C2C BIZZ
cradle to cradle in business sites

tudor
PUBLIC RESEARCH CENTRE HENRI TUDOR

GUIDELINE
FOR C2C INSPIRED MATERIAL MANAGEMENT ON BUSINESS SITES

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Investing in Opportunities

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INTERREG IVB

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Cradle to Cradle® and C2C are registered marks of McDonough Braungart Design Chemistry LLC. This tool draws on concepts developed by EPEA Internationale Umweltforschung GmbH that form the basis of the C2C methodology cited in the bibliography.

Tudor would like to thank Douglas Mulhall for his critical review of this document and his contribution to the definition of the C2C concepts detailed herein. We would also like to thank all the C2C BIZZ partners for the amazing collaboration we developed together in the past three years. Special thanks to Helma Smolders who is no longer with the project but whose contribution nevertheless shaped the development of the C2C BIZZ project and made it all possible.

CONTENT

INTRODUCTION

About the C2C BIZZ project

In the INTERREG IVB Project C2C BIZZ (Cradle to Cradle in business sites), 11 North-western European partners are, since 2011, working together with the objective of enhancing the implementation of C2C on new and existing business sites. Participating partners include governmental agencies, knowledge institutions and private companies from six European countries (Netherlands, UK, Belgium, France, Germany and Luxembourg).

Cradle to Cradle (C2C) is a quality focused innovation platform for designing beneficial economic, social and environmental features into products, process and systems, starting by determining the intended benefits of a product or service rather than minimizing negative environmental impacts. (Mulhall and Braungart 2010).

About this tool

The purpose of this guideline is to provide practical recommendations to business sites and companies on how to improve their material management practices by using C2C concepts. The challenge is to go beyond a generic recommendation of “buying C2C-defined products” and address the needs of users on how to adapt the C2C methodology for application to specific material issues occurring on business sites.

Material management concepts, tools and approaches from a C2C perspective are addressed, in line with the relevant “waste=food” C2C principle where everything is a resource for something else. The relationship between “waste=food” and other C2C principles is also explored. The aim is to clarify for the reader how C2C can be applied within the context of material management and business sites.

The intended users of this tool are site developers, site managers and individual businesses present on the business site wishing to implement circular material concepts in their operations.

How to use this document

Chapter 2 gives a basic definition of the principles of Cradle to Cradle ® used in this document and the C2C BIZZ project. Chapter 3 defines the concept of business sites considered in this project, identifies the main types and characteristics of business sites, and provides some historical context into the evolution of business sites.

Chapter 4 analyses how material properties and material management practices affect the recyclability of materials on business sites and identifies the most important considerations for material recyclability at a high level of quality. The main material related concepts of the C2C methodology that define C2C inspired material management practices are described.

Chapter 6 identifies material related processes on business sites and associated materials and describes C2C inspired material management strategies and practices that can improve the value and recyclability of the materials flowing through the site.

Chapter 7 summarizes the main benefits and opportunities that arise from the implementation of C2C inspired material management practices on a business site.

Chapter 8 identifies the main challenges that can arise from trying to implement C2C at a business site and proposes possible solutions.

Several material management strategies inspired by C2C and concepts like circular economy, industrial ecology and functional economy are proposed in the following chapters. These should be used for inspiration and combined and adapted as to best suit the specific circumstances of their site of application and its surroundings. They should not be interpreted as prescriptive requirements but rather as a range of recommendations to choose from. These recommendations are clustered as much as possible around the processes they are related to.

This entire work is premised on the argument that the wider adoption of C2C principles within the built environment depends on the rate of uptake by the private sector. The private sector, being profit driven, are likely to engage in C2C site development if they are convinced of its capacity to contribute to their business goals which ultimately is a return on their investment. The tool development described in this document attempts to provide a framework for collating an evidence base that can assist in articulating the business case for C2C in business site developments.

2 ABOUT CRADLE TO CRADLE®

Cradle to Cradle® (C2C) is an innovation platform for the design of beneficial economic, social and environmental features into products, systems and services, starting by determining the intended benefits of a product or service rather than minimizing negative environmental impacts (Braungart and Mulhall 2010).

The C2C design approach integrates multiple attributes, including safe materials, continuous reclamation and re-use of materials, clean water, renewable energy, and social fairness (MBDC 2012). The related concept of circular economy emphasizes a shift from linear to circular patterns of consumption, focusing on value creation from secondary materials.

Although C2C certification is, for the moment, available only for products, the principles and design guidelines of the methodology can be applied to the design of a wide variety of systems like for example buildings, cities, manufacturing processes and facilities, and, as is the intention of the current project, area development.

Cradle to Cradle is grounded in three main principles, commonly referred to as:

Waste=Food, or everything is a resource for something else

One of the key aspects of the C2C design methodology is the conception of materials as valuable resources that can circulate indefinitely in cycles of production, use, recovery, and remanufacture at without degrading in quality (McDonough, Braungart et al. 2003). Products and materials should be designed so that they are safe for people and the environment during and after their use and returned to the correct continuous technical or biological metabolism.

> "Consumption products" that is, those that are consumed or degraded during use are designed to be safely biodegradable and beneficial to the biological systems they integrate. "Service products" contain scarce resources and should be designed to be reintegrated into future technical product cycles after fulfilling their function, preserving the value of those resources for future use.

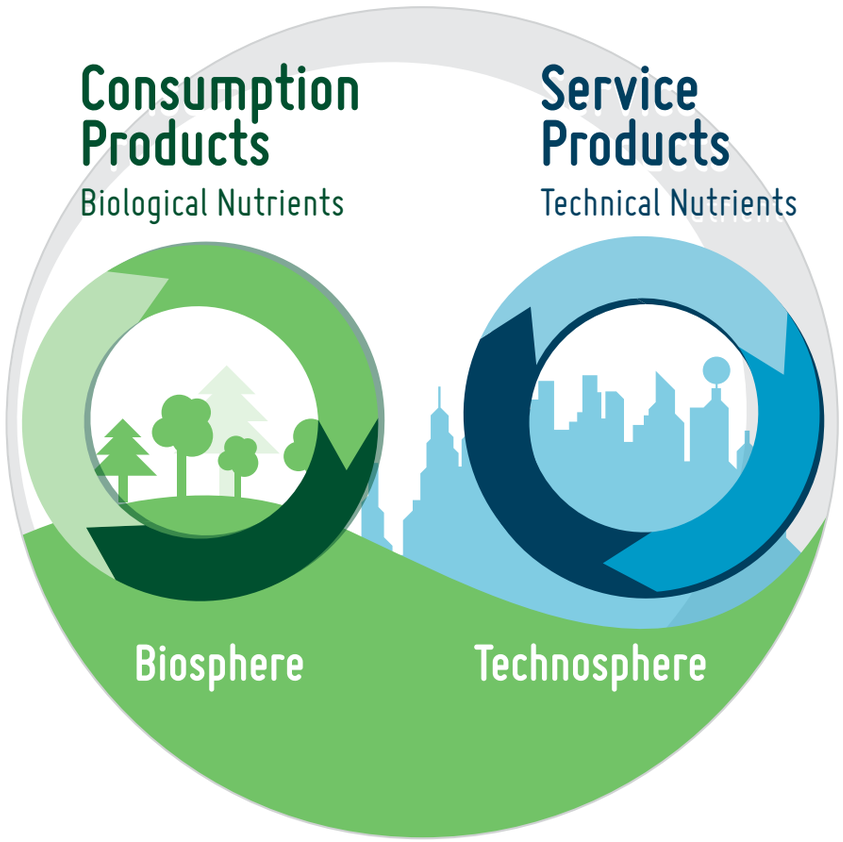


Figure 1 Image ©EPEA

The main distinction between “Consumption Products” and “Service Products” is the intended use period; consumption products such as food are designed to decompose in the environment, often after only one use. Service products like furniture are designed for multiple uses at a high level of quality. The defined use rather than the type of material is the determining factor between the two types of product. Biobased materials can also be used as service products, for example, polymers designed for multiple re-uses can be leased as a service, for example in furniture.

Use Renewable Energy

According to the C2C methodology, human activity aims to produce a net positive impact on its environment. For energy, this means creating products, buildings and sites that generate more energy than they need through the use of rapidly renewable energy from sources like solar, wind, hydro-power, biomass (as long as there is no competition with food production and the biomass source is scalable to meet the intended demand), geothermal and hydrogen fuel cells. The core principle is to use energy that is ultimately generated by the sun or by gravity. For example, shallow geothermal originates from the sun warming the upper layers of the Earth. This goal can be supported by energy application methods that optimize utilization of renewable energy (smart grid, breakthrough energy-efficiency and energy storage concepts).

Celebrate Diversity

Diversity makes ecosystems more responsive and resilient in changing conditions. In the C2C conception, celebrating diversity encompasses cultural diversity and the promotion of social fairness, conceptual diversity and technological innovation for developing creative designs and enhancing local biodiversity. It implies consciously integrating a variety of concepts, uses and cultures, adapting to local circumstances, enhancing stakeholder value and users’ well-being and enjoyment.

3 FROM TRADITIONAL TO C2C BUSINESS SITES

Definition – what is a business site

Business sites, also commonly referred to as business or industrial parks, economic activity areas, or business clusters, have evolved over time from loose agglomerations of businesses and industries in close proximity into deliberately developed areas with the provision of common services. Such services include infrastructure for transport, energy and water or common facilities as waste collection, waste treatment, recycling, tool rooms, refrigerated storage, security and recreation areas among others (Falcke 1999).

Characteristics

Although they often drive economic development through business concentration, SME incubation, innovation, cooperation opportunities and job creation, business and industrial parks are also associated with poor environmental management, pollution, traffic congestion and reduced quality of life (Memedovic 2012).

Often allocated by local, regional or national government, business sites are typically initially located outside of urban areas and accommodate companies that provide services or that produce, transfer or store goods, with accompanying heavy traffic from logistic activities. However they are often overtaken by urban areas as cities expand, posing additional logistics and noise challenges. For historical industrial sites (brownfields), land contamination is often an issue. Industrial processes usually also involve high energy use and waste materials from the production process.

Industrial Ecology

In order to overcome these negative effects, the concept of eco-industrial parks (EIP) and the discipline of industrial ecology as a field of study have been proposed, seeking to minimize environmental impacts through industrial symbiosis- the exchange of materials and energy flows between companies in an eco-industrial system in a collaborative way. However, the goal of industrial ecology, like many conventional sustainability strategies, remains on increasing the efficiency of existing industrial systems, minimizing waste and environmental pollution.

Cradle to Cradle Business Sites

The Cradle to Cradle approach marks a radical departure from this paradigm, as the goals of business/industrial park development shift from the minimization of negative environmental impacts to the maximization of benefits for the environment, workers, local community and the economy.

What is a C2C business site?

Drawing from the definition of a C2C building proposed by Mulhall & Braungart (2010), a C2C business site can be defined as one that adds value, celebrates innovation and enjoyment by measurably enhancing the quality of materials, biodiversity, air and water, using renewable energy, being deconstructable and recyclable, and performing diverse practical and life-enhancing functions for its stakeholders. Under the Cradle to Cradle methodology a business site is one that is designed for multiple uses, for maximum flexibility and creates a truly beneficial positive relationship between eco-industrial systems and natural ecosystems with long-term positive impacts – an outcome termed eco-effectiveness.

Types of business sites

Business sites differ according in their size, type and organisation and their characteristics are determined by the individual mix of industries and companies on the site. They can thus be classified according to different features (UNIDO 1997; UNIDO 2012):

- **Park composition:**
  - **Composite:** containing businesses engaged in a variety of unrelated industries
  - **Ancillary:** containing businesses, usually small, in various fields, but all serving one large establishment and frequently supervised by the parent enterprise
  - **Single trade:** often called “functional”, accommodating either establishments engaged in the same trade or producing the same class of articles
- **Ownership:** public, private or public-private partnership.
- **Land development:** ‘brownfield’ if the park is established on existing but disused facilities of former companies or ‘greenfield’ if developed in a new area.

Different variations of industrial or business parks can also be categorised based on their function as science/technology parks, research parks, light industrial areas, heavy industrial areas or export processing zones (UNIDO 2012).

For the purpose of this guideline, it is considered that a business site can contain varying combinations of services, logistics and industrial companies. Housing and natural areas in proximity to the site should also be considered in the development, whether they are located within the borders of the development area or not, as they are an essential aspect to consider for C2C-defined site development.

The intention is to develop a business site that is connected with its surrounding environment and positively contributing to the natural, human and economic systems it integrates.

4 MATERIAL FLOWS ON BUSINESS SITES

In order to define appropriate material management strategies for business sites inspired by Cradle to Cradle, first the main material related processes need to be identified and systematized, in terms of the processes on the site that originate them, the types of material needed and residual materials generated which might be resources for other processes or products.

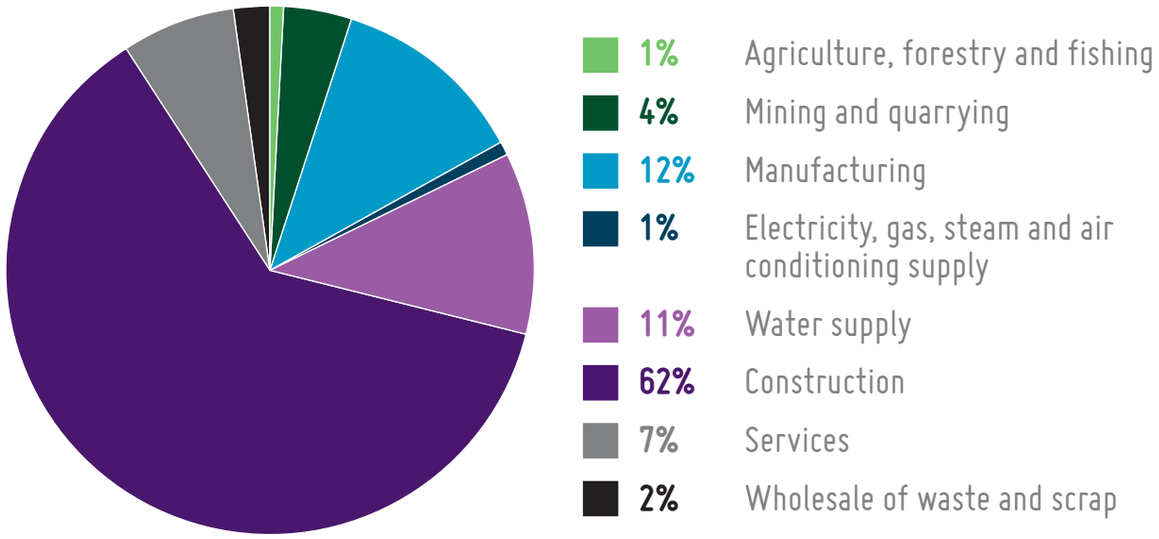
These materials are generated during the following phases:

- Manufacturing of products used during the construction of the site and buildings.
- The infrastructure & construction phase, where up to 1/3 of materials are discarded.
- The use of the site, which generates as much or considerably more materials throughput than the construction phase depending on the use of the site.

As defined in the previous chapter, a mixed use business site can host different combinations of activities on one site– industrial sectors, including manufacturing and processing industry and utilities (electricity, water, heat, etc.); wholesale and distribution companies; service/administration activities, as well as a variety of site support services like hotels and catering, daycare services, shops and services, etc.

Figure 2 shows the relative amounts of waste generated by different economic sectors in 2010 in the six EU countries participating in C2C BIZZ (Belgium, Germany, France, Luxembourg, Netherlands and United Kingdom) based on EU waste generation statistics. It is noteworthy that the graph does not distinguish between waste which is unusable for other purposes without further processing, and residues usable for other purposes. The information gap is a major barrier in gathering accurate statistics which distinguish byproducts and residues from unusable waste. One of the aims of using C2C in business sites is to solve this data problem with more accurate information gathering.

Figure 2: Relative waste generation by economic sectors in the C2C BIZZ member countries



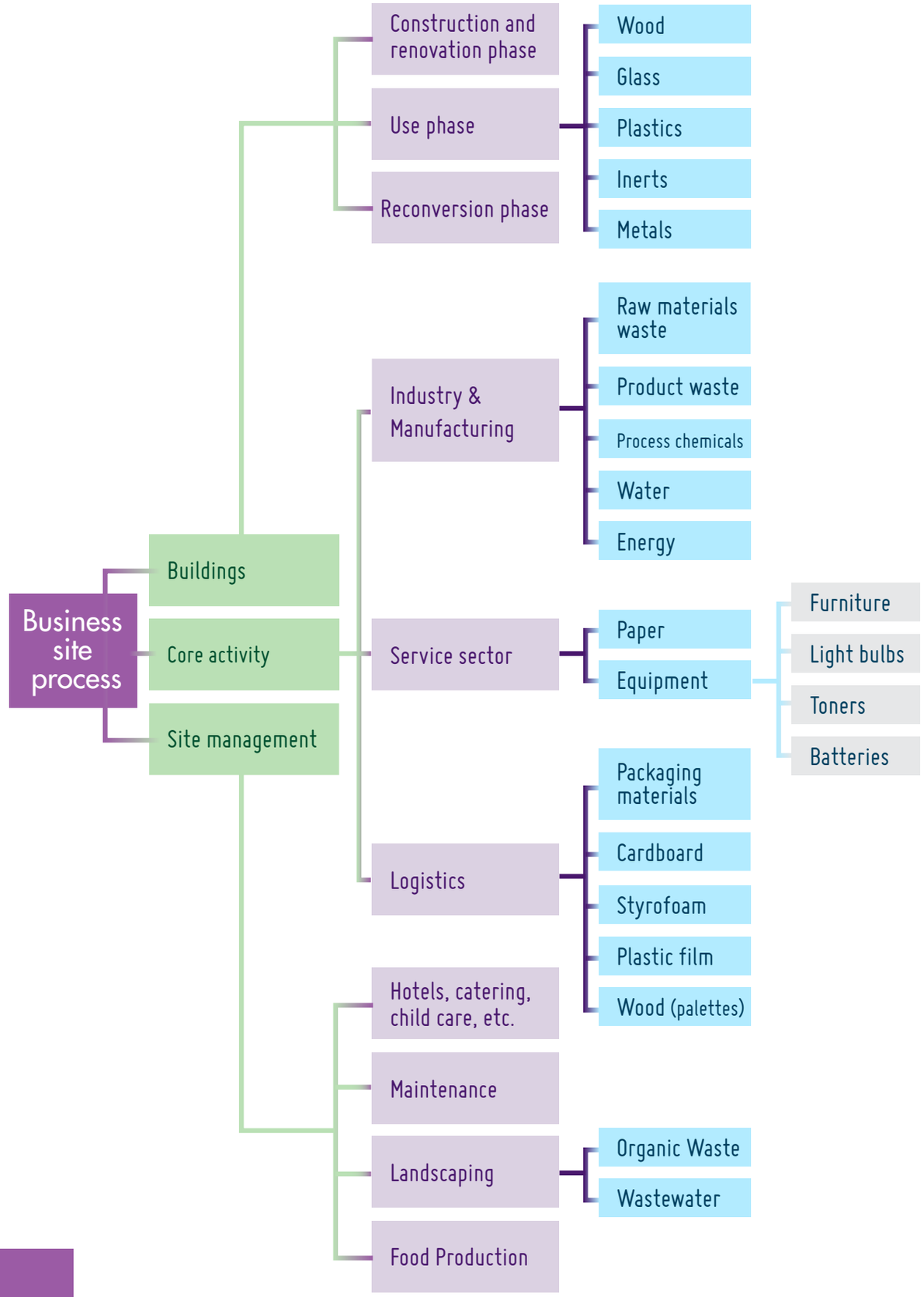
For the purpose of this guideline, material flows will be attributed to the following site processes:

- **Construction and infrastructure related processes** - material flows generated in connection with the physical facilities that businesses and industries are housed in, from the construction of those facilities to their furnishing and equipping, throughout their use and maintenance up to their renovation or re-purposing and finally partial or total deconstruction or demolition. For the purpose of this guideline, processes related to soil removal, road excavation and deposition during the construction phase are not considered.

- **Core activities** - Core activity processes are considered as those that deal with materials associated with the main activities and operations of the companies on the site, be it manufacturing, logistics, distribution and transport of goods, or administrative or service based activities. Each of these companies and activities will have specific needs for raw materials, process chemicals, equipment and products which correspondingly generate products, by-products and waste materials.

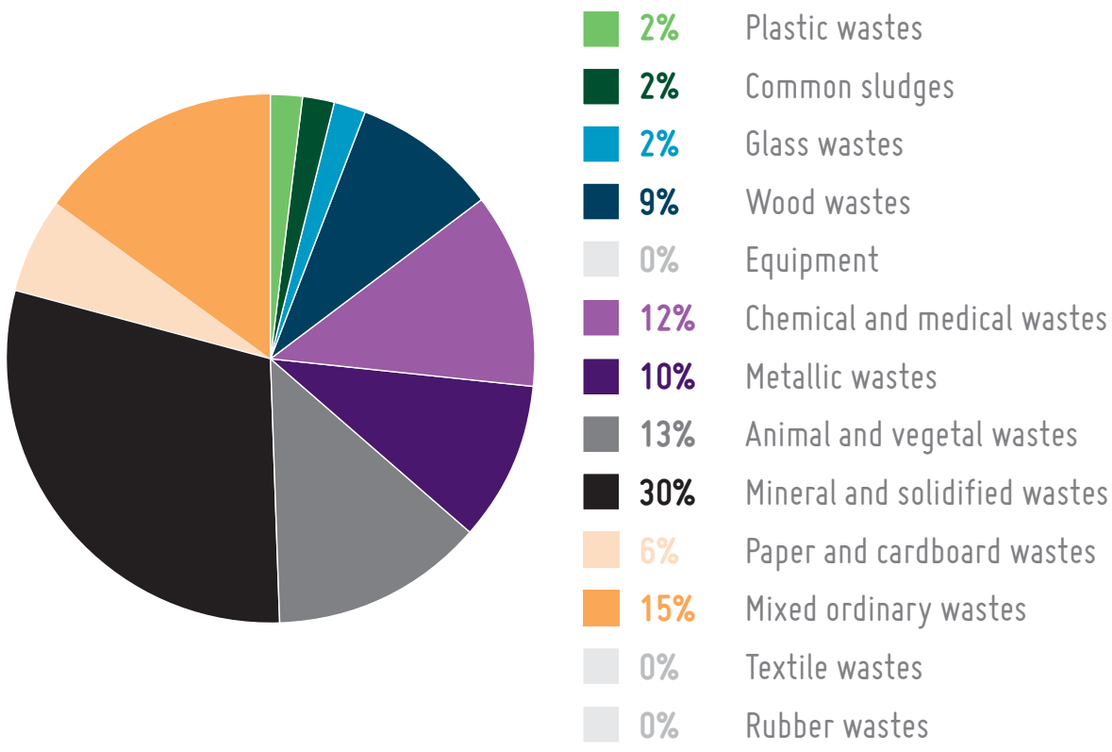
- **Site management** - Site maintenance and management processes generate material flows through activities like maintenance and repairs, landscaping, water treatment, equipment servicing and replacement, etc.

The main material flows associated with these site processes are outlined in the following scheme:



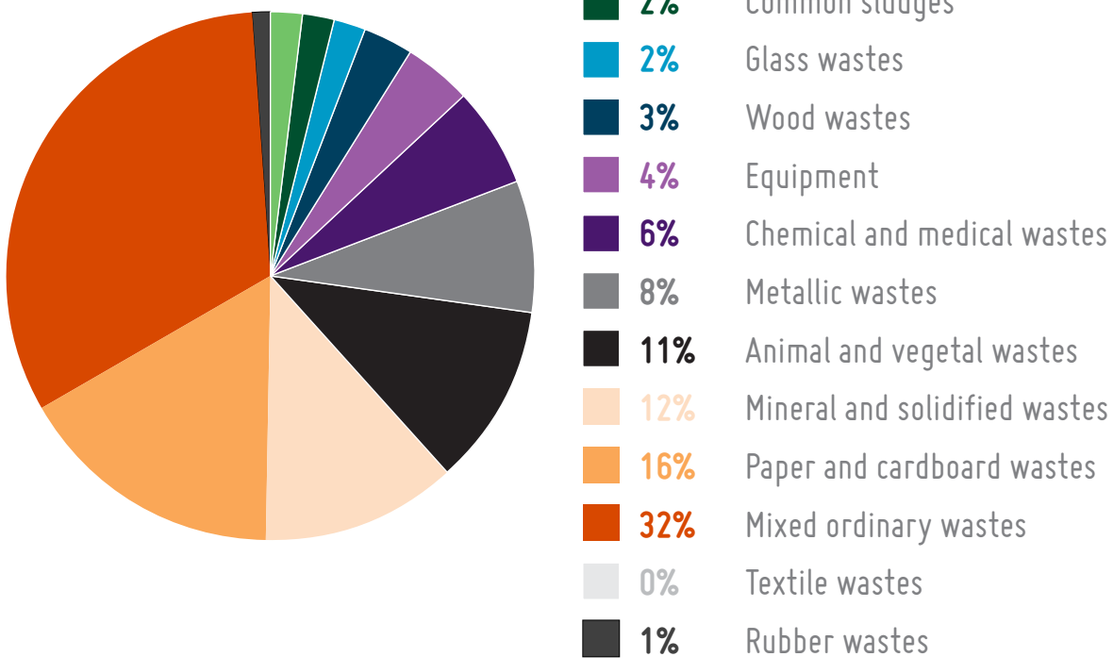
Manufacturing waste can comprise a variety of materials and will be extremely specific to each company. An average distribution of waste streams generated by the manufacturing sector by category in the six C2C BIZZ countries can be seen in Figure 3.

Figure 3: Manufacturing waste



A part of material flows is also generated by the use and occupation of buildings, resulting in material flows associated with human presence on the site. In the case of service sector companies, this accounts their core activity material flows, since no other production activities are present. The service sector includes also wholesale and distribution activities which are treated separately in this guideline. Figure 4 shows an average distribution of waste generated by the service sector by category in the six C2C BIZZ countries.

Figure 4: Service sector waste



5 THE NEED FOR C2C INSPIRED MATERIAL MANAGEMENT

5.1 C2C for improved recycling

The recycling of products and materials depends on an economic calculation balancing the value of the materials and the cost (in terms of energy and labor) of the extraction of those materials. Thus, to ensure the recyclability of products, their design and properties need to correspond to the needs of recyclers.

One of the distinguishing features of C2C is the concept of “C2C-defined recycling”, where the focus is on maintaining or improving the quality of materials throughout their successive uses so they can be reintegrated in other products after their use. This contrasts with the more conventional downcycling – where the recycling of products not intended for recycling leads to a loss of quality of materials and products (for example through the accumulation of contaminants or the deterioration of their properties) and only temporarily delays their inevitable elimination in a landfill or incinerator.

Material safety

A key aspect of C2C is the prioritization of human and environmental health, with the preferential selection of beneficially defined materials as a goal and, at a minimum, the removal of harmful ingredients from products at their intended level of exposure, as well as those that degrade material quality and prevent the recyclability of materials to their full potential.

Recyclability

In order to enable high quality material recycling it is essential to preserve the material stream quality by increasing the value of the material stream and avoiding the contamination of future material streams with poor product design, which makes recycling more economically attractive.

To be able to influence the quality of end-of-use material streams and, accordingly, the quality of recycling those materials are able to undergo, a number of factors need to be taken into account that affect the recyclability, or up- or downcyclability of a product or material.

Those factors include:

- the purity of the material stream,
- its quality- in terms of material grade and contamination with non-target materials
- the ease of separation of target materials.

Material stream composition

Increased source separation improves material stream quality and recycling efficiency. However, the need for separate collection and minimizing contamination needs to be balanced against user convenience to ensure high recycling participation.

As the presence of contaminants in the material stream can affect the quality of the recycling materials, the accurate identification of materials and products is of great importance for recycling. The presence of one single PVC container in the recycling of PET, for example, will cause the entire batch of material to be discarded.

The ability to separate the different components and materials is also essential. Composite and blended materials, and materials with historic contaminants make it very difficult to separate recyclable materials, with the end result that such materials can only be downcycled or disposed of.

Critical volumes

Another issue is obtaining the critical volume and the availability of enough quantities of the same kind of materials, as the efficiency of recycling and the cost-efficient development of the best recycling processes depends on the availability of sufficient volume of materials. Here, the scale of business sites can help generate the necessary volumes to make collection and recycling worthwhile, environmentally (transport, energy use) and economically. Pooling together the same kinds of materials from different companies and buildings can enable a higher degree of material separation, while maintaining collectable volumes and increasing the quality and value of the materials.

Size reduction

The availability of size reduction equipment for materials (like compacting and shredding equipment) and storage space on site can enable the pooling of material streams from different companies and facilitate their more efficient transport for recycling. Having a company or facility on site that is able to accomplish this is a great asset.

Market for recyclable materials

The availability of a market for the produced secondary materials is also an aspect to consider, for which material quality and commodity and raw material prices are of great importance. Economic incentives are strong motivators for recovering and recycling valuable materials like metals. Toxic materials, on the other hand, are subject to legal restrictions and constitute a liability. As such, high quality materials that are easier to recover and recycle and produce secondary raw materials that can be incorporated into other products closer to their original purpose have much higher market value, especially when they are cheaper than primary materials and provide significant environmental and economic savings through their recycling.

In conclusion, to ensure the recyclability of business site materials so that they can continue to circulate in C2C material cycles, it is important to preserve the quality of future materials streams by adding value to end-of-life materials through the design and management stages of those materials. The C2C concepts that allow us to do that and various strategies to maintain and improve material stream quality are further explored in the following sections of this guideline.

5.2 C2C material properties

In order to address the recyclability issues described above, C2C aims to preserve the highest possible quality of materials throughout the value chain and ensure that materials are able to be endlessly recycled in technical or biological cycles. According to the C2C waste=food principle, we can identify a number of key “C2C properties” that products and materials need to possess in order to fulfill the requirements for material safety and recyclability.

The following concepts have been identified as relevant to the implementation of C2C principles on business sites and specifically to the C2C inspired management of materials on such sites.

- **Defined use pathway** – materials and products should be designed according to the function they are supposed to fulfill with their use, as well as specific material pathway at the end of their life and for a specific use period (which enables the manufacturers to recover the product and its materials at the end of its planned use). The defined use pathway is the main mechanism for determining the safety of materials in a product.

For example materials which might be considered unacceptable if exposed directly to humans or the environment during their use are often considered acceptable if there is no direct exposure and the material is recoverable. For example televisions contain hundreds of materials which might be harmful if they offgas into a room, but are considered safe if they do not offgas and are recoverable later. The use and exposure pathways determine the toxicity risks.

- **Material health** – the defined use pathway goes a step further than traditional material safety, by defining materials and ingredients as safe or beneficial or dangerous to humans and environment, and should not contain toxic ingredients or contaminants generated from the production process. If products do include hazardous ingredients, like for example metals, they should be contained in the product and recoverable at the end of its life and not released into the environment in an uncontrolled way.

- **Known composition** – in order to ensure material health, all materials, chemicals, ingredients and additives in a product or material need to be identified and defined (down to a concentration of 100ppm).

- **Design for recovery** – can be defined as the design of products and materials to optimize the recovery and utilization of materials from products and the preservation/ increase of their value. Design for recovery implies:

  - **Identifiable materials** – the different kind of materials and components contained in the product are properly recognizable and identifiable for recycling/ remanufacturing processes.

  - **Defined material pathway** – describe whether the material is supposed to integrate into the technical cycle (as a technical nutrient) or the biological cycle (as a biological nutrient). If a product contains both types of nutrients they should be easily identifiable and separable.

  - **Design for disassembly and remanufacturing** – design to facilitate the reparability, component replacement, disassembly and recycling of recovered products using standard tools and recycling or remanufacturing processes.

6 C2C MATERIAL MANAGEMENT STRATEGIES FOR BUSINESS SITES

6.1 Buildings & Construction

Buildings and structural elements constitute the longer lasting part of the business site, with lifetimes spanning from 15 to 50 years. Other materials used in construction flow faster through a building's lifetime, getting renovated or replaced several times throughout the building's use. During renovation and reconversion, building systems like heating, cooling and ventilation equipment can be replaced, space reconfigured with walls demolished, partitions moved or replaced, etc. Or the whole building can be demolished to make room for new construction.

Construction and demolition waste accounts for the majority of waste generated in Europe and is considered a priority stream by the EU [WFD 2008]. Construction materials concrete and steel are also very energy intensive to produce, resulting in the high "embodied energy" contained in those materials. However, after a typical demolition, the majority of inert materials like concrete and ceramics can only be downcycled into lower value aggregate filler material or landfilled.

From a C2C point of view, in order to recover the most value from those materials, their structural integrity should be preserved so that they can be used again as components in other products or projects. In order to do that, C2C principles should be applied at every stage of a construction's lifecycle, from design and construction, to its maintenance and renovation until its final deconstruction. Different strategies for C2C inspired material management are proposed here for each stage of development.

Material banking

To create eco-effective systems with a positive impact, design is the first aspect to address. Applying the C2C methodology to the built environment involves designing buildings as "material banks" for long term storage of valuable materials for future use, with their final recovery and recyclability planned in advance. This affects the choice of materials used in the building, construction techniques, building features, building systems and equipment, waste management, etc. Assuming that the current trend of commodity price increases remains in place, construction turns into an investment in the future value of materials.

Source: Philips , 2014.

A pioneering collaboration project between Philips and RAU Architects demonstrates a performance model based on selling light as a service. Instead of purchasing the lighting infrastructure for its headquarters in Amsterdam, a “Pay per Lux” service was negotiated. A holistic lighting concept was installed, which maximized the building’s natural light and combined it with a sensor-controlled LED installation regulated according to presence and daylight availability. (Ellen Macarthur Foundation 2014)

Tendering

Starting from the tendering stage and architect and contractor selection, the project’s ambitions and goals are defined and C2C criteria integrated into the tendering procedure. The number of C2C certified architecture and engineering companies is growing year by year, increasing the availability of professionals experienced with the concept to involve in the project’s development.

Supplier involvement

The selection of C2C materials and building elements should be prioritized from the beginning, and suppliers involved in early stages of the design and construction process, rather than left to be subcontracted at the lowest cost by the winner of the tender. Setting a budget and asking suppliers to compete on quality rather than price also tends to raise the overall quality of the development and the value added for stakeholders.

One example of supplier partnership is the leasing of building elements like technical equipment, furniture, lighting, windows, etc. In this case, the manufacturer retains the ownership of the product and the client pays only for the function it provides, removing the liability for the materials and their disposal. In this case, the manufacturer/supplier has an incentive to design products that can easily be refurbished or remanufactured, using high quality materials with the guarantee of their recovery.

Material selection

Applying C2C principles to the selection of construction materials and building elements means opting for materials of known composition, without the presence of harmful substances released during their use like formaldehyde and other VOCs (among other banned substances). Intended use periods and material pathway for materials and elements recovery, reuse or recycling should also be defined in advance.

Several online catalogues are available listing existing C2C construction materials (for example on c2c-centre.com or c2ccertified.org). Additionally, a newly started register of C2C elements in existing buildings might be able to provide additional inspiration. The LEED green building certification standard was recently updated (v4) to include C2C criteria. However, in a multiple building development like a business site, it might be interesting to compile an own database of preferred suppliers and C2C inspired elements and materials that can be continuously updated throughout the lifetime of the development.

Source: Park 20|20, 2014.

Park 20|20, one of the first area developments to integrate the C2C methodology into its operations, invited their suppliers to join their supplier community, establishing a pool of suppliers they could choose from to address their specific material and product needs at any moment. They also developed a continuously updated database of available C2C construction materials. A 3D Building Information Modeling (BIM) system is being adapted to track all construction materials, elements technical equipment and construction techniques used in the building. At the end of the building's life, it will provide information on disassembly procedures, construction materials and structures used on the site.

Material tracking

As seen in the previous chapter, the ability to identify and track materials throughout their lifecycle in a building is of crucial importance to their end of life management. In order to do that, updated inventories should be maintained of the building and its technical equipment, through a dedicated database system, for example, or through an adapted building information software.

Renovation

Building renovations provide a good opportunity for bringing in assorted C2C measures in a building and converting existing systems. These measures can include, for example, replacing undefined interior fittings, furniture with C2C products, implementing partnerships with suppliers and negotiating leasing contracts for building systems and equipment and recovering used materials and products and returning them for remanufacturing or recycling.

Design for disassembly

Another important aspect is to design the buildings for disassembly, modularity and flexibility, using construction techniques that enable building elements like structural elements, façade cladding, roofing, windows, etc. to retain their structural integrity, allowing them to be reused for new construction. Buildings constructed so they can be adapted to different needs during their use minimize the need for extensive renovations, and enable whole elements and building parts to be reused elsewhere, retaining their original value.

Designing for disassembly includes using standardization of elements and connections to enable their dismantling and reuse, relying on accessible physical connections rather than chemical bonds and separating mechanical, electrical and plumbing systems (Guy and Ciarimboli 2006). Design for disassembly has the advantage of making the construction process easier and faster, saving on construction times and costs.

Brownfield demolition

In the case of brownfield site developments, it might also be necessary to carry out the demolition of existing legacy buildings and structures in order to redevelop the site.
As these structures would not have been designed with deconstruction in mind, a lot of problematic materials will be present that are either hazardous or not possible to recycle at the same level. Maximizing the separation of different materials at the demolition stage and employing selective deconstruction methods would allow to extract the maximum value from whatever valuable and recyclable materials are present.

Further reading

For more on C2C application to the building and construction aspect of business sites, see also the publications “Cradle to Cradle® Criteria for the built environment” “Creating Buildings with Positive Impacts. Using C2C-Inspired Quality and Value for the Circular Economy”(Mulhall, Hansen, Braungert 2014).

6.2 Manufacturing

Manufacturing and processing activities typically generate material flows related to the use of raw materials, processing of those raw materials though physical or chemical methods and resulting in production waste, by-products, rejected products, process chemicals, etc. and finally the finished goods destined for further processing, distribution or final consumption.

The manufacturer may also be responsible for taking back and recycling waste products from their costumers, as a result of producer responsibility regulations. Additionally, manufacturing companies also have material flows related to the structure of the building or factory where they are housed, as well as equipment and machinery needs for their production process, tools, spare parts and substances needed for equipment operation. They are also integrated within a supply chain, sourcing their raw materials and ingredients, as well as equipment, chemicals, packaging from a variety of different suppliers.

The application of C2C to manufacturing companies is relatively more straightforward, as this is type of activity is effectively addressed by the C2C certification criteria for products, which is performed by an independent non-profit institute in collaboration with authorized assessors. Companies interested in the C2C benefits can this begin their certification process for their products and adapt their operations accordingly.

For more information on certification see:

http://www.epea.com/en/content/cradle-cradle-certifiedcm-certification.

If a company does not wish to pursue certification for whatever reason, it can still make use of the C2C principles to reap environmental, economic and social benefits from applying the methodology to its activities. A diverse range of non-profit and consultancy organizations provide advisory services to companies wanting to apply the C2C methodology and especially to support quality assurance in the built environment.

It is recommended to use one of those authorized organizations when starting to apply the approach. Accordingly, the application of C2C in manufacturing can go from the design of the factory building and production process, to product design and material selection to the business models involved in the commercialization of the product to the take-back and recycling of used materials and products. Several options for material management in manufacturing are therefore proposed, addressing different stages of the manufacturing process.

Supply chain

This section refers to the upstream chain of suppliers and intermediaries involved in the sourcing of the raw materials, components and services necessary to manufacture a company's products.

Several possible strategies to involve those suppliers in the company's shift towards C2C production are suggested:

- Identify a pool of C2C frontrunner preferred suppliers to source raw materials and products from.

- Create supply chain partnerships with key suppliers and help them adjust their processes to the supply of raw materials and products according to C2C criteria and work together towards implementing the necessary changes.

- Identify problematic materials and substances in your supply chain and work together with suppliers to substitute them with beneficial ones.

- Establish agreements for the return of production waste to suppliers for high quality recycling.

Rolls-Royce has developed relationships across its operations, resource and waste management service providers and raw material suppliers to return its off-cuts, turnings and unused materials related to certain metals and alloys through the resource and waste management service provider. By returning an agreed amount of this used, high quality material, Rolls-Royce receives a discount on new material purchases from the same supplier. As such, Rolls-Royce has effectively become part of its own raw materials supply chain, ensuring that it avoids treating key materials as waste within its systems. (IEMA 2014)

Product design

A large part of implementing C2C in manufacturing activities relates to the need to design products according to the C2C design criteria and principles described earlier.

This means redesigning products and rethinking the production process so that the final goods are:

- Healthy or beneficial for humans and the environment
- Free of problematic substances in terms of toxicity and recyclability
- Designed for a specified recovery and recycling process in the biological or technical cycle
- Designed for recovery, remanufacturing and disassembly.
- Of high value for recovery and recycling.

Cradle to Cradle encourages manufacturers and product designers to analyze the function or need the product is supposed to fulfill for the consumer and how those needs can be fulfilled while still retaining the ownership of products and materials.

Manufacturing process

When implementing C2C measures, whether or not C2C certification is pursued, a company's manufacturing process can still be adapted to eliminate production toxicity and hazardous by-products and waste, increase the reutilization of high quality, defined secondary materials in production and increase the value of the finished products, their utility for costumers and their ability to reintegrate circular production systems at the end of their lifetime. In order to further those goals, a number of actions are suggested at several stages of the production process in this chapter.

- Introduce healthy materials into the production process:
  - Select raw materials compatible with C2C criteria, healthy for humans and the environment and suitable to integrate continuous technical or biological material cycles.
  - Change processing methods to eliminate the addition of contamination and problematic substances to the final product – for example use physical or heat treatment instead of chemical additives.
  - Select additives, chemicals and processing agents that are not harmful for their defined use and that do not contaminate the final product.
  - Recover, regenerate and recycle used chemicals like solvents, catalysts, acids or bases, coatings, etc, either on site or by returning them to the manufacturer or specialized recycler.

Chemical leasing – similar to the leasing business model that can be applied to cars, tools or technical equipment, chemicals can also be leased from manufacturers. Within this model, it is the performance of the chemical that is sold rather than the substance itself. Customers pay a fee based on a functional unit of performance, with the manufacturer retaining the ownership and responsibility for maintenance and recycling of the substance.

- Adapt manufacturing processes to reduce the production of unmarketable by-products and manufacturing waste by, for example:
  - Using additive instead of subtractive manufacturing processes, where material is added to form the final product rather than removed.
  - Reintroducing by-products and production waste into the production process, in the same production system or through third party recyclers and material dealers.
  - Increasing production quality to eliminate rejects and raw material waste.
  - Use dematerialization as an approach to deliver the same product function with fewer materials.

- A higher level of C2C quality compared to waste reduction is to improve material reutilization by integrating high quality recycled materials into the manufactured products so that the quality of the resulting material stream is maintained or improved rather than decreased after use.

Source: FLOOW2 , 2014.

FLOOW2 is a business-to-business marketplace established in early 2012 that enables companies and institutions to share their business equipment and knowledge & skills of personnel that is currently underutilized. The platform generates additional revenue streams through the rental of equipment and personnel, providing other companies access to equipment they need at rental prices that make it worthwhile as an alternative to investing in and owning the equipment.(Ellen Macarthur Foundation 2014)

Industrial equipment

Industrial equipment and machinery is an important part of manufacturing and probably holds the most material value in the production line in terms of expensive technology, rare earths and metals and high end instrumentation and robotic systems. In this area it is also worth considering alternative financing mechanisms like leasing, renting and return agreements, in order to preserve the value of the equipment so that it can be also used as a high-tech material bank, rather than accounted in terms of its depreciation in the companies' bookkeeping system.

Here, developing partnerships with the equipment suppliers and manufacturers and establishing agreements to ensure that the equipment gets returned and the maximum value is created from it through repair, remanufacturing and component and material recycling.

Where available, C2C equipment could also be used in the factory floor when new equipment is installed or replaced. As an example, company Vanderlande produces a C2C certified conveyor belt that can be used in many industrial and logistic applications.

Reverse Logistics and circular value creation from secondary market

Reverse logistics is a key part of developing circular systems for materials and consists in the flows of materials and products from the consumer back to the producer, including also the operations of remanufacturing, refurbishment, recycling and redistribution for the purpose of value recovery or final disposal. In order to recover value from post-use products, several strategies can be employed in a cascaded system, by order of decreasing value preservation:

- **Direct resale** – still functional products can be resold directly in the secondary market.
- **Remanufacturing** – partly useable products can be repaired, refurbished and sold or leased again.
- **Component reuse** – still functional parts or components of products can be directly reused into the manufacturing of new products.
- **Material recycling** – when reuse and remanufacturing is no longer possible, materials can be recovered and returned to the technical or biological cycles through physical or chemical processes.

Ricoh's strategy for resource management is to reduce its input of virgin materials by a quarter by 2020, through the reuse of parts and products, extending the lifetime of products in its range, remanufacturing and substitution for lower risk materials. Its EcoLine product range takes previously leased copiers, inspects, dismantles, renews components and updates software before selling them as remanufactured products.(IEMA 2014)

6.3 Service sector

Depending on the specific circumstances of each site, a significant amount of service and administration type of companies is often present on the site. Typically, these are housed in office buildings and consist of companies whose main asset is human capital such as banking, insurance or consulting. These companies don't have any production and processing facilities in place and their material flows are typically related to the presence and activities of their workforce and building maintenance.

The service sector also includes businesses and industries involved in logistics activities such as warehousing, distribution, retail and wholesale. These types of companies typically have a high throughput of packaging and transportation materials like wooden pallets, plastic or wooden crates, cardboard boxes, plastic film, polystyrene, etc. The materials these types of activities generate are considered as comparable to municipal solid waste. In order to extract the most value out of these streams, a few recommendations are provided.

- Develop initiatives to increase the awareness and involvement of all material actors on the site including employees, cleaning services, maintenance services, etc.

- Establish partnerships and negotiate contracts with suppliers for C2C purchasing. Most companies use B2B contracts for their IT and equipment, meaning that the companies that provide and service that equipment, including computers, phones, copy-printers, lights, are also responsible for the maintenance and take-back and recycling of the end of life equipment. These contracts B2B contracts can be leveraged for C2C value creation by optimizing the recycling value of the products and making deals with providers.

- Waste collection services can also be used to recover material value from the sites' waste stream. In order to do that, the valuable waste streams need to be identified (through data collection) and their optimal recycling pathway identified. The degree of waste separation to maximize material quality and recycling value from the recyclable material waste stream from the business site can also be determined and implemented.

6.3.1 Logistics and distribution sector

Within the logistics and distribution sector the opportunities for C2C implementation are related to the implementation of distribution systems for C2C materials and their end of use recovery and recycling. Logistics innovations can accelerate C2C implementation across the supply chain, enhance collaboration with other supply chain actors and leverage available resources, and play thus a key role in the development of circular business models. Additionally, packaging materials are an important material flow at different stages of the logistics chain, and can also be optimized according to C2C.

In order to extract the maximum value out of end-of-life products, a logistic system can be put in place by the manufacturer to recover products, parts and materials for reuse, remanufacturing and recycling, either directly or through a third party contractor. The implementation of extended producer responsibility schemes means that product recovery is often collectively organized and financed between several manufacturers.

Product recovery

In order to retrieve the products from consumers, collection facilities can be put in place. These can be provided by retailers, central collection points or by the distributor upon the delivery of new products. Innovative partnerships with postal carriers by some manufacturers, can also allow product return through the mail. Direct exchange between manufacturers, retailers and distributors is also used for reusable packaging and transportation materials like Euro-palettes or drink bottles and crates. Another possibility for product recovery is “backloading”, or the integration of the forward delivery channel with the recovery end-of-life products at the same time.

Warehousing and distribution

The warehousing and retail facilities located in business sites provide the opportunity to locate the necessary operations of sorting, testing and disassembly so that components and materials can be recovered in the proximity of manufacturersz and large waste producers. Furthermore, transportation and retail actors can be a valuable partner to assist manufacturers with the recovery of their products and materials, and provide central collection points for product redistribution. The concentration of wholesale, retail and manufacturing activities on one site can also provide the opportunity to combine shipping and distribution activities of different partners.

In a pioneering logistics collaboration project between competing manufacturers, Nestlé and PepsiCo have bundled the warehousing, co-packing and outbound distribution of their fresh and chilled food products to retail customers in Belgium and Luxemburg. By proactively consolidating, balancing and synchronizing the part loads of Nestlé and PepsiCo into Full Truck Loads, the collaboration is creating improvements in total logistics cost and better service levels for the retail customers. The total synergy gains are divided through a fair gain sharing mechanism, allowing additional fresh & chilled manufacturers to easily join the community in the near future. (STEF 2014)

Source: Ecovative Design, 2014.

Ecovative Design developed innovative high performance biobased and fully biodegradable packaging materials made from mushroom and agricultural waste. (http://www.ecovativedesign.com/) At Ecoparc Windhof, moving and data destruction company Streff uses its broken wooden transportation pallets as fuel for the heating system of its warehouse.

Packaging

Packaging materials are an important waste flow in business sites, where a significant number of distribution, warehousing and retail companies are present. It accounts for 20% of total household waste and adds up to a significant amount of a products production cost, yet it is mostly discarded after a single use, with the combination of materials used often posing a problem to its recycling (Ellen Macarthur Foundation 2013).

One strategy to shift towards more circular material management strategies especially at a B2B level is to opt for reusable packaging and transportation systems as much as possible, adapting the distribution system to the recovery of those products. This is facilitated by standardization of packaging materials across the industry and common collection standards to enable the same products to be used by multiple manufacturers and distributors.

Another approach is to design or select biodegradable packaging, which is particularly suitable for single use products that have been in contact with organic materials and that are difficult to recover after their use. However, in order for biodegradable materials to actually decompose specific conditions are required that are mostly only found in industrial composting facilities, thus needing to be collected separately along with the organic waste stream.

Other packaging materials that are not reusable or biodegradable can be optimized to be recycled into the technical cycle. Here, the large volumes of materials available in business sites allow for increased separation between different materials, and make it worthwhile to collect them separately for the whole site, thus increasing their value in the recycling market.

6.3.2 Implementing Circular Business Models

A large part of implementing circular material systems is the development of business models that make it possible to create value from secondary materials and additional revenue streams. For service sector companies on business sites, especially those whose activities on a business site are mostly administrative, embedding circular material management in its key processes and activities can bring about large benefits and economic opportunities reaching beyond the physical limits of the site.

This could mean changing the company's procurement procedures to favor healthy C2C materials, creating innovative products and services that enable circular material flows, material reuse and recycling like insurance and finance products that facilitate product leasing and reuse, or developing strategic partnerships with other companies that enable them to participate in a circular material system.

Circular business models include those that enable and facilitate the retention of product ownership by its provider, so that the materials in the product are able to return to their proper cycle after their use, such as for example the leasing or renting of product, trade ins, guaranteed repurchase price, deposit systems, etc.

More information on the practical implementation of circular business models in the company's activities can be accessed in the C2C BIZZ publication "Guided choices" and Ellen MacArthur Foundation reports on how to implement circular business models, as well as in the publication Creating Buildings with Positive Impacts (see bibliography).

6.4 Site management

As discussed in chapter 2, one of the key differences between area developments like business sites and isolated buildings and industries is the access to the spatial resources of the site. This means that C2C solutions can be considered not only on an individual level but integrating the whole site, its buildings and the diversity of companies present on it. This chapter relates to activities and management processes that are most effective when applied to the whole site.

Biological Nutrient Management

Many business site businesses and activities will generate significant amounts of organic residues. Landscaping activities for example, will generate a substantial amount of green residues like wood, grass clippings, fallen leaves, soil, etc. Significant amounts of food residues are generated by restaurants, hotels, cafes and cafeterias, childcare facilities, supermarkets and food retailers, among others. All of those establishments need a constant supply of fresh food, fruit and vegetables. The human presence on the site will also generate biological nutrients in the form of sewage.

The mismanagement of biological material can have many negative consequences like soil depletion, decreasing crop yields and loss of topsoil, excessive fertilizer use and water eutrophication, carbon emissions to the atmosphere, among others. Legal restrictions like permit requirements and limits to nutrient application may be applicable, for example, on how, where and how much biological nutrients can be added to the soil. That is for example the case with application of wastewater treatment sludge to soils in Europe. The key point is to apply biological nutrients where they are needed, so they can perform a useful function for the site and its occupants.

In order to leverage the scale of the site and the agglomeration of food businesses and human activity, the management of biological nutrients should best be considered at the whole site level. Several management strategies can be applied to biological materials, depending on the characteristics of the site and what materials are available. Different strategies can serve a variety of purposes like for example soil enhancement (composting), energy production (biodigestion), food production, air or water purification (through green roofs and helophyte filters), etc.

Different combinations used together can also complement each other and maximize the value they create for occupants and stakeholders.

Several examples of strategies to manage the biological materials that pass through the site can be identified:

- **Nutrient cascading** consists in extract the maximum value from biologic materials by extending the number of life cycles a product or material can have through their controlled downgrading in successive applications in different value streams before returning to the biological cycle. An example of cascading might be the use of timber for construction, then for furniture and finally paper production, before finally being composted or incinerated for energy production.

- **Organic residues as a resource** – food residues, crop residues and food processing by-products offer many opportunities to create innovative products and business models, for example by extracting high value chemicals and molecules for the pharmaceutical industry or biobased material production like fibers and bio-plastics.

- **Food production** – to make use of the site's biological nutrients, instead of traditional landscaping, available unbuilt areas could be used to connect with and support local ecosystems or as food production areas for the site's catering facilities. Food production can also be incorporated into the site's built up infrastructure such as "building integrated greenhouses". Small scale integrated agriculture initiatives are also a great educational tool.

Source: Products Innovation Institute 2014

Wet-Green® is a C2C Gold certified plant-based leather tanning agent produced from olive tree leaves, a by-product of the olive oil industry. The associated tanning process eliminates the use of hazardous chemicals, removing the need for REACH registration, is health and environmentally harmless across the entire value chain, and improves the properties of the final product.

- **Separation of organic residues** is the first requirement to utilize the biologic nutrients available on the site, organic residues first are separately collected, prioritizing large producers like cafeterias, restaurants, hotels and fresh food retailers. Dedicated bins for organic residues should be installed in key production points. A few central collection points for the whole site might also be interesting for smaller and more distributed quantities.

- **Composting** is a well-known and widely disseminated strategy to divert organic materials from landfills and incinerators and turn them into a valuable ecologic soil enhancing fertilizer. Composting can be done small scale for local landscaping application or food production, which can also be used for educational purposes. Centralized industrial composting facilities produce a more standardized commercial fertilizing product and have the advantage of being able to handle biodegradable materials that require specific treatment conditions not achievable in small scale composting.

- **Biodigestion** is the anaerobic biologic reprocessing of organic residues with the production of biogas that can be used for energy production and a nutrient rich organic material that can be used as soil conditioner or further processed for use as fertilizer or other uses. It is typically used for treating wastewater and animal manure, as well as food residues and biofuel crops.

Source: NIOO-KNAW 2014 Photo: Guy Ackermans

In the building of the Netherlands Institute of Ecology (NIOO), inspired by C2C principles, different water streams for rain water, domestic water and toilet waste water are separated and treated with a plant purification systems, reused and safely released into the local water system. In a pioneering research, NIOO is converting biomass from the waste water into biogas for energy production and valuable nutrients like minerals and phosphate into agricultural fertilizer through an algae cultivation system. A green roof completes the design, where scientists are studying its effect on conserving biodiversity, while another company experiments on plant based power generation. (NIOO-KNAW 2011)

- **Closed water and nutrient cycles** – water and biologic nutrients in wastewater can also be recycled. Systems for water recycling and recirculation can be implemented throughout the site, and can be coupled with treatment systems that extract and valorize nutrient like nitrate and phosphorous from human and animal manure for use as fertilizer in agriculture.

- **Green roofs and living wall systems** are also a part of the biological nutrient system, contributing to the building's water regulation, filtering and rainwater management, enhancing indoor and outdoor air quality, regulating temperature and converting solar energy and biologic nutrients into biomass.

- **Local biomass application** – locally produced biomass like tree and landscaping cuttings or waste materials like broken palettes can be used as mulch applied to trees, bushes and plants for soil protection and water management on the site's green spaces.

Industrial Symbiosis

One of the benefits of the location of businesses on business sites is the establishment of local partnerships and material and energy synergies with other companies located on the site. Potential area level actions include the different strategies for the management of biological materials from composting and biodigestion to food production and closed water and nutrient systems, as well as the sharing of materials, common facilities and infrastructure. The following strategies are suggested to make use of collaboration, partnerships and symbiosis in business sites.

- **Material exchange** between companies as well as other flows, including water and energy can offer significant opportunities for companies to integrate high quality secondary materials into their production process and save on raw materials and inputs.

- **Facility sharing** for infrastructures, equipment and services such as storage space, equipment and tools, maintenance services, technical services like heating cooling or ventilation, meeting and conference rooms and other specific occasional use facilities like child care and sporting facilities can achieve considerable material and economic savings for companies when implemented on business site level and provide additional services otherwise out of reach for small and medium companies.

- **Material pooling**, by combining and centralizing material streams of several resource outputs or waste flows from different companies to create a critical mass of materials. While a single material stream from one company might be too small to recover and recycle economically, combining several similar streams would increase the critical volume of material available for collection and recycling, and make it more economically viable to collect. This will also enable a higher degree of separation in the materials stream, allowing for the economical collection of more differentiated materials, thus increasing the quality of materials available to recyclers, and, therefore their market value.

Material partnerships in the C2C BIZZ project

Irisphere

At the C2C BIZZ pilot site Irisphere in Belgium, chemical company Solvay produced an outgoing waste water stream of 60.000m3 of low mineralized water a year, adding to the company's waste water treatment costs. A workshop allowed the identification of several industrial partners interested in using this water as a washing fluid within their processes. A partnership was established with an automotive company that could use this demineralized water stream to wash their mechanical pieces for free, replacing the drinkable water they previously had to pay for.

This industrial synergy also offers additional benefits for the automotive company as it provides a better washing performance and reduces the need for detergent use.

Ecoparc Windhof

In Ecoparc Windhof, in Luxembourg, a strategic partnership was identified on the site to replace several different waste and recyclables collectors by organizing collection by one of the site's partners that possessed the logistical capabilities to undertake this activity. Centralized collection enabled the separation of waste office paper from cardboard, therefore increasing the value of the material stream and enabling the recycling of materials at a higher level. Separation of high grade office paper from low grade carton significantly increases the value of the waste stream and enables the longer cascading of the cellulose fibers along the biological nutrient cycle.

Role of park management

The role of the park manager, site developer or any other organization or individual that manages and oversees the day to day operation of the site, arranges for the common provision of services, allocates the plots, buildings and office space is extremely important for the identification, development and implementation of material opportunities on a business site.

As the connecting link between the site/land owner(s), the building owners, companies present on site (as owners or renters) and local authorities, the site manager is in a unique position to bring together the necessary actors and stakeholders and take measurable steps in the direction of Cradle to Cradle® material management.

As part of their role of "matchmaker" on the site, their involvement can include:

- Identifying opportunities for innovation – site managers have the benefit of an overarching perspective, being able to spot potential synergies between companies and taking the necessary steps to put them in contact with each other.

- Providing common services – as the manager of the entire site and its common spaces, it is the role of park management to provide its members with basic common services needed for their operation such as landscaping, parking, security, etc. Taking this role further, the site manager can also provide its members with common maintenance services, centralize and combine its waste management collection, provide common facilities such as recycling centers, tools and equipment, etc.

- Negotiating common contracts – as representatives of the site and its members/companies, site managers are in a position to use its pool of members to bulk their purchasing power, thus being able to negotiate better prices or additional quality of service for the provision of goods and services for the site, being able to negotiate group or bulk discounts for its members.

Source: Park 20|20, 2014.

Ecoparc Windhof, in Luxembourg, was able to negotiate C2C-certified carpets for its Solarwind building at a lower price than the conventional commonly available solution.

- **Establishing communication and collaboration** – making the connection between the right actors and companies, and putting them in contact with each other, establishing regular meetings and collaboration processes between companies, informing and engaging companies and their employees in the site's mission and goals and getting them to act towards those goals.

- **Attracting key companies and partners to the site** – when specific company needs and inputs or outputs have been identified on the site, it is the role of the site manager to identify and attract the relevant companies to relocate to the site, or provide incentives for surrounding companies to join the organization. Attracting companies that are already frontrunners in C2C implementation would also help establish the site's reputation as a C2C-inspired site and inspire other companies to follow their steps.

- **Marketing and promotion** – It is also the role of the site manager to market and promote to the outside world regarding the intentions, benefits and advantages of the site, be it to governmental actors, potential workers, companies and neighboring communities.

7 BENEFITS AND OPPORTUNITIES OF C2C FOR BUSINESS SITES

The main distinctions between business sites and isolated buildings or companies are:

- their access to spatial resources
- the availability of a diverse ecosystem of companies and industries in the area
- the long term time frame of the development process.

As such, business sites are uniquely positioned to take advantage of economies of scale to leverage environmental, social and economic benefits.

This puts the implementation of C2C in an area development in a different perspective as it allows for continuous learning and improvement from one development stage to the next, as well as the development of long term collaborations with suppliers and businesses on the site.

Spatial Resources

The scale of a business site allows the developer to plan common site facilities and integrated systems like heating, cooling and water treatment, increasing the integration between those systems over time and boosting synergies between complimentary functions. Examples include ecological water treatment systems that provide habitat for local species, the use of building integrated solar panels that double as shading systems, a shared heating system for the whole site, or a smart grid installation that balances the supply and demand of energy on the site.

Providing technical systems like ventilation, heating and cooling systems commonly for the whole site also removes the need for a technical room in each building, maximizing its lettable floor area. Providing common facilities and services also improves the attractiveness of the site for companies that might not otherwise have access to those services.

Diversity of Stakeholders

Implementing C2C inspired material management practices can bring about mounting benefits for all kinds of stakeholders involved or affected by the business site. Healthier materials improve worker health and productivity, the value of materials and buildings at the end of their life, and the environmental quality for local community and ecosystems. Additionally, multi-functional, modular and easier to disassemble buildings provide added flexibility to site developers to adapt existing buildings for a variety of needs and clients.
Business sites provide increased opportunities for collaboration between different companies which can generate new business opportunities. Additionally, a diversity of companies and industries on a site increases the chance for the availability of outputs of materials and energy that can be used as a secondary raw material for other companies. A diversity of companies on the site also increases its resilience, thus making the management organization less dependent on any single company.

Collective site management organizations and site developers representing the businesses on the site can additionally gain increased negotiation power for C2C purchasing, utility and service contracts, suppliers, etc. which can be leveraged for better prices and increased environmental quality at the same cost. Ecoparc Windhof used its negotiation power to purchase C2C certified carpet for its offices at a lower price than regular flooring options.

C2C inspired business sites can thus provide additional value added functions for its stakeholders and occupiers and increased their level of service quality, which in turn allows them to generate revenues on a per-square-meter basis. The additional benefits like lower service costs, increased productivity and the marketing value of a “green” business site or building still make it a good investment for the tenants.

Timeframe

The long term time frame of a business site, where buildings are developed in stages, sold or rented and occupied by successive tenants allows the developers to learn from one development stage to the next and implement continuous improvement from one building to the next. This long term perspective also allows the developer to plan for future expansion and plan the site’s systems for the needs of its future users.

Further reading

A more comprehensive list of added values from C2C developments can be found the publications “Guide to Cradle to Cradle® Inspired Business Sites” (part of the C2C BIZZ project) and “Creating Buildings with Positive Impacts. Using C2C-Inspired Quality and Value for the Circular Economy”(Mulhall, Hansen, Braungert 2014).

8 OVERCOMING CHALLENGES

Despite the many opportunities for achieving meaningful benefits for its members, workers, local community and the environment, managing materials on a business site is not without its challenges. Some common challenges that businesses sites might face are described below, along with possible solutions to address them.

- **Communication and stakeholder engagement** – As we observed from our work with Ecoparc Windhof, communication is a crucial aspect and can often pose a significant challenge.

> **Possible Solution:** The engagement of all stakeholders in the process is a key issue, including actors that are typically not considered such as renters, employees, consumers, visitors, service providers, suppliers, and other "material" agents along the chain.

- **Employee engagement** is another common challenge. A frequently mentioned issue is the lack of employee participation in a company's environmental efforts like recycling and energy saving. However, the reasons behind their behavior are often overlooked. Employees can do as much source separation as they want in their offices, but their efforts will be lost if the cleaning service then throws all waste into a single bin. Or maybe the recycling bin is too small or too far away to be convenient.

> **Possible Solution:** The reasons behind company and employee behaviors should therefore be analyzed, in order to find the right solutions that will motivate participation. Maybe the solution is to provide additional bins, or to involve the cleaning service in material separation.

- **Data collection** can pose its own challenge and can sometimes involve significant efforts, as observed in our pilot sites. Companies on the same site can have different service providers, different units of measurement, different understandings of the same terms, different arrangements for their waste collection, etc. Not all the data might be available or it may not in the same format. Or requests for data might go unanswered by short-staffed companies.

Possible Solution: A proactive approach to data collection is then needed, with personal site visits needed and a designated coordinator to compile and analyze the collected information. Often, unit conversions, rules of thumb and averages need to be used to make the data comparable.

However, it is important to consider what the data will be used for. Is it necessary to get detailed information from each company or will an average or rough estimation do? That way, efforts can be optimized to achieve the best returns.

- **Attracting the right companies** can also pose a challenge. Possibilities for material exchange are strongly dependent on the companies that are present on the site. If realizing a material exchange loop is only possible if a particular type of company relocates to the site, then the right incentives should be provided for such companies to join the site. Additionally, companies might be reluctant to depend on any one company for their raw material needs; if that company happens to go out of business then they need to find an alternative source for those materials which might have a disruptive effect on their production.

Possible solutions: So the best solution might be to look for synergies that can be created with the companies that are present on the site, as an added bonus, rather than create a co-dependent business model.

However, the opportunities for spin off companies making use of materials residues should not be overlooked, and the space and opportunity for innovative approaches and alternative business models creating added value products from the material streams available on the site should be encouraged.

- **Organizational aspects**, whether administrative, financial or legal aspects can also create additional burdens. If the site management organization is voluntary and dependent on paid membership, the added values need to be very strong to persuade companies on the site to join the partnership and contribute financially and labor-wise. Organizational and logistical aspects also need to be worked out and agreed upon by companies, suppliers, partners, site management and so on. This means agreeing on responsibilities and specifics on how and where materials will be stored, how the transport and processing should be organized, how to fairly split any eventual costs or benefits between the relevant parties, etc.

Possible Solution: Setting down commitments and agreements between the site management, building owners and tenants in documents like a charter, development framework or a memorandum of understanding can be helpful.

Templates and examples of such documents can be found in the C2C BIZZ project deliverables.

- **Legal and zoning restrictions** might also come into play for the types of uses and activities allowed on the site. Legal restrictions apply to what can be done with materials once they are classified as “waste” on the site, potentially limiting re-use and recycling options. Zoning restrictions might impede potential alternative or mixed uses for the site, for example, construction on agricultural land, application of biological nutrients on site, agricultural use of the business site, land availability, among others.

Possible solutions: Applicable restrictions need to be researched before planning a site. Bringing the relevant administrations on board with the C2C intentions and benefits of the site can, however, result in a negotiated agreement advantageous for all parties.

9 CONCLUSIONS

Cradle to Cradle material management is essentially about creating additional value by improving the quality and uses of materials on the site as well as developing new business models and revenue streams from the recovery and valorization of those materials.

The unique conditions found in business sites provide extensive opportunities to implement different approaches to circular material management. The availability of a diverse ecosystem of companies and industries in the area lends itself to the development of long term collaborations among different businesses as well as different actors in their supply chain that can lead to new business opportunities. The long term time frame of the development process allows for continuous learning and improvement from one development stage to the next.

At each stage of the site development, different strategies can be applied to maximize the value of materials associated with different processes on the site – buildings and construction, manufacturing activities and service related sectors including logistics.

In order to enable materials to circulate indefinitely in the technical material cycle, the design stage of the building, product or process is very important to consider. Material selection and product design heavily influences the material health and recyclability properties of the final product or building. Further, the construction or manufacturing processes also need to be adapted so that the end result can be easily disassembled and reused, remanufactured or recycled. Multi-functional, modular and easier to disassemble buildings also provide added flexibility to site developers to adapt existing buildings for a variety of needs and clients.

Collective site management brings increased negotiation power for more favorable terms in for common contracts and services, resulting in better prices and increased service and environmental quality. The high material volumes available on the site make increased material separation and collection economically viable, improving the quality of recycled materials resulting from the business site. Additionally, a diversity of companies and industries on a site increases the chance for the availability of outputs of materials and energy that can be used as a secondary raw material for other companies.

The availability of logistic and distribution companies on a site can also lead to fruitful partnerships that enable companies to organize the collection, reuse, disassembly, remanufacturing or recycling of their products. Implementing innovative circular business models that let the producer retain the ownership and value of their products and develop new revenue streams based on secondary materials is another option.

Biological nutrients are also abundantly present on a business site and should be managed holistically. Different management strategies are suitable for different purposes like soil enhancement (composting), energy production (biodigestion), food production, air or water purification (through green roofs and helophyte filters). Used in complementarity, they can maximize the value they create for occupants and stakeholders.

The park management organization serves an important function in the circular management of materials on business sites in the identification of innovation opportunities and putting the right companies in contact to stimulate new partnerships and business opportunities.

In conclusion, integrating C2C inspired material management practices can bring about holistic benefits for all kinds of stakeholders involved or affected by the business site. Healthier materials improve worker health and productivity, the value of materials and buildings at the end of their life, and the environmental quality for local community and ecosystems. Additional value added services for stakeholders and occupiers increases the occupancy and profitability of the site and creates additional benefits like lower service costs, increased productivity and marketing value of a “green” business site or building that make it a good investment for the tenants.

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