrading) is not taking off yet: Only for a limited set of building product categories, refurbishment and/ or remanufacturing services have been somewhat established. Examples are electronic products/building installations, like Rexel and ElektroNed. The main issues for suppliers to grow in this area are providing guarantee/ warranty/ testing and certification for these reused products and the demand uncertainty to invest in these operations (or partnerships).
- Collection processes of products and materials not organized: Separation of products and materials at site is still not organized mainstream. E.g. gypsum product providers can only harvest their products at construction stage, as with deconstruction/ demolition most of their materials have been physically contaminated with bricks, concrete, paints, etc. There are some best practices with e.g. Mosa tiles that collect their own products at in build phase (cutting losses) in special containers to be used in producing new tiles, or developing specials adhesives to better harvest the tiles at deconstruction.

Industry design standards

Does one of the project's output actually impact the way the different roles interact and do business in the construction industry? In work package 3 on Reversible Building Design protocols, the search for standardized connections between the different building products is being investigated to understand how easy it would be to build, replace and reuse different building elements or products, without having to break down part of the structure. The adoption of the proposed standardization of connections (by product type) could potentially impact how manufacturers/ suppliers, architects, engineers, designers would use the different building elements in the design and influence the transformation capacity of a building's function and reuse potential of the individual products, components or materials. Similar concepts of this standardization we can find in other industries like:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

- Automotive industry: standard connections used across different manufacturers and suppliers of different products to ensure fit in multiple brands / models / makes. E.g. standardized connections for electronic control units (ECU), airbags, seat rails, etc.
- Electronics industry: standard connections, where components are used in many brands / types / models. E.g. for circuit boards, memory cards, cables, etc.

Currently there are no industry wide adopted standards on types of connections, only multiple options being developed.

Detailed product and material composition data

Detailed material composition information, on what materials (or ingredients/ nutrients) are used in a building or in a product applied in a building would benefit current and future requirements to exclude toxic and hazardous substances from re-entering our buildings upon reuse. This includes the identification of hazardous or toxic substances not known today. Companies that focus on these material composition data, can reuse this data in many other industries other than construction. In work package 2 on Material Passports, the prospect of a repository with deep understanding of materials linked to building products, could greatly influence the way products are being designed.

Stakeholder roles in the value chain

Out of the Industry Value Network Analysis, we already conclude that many roles take part in the different phases of a building. From all the roles, there are a set of main stakeholders that would most benefit from industry innovation and are more prone for business model innovation. In below matrix (3.9) an overview is provided of roles that either (have to) contribute on providing the relevant building, product and material information, roles that will maintain the information of the building and products during use and operations, and roles that will use the information to optimize their processes and meet their circular targets. From this list, we can then identify the main stakeholders that will contribute and benefit most from the BAMB outputs. The main direct beneficiary will be the Building Owner, however it is not likely this role will provide and maintain the information, as other roles will have to contribute according to their design, product or services contribution.

Building Phase	Provide new data	Maintain and manage provided data	Consume or Use data
Design & Engineering Phase	**Design Team** (Architect, Engineer, Designer) and **Digital Architect** – *what becomes part of the design/ architecture* **Product/ Material Supplier or Development Partner**, **Installation Supplier** and **Reuse Product/ Material Supplier** – *details on available and potential supply*	**Builder** – *linkage and contribution of build project management tools and databases*	**Building Owner** – *making decisions based on objectives and targets* **Design Team** (Architect, Engineer, Designer) and **Digital Architect** – *what is available for design inspiration, and options for application of reused products, components and materials* **Regulator/ Government** – *understand compliance against rules and circular*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

			opportunities at municipality or country level
Build Phase	**Product/ Material Supplier or Development Partner, Installation Supplier**, and **Reuse Product/ Material Supplier** – *details on applied products and materials*	**Design Team** (Architect, Engineer, Designer) and **Digital Architect** – *maintain, change, add data when designs are updated during build* **Builder** – *maintain updates on building and product profile* **Facility Manager** – *on behalf of Building Owner, coordinate all is maintained for building or product completeness*	**Building Owner** – *making decisions based on objectives and targets* **Regulator/ Government** – *understand compliance against rules and circular opportunities at municipality or country level*
Use and Operate Phase	**Product/ Material Supplier or Development Partner, Installation Supplier**, and **Reuse Product/ Material Supplier** – *especially with performance contracts, maintain all product/ building element data with maintenance, repair, replacement activities*	**Asset Manager** – *ensure that the product and component data is updated and managed through the likes of Asset Management Systems are updated* **Facility Manager** - *on behalf of Building Owner, coordinate all is maintained for building or product completeness (incl. using and connect to Facility Management Systems)* **Maintenance Provider** – *for third party maintenance providers maintain all product/ building element data with maintenance, repair, replacement activities (using the product journey data to enable condition based maintenance or predictive maintenance schemes)*	**(New) Building Owner** – *(real-time) understanding of condition and residual value of building, its embedded products and materials, and options to change building functionality (transformation capacity)* **Regulator/ Government** – *understand compliance against rules and circular opportunities at municipality or country level* **Product/ Material Supplier or Development Partner, Installation Supplier**, and **Reuse Product/ Material Supplier** – *understanding of residual value of products (e.g. with performance contracts), how these products are actual application and opportunities to improve circular design*
Repurpose Phase	**Digital Profiler** – *create a building profile for existing building stock without such profile* **Demolition Company** – *provide data on products and materials based on experience during demolition assessment phase (potential collaboration with Digital Profiler and Deconstruction Company)* **Deconstruction Company** - *provide data on products and materials based on experience during deconstruction planning phase (potential collaboration with Digital Profiler and Deconstruction Company*	**Product/ Material Supplier or Development Partner, Installation Supplier**, and **Reuse Product/ Material Supplier** **Maintenance Provider** – *update latest product journey data (condition, changes) in scope of this role* **Asset Manager** – *update latest product journey data (condition, changes) in scope of this role* **Rework Service Provider** – *update data when products and components are being repaired, refurbished, remanufactured (incl. upgrades)*	**Building Owner** –*understanding of condition and residual value of building, and the reuse options of its embedded products and materials, and options to change building functionality* **Facility Manager** – *use data to plan and coordinate deconstruction and extraction of products and materials* **Product/ Material Supplier or Development Partner, Installation Supplier**, and **Reuse Product/ Material Supplier** – *understanding deconstruction readiness and opportunities to improve circular design* **Demolition Company** – *use data to understand demolition effort planning (resources, equipment, effort, costs)* **Deconstruction Company** – *use data to understand deconstruction effort planning (resources, equipment, effort, costs)* **Rework Service Provider** - *use data to understand repair/ refurbishment/ remanufacturing effort planning (resources, location, effort, costs)* **Recycler/ Refiner** – *use data to select and apply the optimal material recovery process* **Energy Provider** – *use data to select and*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

			apply optimal energy production **Bio-nutrients Company** – *use data to select and apply suitable materials for bio-nutrient applications* **Regulator/ Government** – *understand compliance against rules and circular opportunities at municipality or country level*

3.9 Data Interaction by Role

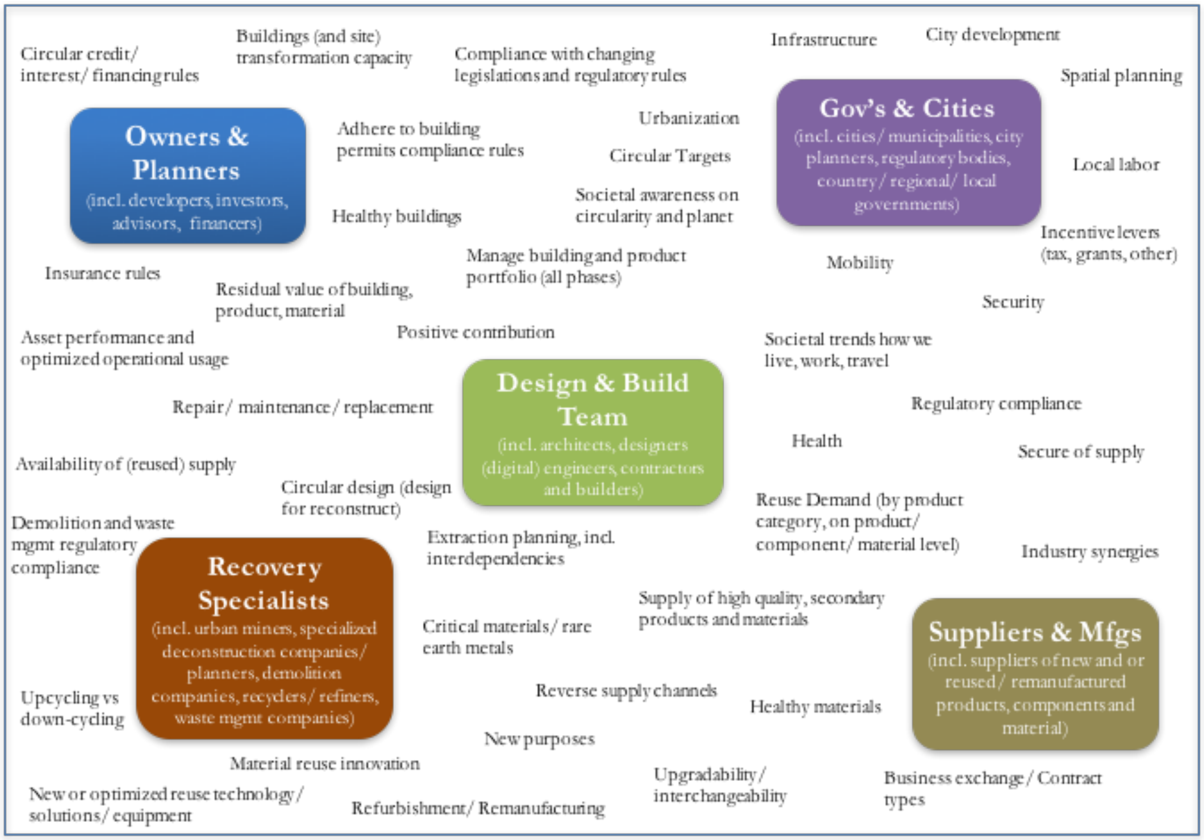
From above table, we conclude that many roles provide, maintain and use the data across the four building phases. These roles are therefore also the main stakeholders to include, as the building, product and material information directly impact their business models and operations.

Stakeholder groups

Even though many of the stakeholders (or roles) contribute, maintain/ manage or use/ consume the relevant data to understand reuse and building transformation options, we can group them into segments where most market trends, (external) influences and drivers are shared.

In below overview (see 3.10) a grouping by main stakeholder group is made, where the different roles in such group share the same trends, impacts and external influences.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.



3.10 Stakeholder Grouping

In below table (see 3.11) we outline which type of roles we target by segment, understand the main business exchange types used (being information, products and/ or financial) and common business model applied. This will lead into common understanding of the main information needs by each segment.

	Owners & Planners	Design & Build Team	Suppliers & Manufacturers	Recovery Specialists	Governments & Cities
Roles included	Developers, investors, advisors, financers, building and product owners	(Digital) Architects, designers, engineers, contractors, builders, material scientists	Supplier of new and/ or reused/ remanufactured products, components and materials	Urban Miners, specialized deconstruction companies/ planners, demolition companies, recyclers / refiners, waste management companies	Cities, municipalities, Country/ regional/ local government, city planners, regulatory bodies

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Main focus and business exchange types used	Information Insights Compliance Building Product/ Components/ Material	Information Insights Compliance Building Product/ Components/ Material	Information Insights Compliance Product/ Components/ Material	Information Insights Compliance Product/ Components/ Material	Information Insights Compliance
Main business model approach	Shared use (*Other Business Model approaches derived from contract exchange between Owner and Supplier/ Manufacturer or service provider*)	Design and build on behalf of the owner (*Business Model approach not directly applicable but derived from contract exchange between Owner and Supplier/ Manufacturer or service provider*)	Product as a service (incl. take-back schemes) Product access as a service Product performance as a service Product lifetime extension Component reuse Refurbishment/ Remanufacturing	Non-toxic ingredients/ nutrients/ materials Product/ component substitution Product lifetime extension Component reuse Refurbishment/ Remanufacturing Material recovery and reuse	Circular and social targets (*Business Model approach not applicable*)
Common needs	Building regulation compliance (incl. energy, circular targets, etc.) Product and material regulatory compliance (health, liability) Digital building profile Building Transformation Capacity profile Digital product and material profile (i.e. building or material passport, and includes condition or product journey data) Residual value and reuse options of building and product portfolio	Building regulation compliance (incl. energy, circular targets, etc.) Building Transformation Capacity profile Product and material regulatory compliance (health, liability) Digital product and material profile (i.e. building or material passport, and includes condition or product journey data) Available supply of building, products, components and materials	Product and material regulatory compliance (health, liability) Digital product and material profile (i.e. building or material passport, and includes condition or product journey data) Available supply of building, products, components and materials Residual value and reuse options of product portfolio	Product and material regulatory compliance (health, liability) Digital product and material profile (i.e. building or material passport, and includes condition or product journey data) Available supply of building, products, components and materials Reuse options of product portfolio	Building regulation compliance (incl. energy, circular targets, etc.) Product and material regulatory compliance (health, liability) Digital building profile of cities Building Transformation Capacity profile of cities Available supply of building, products, components and materials to understand (future)resource constraints

3.11 Summary commonalities of business approaches and information needs

Regarding the Government & Cities stakeholder group, the public sector can be a powerful driving force in stimulating targets for circular building demands, either by public tendering, regulatory rules or part of new development and renovation requirements.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

4. Business Model analysis in BAMB pilots

In this section, we will zoom into more detail on two BAMB pilots, the analysis of four companies or frontrunners and the learnings we can derive from them, and one case study of a renovation project in Amsterdam.

Two pilots selected:

1. Pilot 1 – Green Transformation Lab (Netherlands)
2. Pilot 6 – New Office Building (Germany)

Four frontrunner use cases:

1. Venlo City Hall (Netherlands)
2. PROgroup (Luxembourg)
3. Karlstad hospital (Sweden)
4. RotorDC (Belgium)

One case study:

1. Office renovation in Amsterdam (Netherlands

4.1. Lessons learned from Pilot 1 - Green Transformation Building Lab[6]

The Green Transformation Building Lab (GTBL) pilot is a project aimed to show the capacity of a building to be designed, built, used and transformed in a certain period of time. Design and supplier selection are in progress while the built is aimed to start early 2018. That will limit at this stage the learnings that can be already extracted but nevertheless what is reflected here are the initial intentions, designs and supplier experiences throughout the preparation phase. Furthermore, the GTBL is not a commercial project requested by a client which would mean some of the learnings will be less practical, nevertheless it will provide a significant opportunity to explore the circular supply capabilities and the design capability.

There are around 20 suppliers that are considered, as part of an innovation platform.

The starting guiding principle is that human needs change often during the course of a lifetime and through various phases of life, while the built environment is built in a rather static way. There is a mismatch between the dynamic needs of the users and the supply of the static end product/building. The solution is to develop construction methods that will support more adaptability. Materials are there for a functionality and that functionality is changing with time.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Design for repurposing and for optimal user experience: A foundational capability

The design capability towards reversible building design is a foundational cornerstone that is to be explored and assessed in the GTBL pilot. This is in line with the highest value potential of the inner reuse loop at building level, before tackling products, components or materials.

The technical design and construction methods would aim to support adapting to functionality changes. That will mean the creation of functional modules that are easy to deconstruct and that are exchangeable. The connections type will be a crucial element of the design to enable such potential for repurposing. The standardization of connections will be even more important than the standardization of sizes.

The design protocols will be tested in the supply market and in the construction methods to be used during the GTBL construction.

Besides the reversible building design, the GTBL naturally aims to ensure an optimal user experience inside the building, which is the most important value proposition for the user. That will include the optimal lighting through as much natural light as possible (solar chimneys), suitable natural ventilation through air pockets, high quality of indoor air, comfort and wellbeing (psychological perception)

Supply network for reused or "circular" products

In designing "Circular" Buildings, there is often the decision and choice between using reused material or components or selecting new products that are designed in a fully circular way (careful material selection that is fit for usage and recycling, upgradable design, modular connections, standardization of dimensions and connections).

Often it is combination of both and the GTBL lab presented the same hybrid choices with a clear dominance for the second choice.

The flooring had to be a rigid floor viewing the nature of the application (being a lab) and the architect managed to find already used concrete slabs that could be fit and make up the floor of the GTBL lab.

Confirmation of the need for the relevant information and visibility

The effort and time spent to find the reused flooring confirms the critical need for quick access to the relevant data around the products available that could meet the need of the architect of the GTBL lab. The concrete slabs were found through a personal connection, which makes the supply search process currently random and not scalable to make it an industry best practice.

The other challenge experienced with the 2nd hand concrete slabs usage was the planning and timeline. The owner of these slabs was in a hurry to dispose of his products due to lack of space and he needed a quick confirmation otherwise they would have been sent to a shredder. The architect had to arrange in few hours a storage place otherwise a much cheaper and appropriate product selection would have been dismissed, which would have presented a missed opportunity for lower cost and improved environmental performance vs ordering new concrete slabs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

The search for glass panels proved to be difficult and it was abandoned and new choices were considered subsequently. Currently the BAMB outputs do not provide information of availability of products and/ or components to be reused (i.e. marketplace functionality).

To be explored moving further in the GTBL pilot

- There is a focus on the initial cost of the building, with the assumption that transformable buildings are more expensive.
- Need to establish the business case for transformable buildings, trying to highlight the cost but also the longer-term benefits of such choices (flexibility, lower risk upon vacancy, etc.).
- How mature and what is the potential of the supply market to adapt to the reversible building design supplies?
- Can governments be the launching customers through public tenders? (see also Karlstad hospital in front runner use case analysis 4.2.3)
- Adapt legislation to facilitate exchange of products and materials.

4.2. Lessons learned from Pilot 6 - New Office Building[6]

In their pilot Drees&Somer (D&S) and the client aimed to test few business models towards achieving circularity across various parts of the building. The client wanted to adopt and test to a certain extent the circular economy principles in their building.

The definition of a "Circular Building" is differing from situation to another. In the D&S example, there are two guiding principles that make it circular: Using recycled materials or reused/ reclaimed products and materials where possible, and using new products that are leased or that can be easily deconstructed. Furthermore, the owner of the building wanted to add the health aspect since this was deemed as important for the wellbeing of the employees. Ultimately the owner of the building who is the client of D&S opted for a focus on the health aspect of materials more than the long term reuse potential, especially when this necessitated an extra short term investment.

Principle 1: *Using new products or materials with intention of reuse or recycling: Legislation obstacle*

The façade systems and flexible internal wall systems were assessed for potential leasing models. There were difficulties encountered, namely with legislations, to implement such models mainly in the façade systems. It is more difficult to implement take back or leasing systems when the product is fixed or connected to the building on a "permanent" basis (like façade systems). However, we see that this could differ by country since in the Netherlands the take back or leasing models for façade systems is starting to be applied in a joint project between VMRG and TU Delft.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Façade systems

The façade manufacturer Schuco provides C2C certified façade systems and there was an assessment around leasing systems for facades. The assessment showed difficulty to adopt leasing systems or take back systems for facades, mainly due to legislations. In the less likely but potential case of the owner of the façade retrieving their product, the building is exposed to the outside elements such as rain and wind. Damage resulting from that and the resulting liabilities will be a problem to resolve with the insurance companies. In the end, whose liability is it? Who will pay for it? These aspects are still not clarified and prevent adopting leasing systems for the façade systems in Germany.

Flexible Internal Wall Systems

The wall systems used in the building were modular, having their embedded functionality. Wall systems proved easier to be leased potentially due to the lack of liability risks upon their extraction during usage.

Value of materials passports for the building owner

D&S expanded a building energy assessment tool of their own with circular and cradle-to-cradle data elements, including health aspects which was part of the owner's requirements. The creation of the Materials passport for the building with the purpose of reuse in this case was not expressed as highly needed by the building owner, who was not willing to pay more today for a promise of higher residual value in the future. This reflects the lack of articulation of improved residual value of the building. The approach here was rather explore take back systems with the suppliers so that the reuse enablement and reuse take back systems are explored by them, and where performance during usage is optimized for the building users (same as the owner in this case).

As for Reversible Building designs, there was less focus on the adaptability and flexibility of the design but rather on the connections to make it easy to deconstruct. That will increase the channelling towards recycling rather than reuse at product level.

Principle 2: *Use Recycled material or reused products*

Recycled Concrete

D&S assessed using recycled materials as much as possible in this project and one of the areas that was looked into was the use of recycled concrete. In some areas of Germany, you could manage to buy recycled concrete at around the same price and quality as that of new. However, in the area of Essen (close to the pilot) there was no supplier of recycled concrete in a perimeter of 100 km which resulted in an additional cost of 100 K Euro to purchase recycle concrete. The same recycled product can be offered at a higher cost in various cities within Germany, due to the lack of decentralized recycling facilities within Germany. Furthermore, the health aspects in buildings were taken in account in the design, materials science and construction

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Confirmation of the need for the relevant information and visibility
The effort and time spent to find suitable suppliers for recycled concrete or other suitable used products suppliers that are in geographic proximity was considerable viewing the lack of the appropriate and reliable sources of information across the built environment spectrum of products. Like with Pilot 1 Green Transformation Lab, currently the BAMB outputs do not provide information of availability of products and/ or components to be reused (i.e. marketplace functionality).

4.3. Lessons learned from Frontrunner Use Cases[7]

The team has interviewed four "frontrunner" cases which have pioneered in incorporating elements of building circularity. The study included well-known cases such as the new Venlo city hall (the Netherlands), PROgroup (Luxembourg), Rotor DC (Belgium) and Karlstad hospital (Sweden), while taking a fresh focus on business aspects such as value propositions, stakeholders, financials and operations.

Preliminary analysis suggests that successful circular building projects are devised with a holistic view on various sustainability elements and ecosystem stakeholders. In comparison to more developed building sustainability elements such as energy, material circularity is still rather new in many aspects. Related business models vary significantly in maturity depending on product/material category, overall with ample room for growth. Supplier buy-back agreements and product-service systems are being developed, though how to put retrieved items back into the economy, as well as how to establish solid financial cases for involved stakeholders, are among the topics which still need further substantiation. Encouraging advance has been made in deconstruction business models, while more attention is needed to develop second-hand market demand. The potentials of public procurement and regulatory incentives as additional key drivers are also to be further investigated.

Four frontrunner case descriptions

<u>1. Venlo City Hall, the Netherlands</u>: The new Venlo City Hall, completed in 2015, has become an icon of Cradle-to-Cradle inspired buildings. It integrates four major circularity elements: renewable energy, building as material bank, enhanced indoor and outdoor air quality and creating water loops. Next to the design and construction achievements, a concrete business case has also been developed: an additional investment of €3.4M in sustainability is expected to result in €16.9M savings in e.g. energy and water over 40 years. The extra investment was made through mortgage, which is paid off with realized savings. Positive cash flow was already achieved after one year. Better indoor air quality has been shown in literature to link to higher productivity. The Venlo city hall is working with universities to underpin such relation for their building, which can then be translated further financial gains. On material circularity, the Venlo city hall has incorporated Cradle-to-Cradle®

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

certified products, lease contracts and buy-back agreements with suppliers (typically at 15-25% of original prices, for office furniture and indoor finishing). Overall, a 10% residual value was estimated (in a "top-down" manner) for the building in 40 years. The project manager based this value assessment on experience with supplier buy-back agreements in earlier projects, which typically lead to residual value of 5-10%. In turn, the bank has reduced mortgage interest accordingly, with the bank accepting a 5% residual value with the building site as collateral. Overall, the estimate of residual value is still quite exploratory and case-by-case.

2. PROgroup, Luxembourg: PROgroup, founded in 1996, is a group of engineering companies that are active in sustainable buildings based on circular economy principles. Their office buildings in Windhof, Luxembourg feature a wide range of environmental and social sustainability concepts, such as Cradle-to-Cradle, product service systems, transformability, biodiversity, employee well-being and community building. Economic feasibility was demonstrated by low vacancy rates even at above-average rent. In a new steel-structure parking lot project, as contingency for future demand uncertainty, PROgroup has reached agreement with the supplier on a buy-back option of their steel beams at deconstruction. The supplier has agreed to a price point higher than the second-hand market average, since buying back their own products significantly lowers the risks compared to acquiring used beams from other manufacturers. Deconstruction will be carried out by the supplier to ensure proper dismantling and handling. It is speculated that such buy-back schemes may further incentivize suppliers to design for simple deconstruction and standardize beam specifications for various applications.

3. Karlstad hospital, Sweden: Karlstad is a public hospital owned by the county council of Varmland, Sweden. The county council included healthy building materials as a requirement in the neonatal unit renovation project in 2013. As a result, 800 kg of phthalates and 1598kg PVC plastic were avoided, at an additional cost of less than 0.33% of the total project budget. It was recognized that the additional upfront cost is insignificant compared to long-term costs if hazardous materials need to be taken out at a later stage. In fact, there has been a growing demand for healthy building materials over the past decade in Sweden, primarily from the public sector. Although this case is not directly about material circularity, it does provide interesting insight on the role of public procurement in mainstreaming sustainability practices.

4. Rotor Deconstruction (Rotor DC), Belgium: Rotor DC is a spin-off company of the Brussels-based non-profit organization Rotor. Leveraging on years of research and deep insight of the local second-hand building material market, Rotor DC pioneers an innovative way-of-working in deconstruction. The reclaim potential of large buildings is assessed and information is made available to potential buyers already before the deconstruction starts. Cost is made neutral for building owners (deconstruction = demolishing), while additional expenses are paid by sales of used materials.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

Observations from frontrunner use cases

There is ample room for growth in building material circularity business models. In comparison to more developed building sustainability elements such as energy, building material circularity is still a rather new concept in many aspects. Different building products/materials require different business models, determined by characteristics such as lifecycle (e.g. beam vs. partition wall), supply risk (e.g. steel vs. concrete) and value retention potential (e.g. cable tray vs. carpet). The maturity of business models varies significantly: down-cycling and recycling at raw material level date back a long time; product-service systems for shorter lifecycle items are growing; supplier buy-back agreements for structural components are being explored. In the newer business models, how to put retrieved products/materials back into the economy, as well as how to establish solid financial cases for involved stakeholders, are among the topics which still need further substantiation.

Holistic approach is key. Successful circular building projects are devised with a holistic view on sustainability elements such as energy, user health, water and materials management where synergies and trade-offs arise. Furthermore, a common success factor in circular building design emphasized by all is stakeholder engagement from the very beginning. Early co-design processes with end-users, technicians, suppliers and communities take everyone's needs into consideration, therefore resulting in a more holistic design, as well as creating the foundation for future support.

Public procurement can be a powerful driver. Public procurement can play a significant role in mainstreaming circularity practices. For example, healthy building materials remained expensive and niche in Sweden till municipalities started including them as requirements in their tenders. Being one of the largest client groups, demand from the Swedish public sector pulled the entire supply chain and significantly lowered extra cost over time by economy of scale. Finished public building projects are well positioned for further awareness raising and experience sharing.

Regulatory considerations. While energy has become core for most building codes and certification systems, material circularity has received much less attention in comparison. Moreover, some of the major challenges faced by new circular building business models are related to regulations. As a consequence of increased residual value with circular practices, the discrepancy between building (component) market value and book value will likely widen and needs to be properly managed in e.g. accounting and taxation. In another example, important circular business models such as product-service systems with third-party ownership (e.g. leasing) may not be feasible for some building materials due to leasehold property legislations.

Market demand needs more attention. Most frontrunner cases demonstrate the design phase of material circularity, such as choosing Cradle-to-Cradle® certified products and setting up supplier buy-back agreements, which facilitates the supply side of used building components. It is known that supply exceeds demand in today's second-hand building material market. Therefore, in addition to improving technical feasibility and information management on the supply side, further attention is needed to direct stimulation of second-hand market demand, which would be of utter importance to the actual final realization of material circularity in the building sector.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

4.4. Lessons Learned from an office building renovation close to Amsterdam

The practical experience from renovating an old car garage close to Amsterdam to a company office shows that there is a promising gain to be earned from circular design and building, however certain conditions are to be met to make it happen and further scale it up.

Though significant cost savings for buying refurbished versus new were confirmed for some items, with the price of refurbished being around 25% of the price of new items such as window frames, heaters, radiators, there are surely still obstacles to scale up these purchases to a project level.

One of the key conditions for success in the lessons learned, were the harmony and direct line of communication between the project manager of the renovation contractor and the client to occupy the place. This will ensure quick feedback loops to avoid the project planning not to suffer, and give quick green lights to update the original design of the architect if needed. An open mind-set 'client' and a creative contractor will ensure solving issues on the ground that will increase the chance of adopting reused elements in the building, all done in an atmosphere of trust.

Choosing the product that is stand-alone is different sometimes than fitting it, and this is the area where the skills of the contractor are important. Another helping factor is the 'non-rigid' attitude of an architect to adopt changes to the original design, where reality can differ slightly from blueprint drawings, all taking in account of course construction safety.

Another aspect is keeping up with the fast changing safety requirements such as fire proof, heat insulation, etc. Reused products can prove more difficult sometimes to fit in the broader system of installations, that have to meet certain standards.

Finally, it was confirmed that visibility for the contractor of what is available is an important enabler or obstacle to scale the purchase of reused items. In this project, the project manager reached out to his personal contacts to find out a store for 'left out' items and tried to shop on the spot there. A digital platform showing clearly what is available with the right or relevant product information (including product specifications, dimensions, condition, reassembly instructions) would have allowed a much faster decision making, crucial in project planning for construction.

The unit cost savings could be then outweighed by the time spend on finding reused items and trying to figure out if they truly fit. That could push often contractors to take the "safer" option of buying new items.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

5. Conclusions

In Europe, we observed that the circular economy activity in the construction industry is accelerating in recent years. There is a fast growing momentum at business, social and legislative level that makes the topic increasingly on the agenda of main forums and events. Despite these accelerations we identified significant gaps that continue to make mainstream and scaled up adoption of circular economy difficult. These translate to 3 main areas:

- Information: There is still a lack of transparency and availability of the key relevant information relevant for the key stakeholders in construction. That include for example the professional buyer in construction or the architect that needs to have to the precise and credible information about the product, its status, deconstruction profile and its availability. This information should replicate the environment of buying "new", creating trust in buying second-hand.
  Another example is the potential of refurbishment information that should be reflected in the building passport, reflecting important decision making for the building owner or municipalities at city level. The lack of quick access to the relevant info for example in the GTBL pilot is preventing a potential wider adoption of existing suitable used products.
- Connectivity: The availability of the relevant information should entail integration from various data sources and would mean connectivity to various information and business systems such as BIM, Asset Management and Facility management systems, manufacturing catalogues and designer tools such as SketchUp. The automated connectivity is important to avoid as much as possible manual filling of the data.
- Transparency: Trust and transparency are key for professional adoption of buying used products and materials. A lack of transparency pushes away professional buyers that include procurement, architects, engineers and project managers who need a clear overview of for example key specs, delivery time, quality and potential certifications as well as landed cost.

These obstacles contribute to the relatively small scale of present circular activity in construction. To overcome these challenges, we have identified three main areas for change:

1. Techniques and digital technology: The architecture, design and material science innovative techniques will be important to enable buildings that are possible to repurpose and reuse at product, component and materials level. That include the standardization of connections and modularity. This will be critical to enable the easy deconstruction and exchangeability of the products or components. Materials science will enable that ultimately materials value can be extracted with minimal loss, through high quality recycling or even upcycling.
   As for digital technology, viewing the importance of access to the relevant information and to insights to optimize use and reuse, the design unit has to recognize the important of digital architects besides the building architect for preparing the right foundations for future proof buildings that are ready for reuse. Existing buildings can be digitized, putting them as candidates for higher reuse potential in the future.
   An integrated digital platform will ensure that all buildings and related products will be

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

appropriately digitally profiled, and made available upon request for being visible and transacted in a market place.

2. Legislation: Viewing the importance and urgency of the waste, climate change, pollution and public health problems, the appropriate and ambitious Circular economy legislation have to be introduced with ambitious and binding goals, spread across a carefully shaped roadmap at Europe and National levels. City targets can also take the lead viewing that national consensus takes usually longer. These legislations should be perceived as catalyst for innovation and job creation.
   Example of effective legislation could include Circular Economy criteria introduced as mandatory in all public procurement to start with, CE targets at city level, etc. There should be a careful definition with the right pool of experts from private and public sector on what is a CE target, to avoid aesthetic adaptation that will not have effective impacts. This is further to be explored and discussed with Work Package 5 Action 3 on Policies and Standards.
3. Awareness: A bottom up and top down campaigns around the potential significant value to unlock out of reuse should be initiated, whereby new business models will emerge, leveraging the digital enablers to create a "coalition" of forward thinkers and innovators towards a reuse network. This will only succeed through few parties from various industries initiating a proof of concept for an ecosystem and expanding upon it. Sharing successes along the way is important for awareness and hence for expanding that coalition to more companies and stakeholders who will join the wave.

The BAMB project has primarily aimed to explore the technical innovation and information needs to enable reversible and transformational building, where products/ components/ materials can be used and reused through multiple lifecycles.

Through the assessment and findings so far, it was clear that an industry scale enablement of the "buildings as material banks" concept have to ensure the adequate digital representation of buildings and their contents on integrated platforms (like a BAMB platform being developed in this project), where guidance, support and protocols for building or product design are offered, and with the ultimate goal of developing a marketplace where products, components and materials are exchanged for reuse. The current fragmentation of currently available solutions and initiatives, and the absence of fast upscaling reuse in construction, underpins this necessity of integrated tools and platforms and thereby support the buildings as material banks concept.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.