C2C NETWORK

PERSPECTIVE STUDY: BUILD THEME

European Union
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INTERREG IVC
INNOVATION & ENVIRONMENT
REGIONS OF EUROPE SHARING SOLUTIONS

Colophon

This perspective study will serve as frame of reference for follow-up activities and exchanges both within and outside the Cradle to Cradle Network (C2CN) and it aims to reflect the current challenges and opportunities associated with implementing a Cradle to Cradle approach. In total, four perspective studies have been written, in the areas on industry, area spatial development, governance and on the build theme.

These studies are not formal academic literature reviews, but are written from a practical point of view and offer some general understanding and guidelines for those engaged in C2C initiatives, as well as policy-makers. They aim to consider 'on the ground' delivery of the C2C philosophy and reflect on both theory and practice. While the perspective studies focus on applications in one thematic area, a separate document – Theoretical Framework – provides more detailed information on the principles of the Cradle to Cradle concept and its implications at a theoretical level. The framework helps to develop a common language for the Network and underpins the perspective studies and the ongoing work of the C2CN.

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Under the Authority of Suffolk County Council and supervised by Michael Gray, Project Manager, Cradle to Cradle Network

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Summary

This perspective study provides an introduction to the Cradle to Cradle (C2C) concept, summarising the content of the Theoretical Framework established by the Cradle to Cradle Network (C2CN). It further addresses the application of the C2C philosophy, and its interpretation through the Limburg Principles and other frameworks, to the area of 'Build' (building design and construction). It identifies how C2C thinking can be applied to different elements of the built environment.

This study is intended to serve as a frame of reference for future activities by the C2CN. Its purpose is to build on current knowledge, guidance and good practice to enable better exchanges of information within and outside the Network. It will encourage the wider uptake of the Cradle to Cradle approach in the built environment and in other sectors locally, regionally, nationally and internationally. It serves to investigate how the theory and aspiration reflected in the C2C principles of Braungart and McDonough can be applied beyond the field of product design, and be delivered in more complex fields.

We use the BREEAM[1] framework as a start-point for the assessment. By drawing on this tool we consider the constituent parts of buildings, but go wider than considering buildings in the context of waste minimisation and materials management. Instead, we demonstrate a range of ways in which current development can enable transition to a more sustainable future; where sustainability and innovation are mutually beneficial and where development has a positive benefit for stakeholders.

We demonstrate how C2C elements can and are being applied to buildings at the conception, design and construction stages by drawing on good practice examples. We discuss how these examples might guide design and delivery through a transitional period necessary to achieve the ambitions explored by the Network. These examples come from across Europe and both from within and outside the formal Network and their wider partners and collaborators

These good practices are not intended as examples of C2C buildings. A true C2C building does not yet exist, and it remains questionable whether it is even achievable with current systems, approaches, technologies and society. They are instead intended to represent buildings where high ambitions were established at the commission and design stages. Combined with a focus on linkages and networks, and a desire to go far beyond simple compliance or impact minimisation, this has resulted in buildings which have, in some areas, gone beyond 'less bad' and are on their way to being 'good'.

Since Cradle to Cradle is more of a business concept, an approach, or a set of principles to be achieved by a project. It is central to the Cradle to Cradle approach that there is no one solution or set of solutions and a range of approaches and techniques will be combined through this period. It is inherent that the 'correct' approach is shaped by the opportunities and challenges specific to a building and its 'metabolisms' (energy, water, people and material flows).

We identify a number of challenges, including technological and financial barriers, to adopting the C2C approach today. We conclude that the delivery of the Cradle to Cradle principles in buildings requires an extremely high level of ambition and holistic considerations which go significantly further than general current practice. The holistic nature of the approach also means that it cannot be achieved immediately, or in isolation. Rather it will be the culmination of a long period of transition. However, through encouraging and promoting ambition, and looking widely to identify benefits which might be achieved by buildings, it could be possible to drive the changes in wider society necessary to achieve an eco-effective future.

1 The Buildings Research Establishment Environmental Assessment Method

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1 Introduction

1.1 Overall objective of C2C Network

The C2C Network (the Network) is an EU capitalisation network funded under the Interreg IVC programme. The overall objective of the Network is to develop regional action plans which reflect the principles of the Cradle to Cradle concept to enable application at regional level, setting out how good practice, identified by the Network, can be reflected and implemented within regional mainstream Structural Funds Programmes.

Within the overall more strategic objective, the C2C Network project is focussed on the following short term sub objectives or operational objectives:

- To create an enduring network of regions related to Cradle to Cradle;
- To promote regional stakeholder involvement; and
- To disseminate and communicate to wider EU audiences outside the partnership (through awareness-raising) and into the European Commission (by developing policy recommendations) on approved methods for the application of the Cradle to Cradle philosophy to a range of sectors.

Its stated aims are to reduce raw materials' utilisation, generate less waste and less environmental pollution and enhance innovation and economic development. Although the Network agrees that 'no waste' rather than 'less' is the best form of waste management the Network takes a pragmatic and overarching view of the C2C principles. This acknowledges that there will be a period of transition due to existing governance and production structures. Through these activities, and the wider uptake of C2C principles, the intention is that positive changes to society can be encouraged to the benefit of all.

1.2 The role of the perspective study

Within these overall objectives, the initial activities within the Network are focussed on:

- Investigating, and challenging, the application of Cradle to Cradle to areas beyond product design (an area which has received the greatest focus to date).
- Developing four perspective studies. This study addresses the Build theme, and parallel documents are being produced to investigate the application of the C2C philosophy in three other perspective areas:
  - industry;
  - area spatial development; and
  - governance.

These are complex areas and present a significant challenge to the actual delivery of the C2C principles. However they do represent real-world challenges to the implementation of this holistic concept at the societal scale. This document and the other perspective studies assess this challenge, and in doing so move from discussing the 'pure' theory to acknowledging the constraints imposed by the need to work within current structures and mechanisms. Particularly in the more complex areas of Build and area spatial development, this includes the likely need for an extended period of transition before the eco-effective, Cradle to Cradle future is realised.
These perspective studies will serve as the basis for future C2CN work, and aim to reflect the current challenges and opportunities associated with implementing a Cradle to Cradle approach. The perspective study aims to consider 'on the ground' delivery of the C2C philosophy, and reflect on both theory and practice, rather than describe how C2C compares with other approaches in the broad area of sustainability.

While the perspective studies focus on applications in one thematic area, a separate document (the Theoretical Framework) provides more detailed information on the principles of the Cradle to Cradle concept and its implications at a theoretical level. The first chapter of this perspective study summarises that Theoretical Framework. The framework helps to develop a common language for the Network and underpins this perspective study, and the ongoing work of the C2CN.
This perspective study then goes on to discuss how Cradle to Cradle would look in the built environment, and illustrates this with a discussion of a number of good practices identified by the Network.

1.3 Identifying, and encouraging, current good practice

This perspective study briefly presents a number of good practices drawn from across C2CN partner regions. These illustrate the current 'state of play' as regards the delivery of high sustainability projects, discussing them in the context of C2C (and specifically the Cradle to Cradle and Limburg Principles).

These good practices have been proposed by members of the C2CN, and from organisations and individuals within their developing regional networks, and represent international projects from within and outside the C2CN. Whilst they are not necessarily held to be the best practices overall, they nonetheless are felt to represent some individual or combined elements which could be drawn together, incrementally, through the transition period mentioned above, and be constituent parts of a C2C building.

Current good practice in delivering the C2C approach is also demonstrated in another C2CN publication (the Good Practice handbook), which identifies current practices which reflect C2C principles, or the Limburg principles (introduced below) in the four thematic areas being considered.

1.4 The perspective study in the wider C2CN project

The developing perspective study provided a basis for, and has subsequently been informed by, a thematic seminar which considered the application of C2C approaches to building design and construction.
This international conference, held in Cambridge in mid-September 2010, brought together partners from across the East of England and Europe to consider how to apply the highest levels of sustainability in building design. Over seventy attendees representing the Network partners and their own networks came together to discuss the model, and to hear about current and planned examples which challenge current 'best practice'. Visits to several good practices presented in this document also informed these discussions about the application of Cradle to Cradle principles in the context of the Build theme.
Outputs from the various presentations, workshops and discussions at the conference have shaped the discussion presented later in this document, and will help to further refine the C2CN approach, and the role and ambitions of the Network.

2 A theoretical framework for the C2C Network

2.1 Cradle to Cradle framework

The main objective of a theoretical Cradle to Cradle framework is to develop a common language for the Network and an understanding between its partners and other interested parties. The framework sets a basis for the Network's activities through the rest of the project. The Theoretical Framework, available as a separate document but summarised here, presents Cradle to Cradle in general, and considers:

- What is Cradle to Cradle in concept, principle and application?
- How Cradle to Cradle is 'defined' within the Network?

The framework is not intended to be exclusive, but instead looks to identify those characteristics of projects and approaches which deliver eco-effective solutions (beneficial for humans and the environment). However, the framework does not, and is not intended to, develop a tool for formally evaluating 'Cradle to Cradle-ness' – there is no link to the Cradle to Cradle certification system.

2.2 What is Cradle to Cradle?

Although expanded on below, it is useful at this stage to initially consider what Cradle to Cradle is. Although considered by some to be a waste minimisation or management approach, the underlying philosophy is holistic. Rather than a concept solely akin to 'zero waste' it is presented by its 'creators' as a radical, innovative framework which seeks to focus innovation in projects and beyond, concentrating on beneficial solutions and footprints which contribute positively to all stakeholders and all aspects of the outside world. Within this, its well-known reconsideration of waste materials as resources is only one part. Over time, adoption of the C2C approach would create a transition to a healthy and safe society, using only reusable materials, whilst at the same time maintaining or improving quality for all stakeholders.

Rather than considering elements of the world – and in particular equity (society), the environment and the economy (people, planet, profit) – separately, C2C, and its application in the four thematic areas considered by the C2CN, requires a systems approach. Rather than concentrating on single issues, either costs or benefits, the C2C approach encourages and even requires a focus on the connections, relationships and inter-dependencies between otherwise separate issues. In this way factors such as materials and energy must be considered alongside issues such as logistics and social factors. Before going to the core characteristics of Cradle to Cradle, it is valuable to take a broader look at where the concept fits in terms of evolving global societies.

2.3 From efficiency to effectiveness

Increasing industrialisation has brought greater prosperity, certainly in the West, but for many years there has been a recognition that this has come at a price. This 'price' includes the increasing exhaustion of natural resources and social exploitation, as well as developing a way of thinking which considers what level of harm, damage or cost is considered 'acceptable'. These and other such costs would be among those which would need to be considered within any holistic discussion on Gross Well-being Product (as differentiated from the financial considerations represented by Gross Domestic Product) (eg Stiglitz et al., 2008).
Initially responses to this recognition were 'defensive', leading to approaches which looked to minimise harm and develop and enforce legislation. Over time these have developed into more positive collaborative actions (where wider management approaches have looked at implementing preventative measures, avoiding harm). A yet more proactive, holistic approach (represented by concepts and tools such as product accountability, life cycle analysis, and increasing 'eco-efficiency') is still developing.
Even then, such eco-efficiency strategies focus on the reduction of negative environmental impacts made by human activity, without there being a reduction in (socio-) economic value. This thinking, which has long been incorporated into Western economic thought, is challenged by Braungart and McDonough, the proposers of the Cradle to Cradle concept.

2.4 An alternative way of thinking

According to Braungart and McDonough, the eco-efficiency approach stands in the way of a fundamental redesign of industrial material flows, and wider society. Although eco-efficiency techniques can lead to a reduction of negative effects, they do not encourage real alternatives to the embedded and linear "cradle to grave" flow of materials.

For instance, although through adoption of the eco-efficiency model many materials can be recycled, they are usually reused in lower-value applications ('downcycling') because they are combined with, and cannot easily be separated from, less valuable materials. As the valuable materials are difficult to separate out at the end of a product's useful life span, materials are gradually dumped or incinerated (with or without energy recovery).

The concept of eco-effectiveness is a response to the negative effects of the efficiency approach (known as "doing more with less").

"Our goal is a delightfully diverse, safe, healthy and just world, with clean air, water, soil and power – economically, equitably, ecologically and elegantly enjoyed."

EPEA, 2005

This transition, from eco-efficiency to eco-effectiveness, is represented in Figure 2.1 which shows the evolution over recent decades with respect to sustainable materials management. The principles of eco-effectiveness are introduced now, in the transitional – 'redesigning' – stage. However, they continue on into the future, shaping delivery of the new approach (World 2.0).

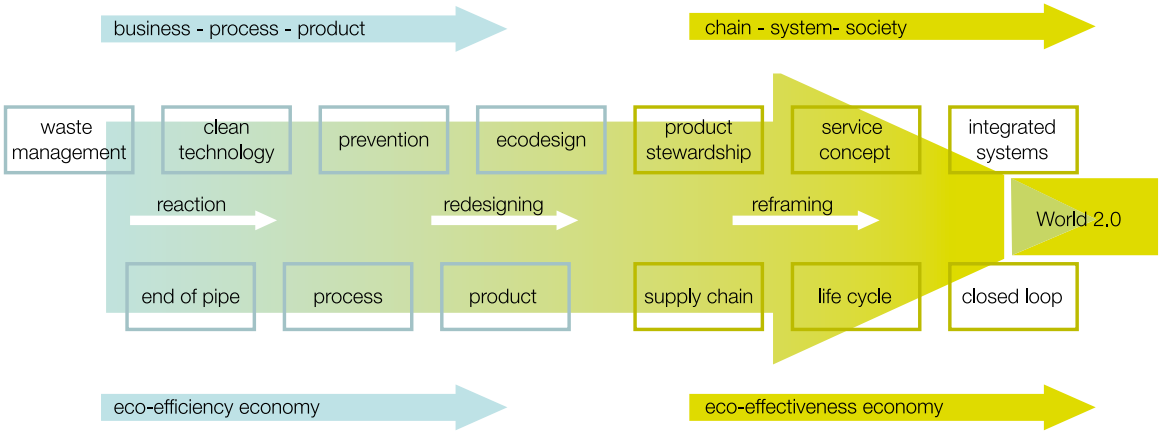

Figure 2.1: Sustainable Materials Management for Europe, from efficiency to effectiveness (source: Sustenuto, KULeuven, Wuppertal Institute, March 2010)

2.5 The eco-effective approach

The holistic approach encouraged by eco-effectiveness provides a broad conceptual framework for solving social and especially environmental issues including the depletion of raw materials, and the production of harmful substances and emissions. While eco-efficiency strategies promote lower consumption, a corresponding reduction in emissions and waste, and an extension of product lifespans, eco-effective measures allow for continued consumption and short life spans. As such it could be considered to be a 'techno-fix' to the current problems, proposing innovation in approach and design as the way to prevent the problems caused by a previous phase of innovation (this industrial revolution). There are clearly potential opportunities for 'freeloaders' – who support the encouraged consumption without this being underpinned by the necessary principles. As such in order to deliver eco-effectiveness the quality of raw materials must be guaranteed and renewable energy must feed the production and consumption. Without this the approach would fail.

Although a key element of eco-effectiveness is providing safe and healthy products, which involves complete substitution of all toxic elements, such substances must still be acceptable for a transitional period if no alternatives are currently available, at least if they are not exposed to man or environment and remain in a closed material system (Braungart and McDonough 2002). Initially the key consideration is that the ambition is to achieve eco-effectiveness, rather than just efficiency. Figure 2.1 acknowledges this period of transition which is likely to be required, over which eco-efficiency (with its reducing negative footprint) is replaced by eco-effectiveness (an increasingly positive footprint).

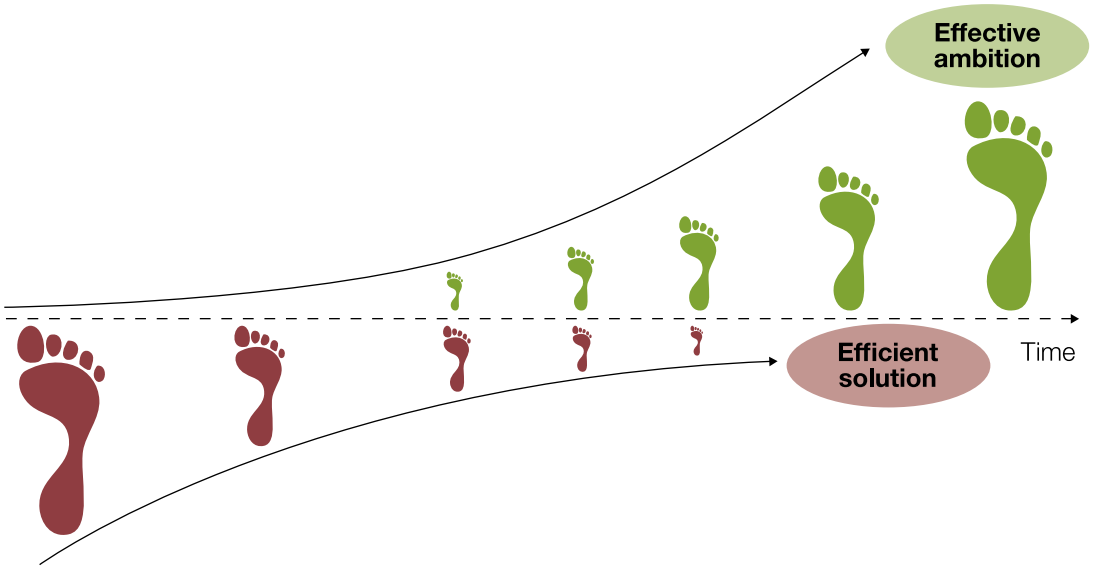

Figure 2.2: The transition from eco-efficiency to eco-effectiveness © Royal Haskoning

Within Cradle to Cradle such a positive approach underpins the design and manufacture of products and services, in which relationships and positive support between economic, ecological and social (business) objectives are strongly promoted. The focus is on doing the right thing, rather than just less of the wrong. Through this, optimising the 'wrong thing' through driving efficiencies is rejected in favour of a re-consideration of what the goals can or should be. In this way, Cradle to Cradle is presented as the next step in the evolution towards an eco-effectiveness based economy, and a framework for delivering World 2.0. However, since this development is pro-active rather than re-active it is clear that the transition from efficiency to effectiveness requires a rethinking and redevelopment of the economic and social system.

2.6 Cradle to Cradle: a framework for eco-effective solutions

When speaking about Cradle to Cradle, the concepts of closing loops, or continual material cycling - closing the material cycle in order that materials are not lost from society but used and reused again – are widely recognised. However Cradle to Cradle is a broader business model, a conceptual framework underpinned by three core principles (section 2.6.2). Its delivery can also be checked by means of a certification system, which is discussed briefly below (section 2.6.4).

2.6.1 Cradle to Cradle Concept

Since 1987 the "Environmental Protection Encouragement Agency" (EPEA), founded by Prof. Michael Braungart, has worked on the development of the framework and principles of Cradle to Cradle. It builds on a desire to reduce and eliminate toxic contaminants which may exist in or result from everyday products around us. The framework has been developed in accordance with nature, where systems have evolved in response to a very diverse set of environments and populations, and where waste is unknown. Together with the architect William McDonough, Michael Braungart further developed the framework which resulted in the book Cradle to Cradle: Remaking the Way We Make Things (Braungart and McDonough 2002). In it they describe how (new) products (but also buildings and areas) can be designed in order to meet eco-effective objectives.

2.6.2 Cradle to Cradle Principles

Three principles are key to any Cradle to Cradle product or development, and these are introduced and briefly discussed below.

- Waste is food: All materials can be used as 'nutrients' for something else. All materials used should be able to be reused within continuous material loops;
- 'Use of current solar income': The use of energy sources that are renewable in the timeframe they are used; and
- 'Celebrate diversity': promoting and combining biological, cultural and conceptual diversity.

Waste equals food

The main trademark of Cradle to Cradle is undoubtedly the "waste = food" concept. It states that everything should exist as either a biological or technological "nutrient" for something else, reused within continuous loops. After the use of products (and services), the embedded materials, water and energy cannot be wasted. Biological materials should ultimately be composted, enabling future growth of biomass, whilst non-biological elements should only be used in such a way that constituent materials can be disassembled and reused in at least as valuable (and preferable more valuable) a form as previously ('so-called 'up-cycling').
A Cradle to Cradle approach would make optimal use of these resources by creating continuous material loops. Whilst in short this is understood as closing the material cycle in practice, much as in nature, materials do not need to come back to the original producer; however it is essential that they are reused. In adopting such an approach, a greater awareness of supply chains is created, enabling mutual benefits to be achieved by creating longer and more complex chains within which materials can be more easily reused, and upcycled, bringing positive economic as well as environmental benefits. A simple illustration of these continuous loops, and the networks they involve, is shown in Figure 2.3 below.

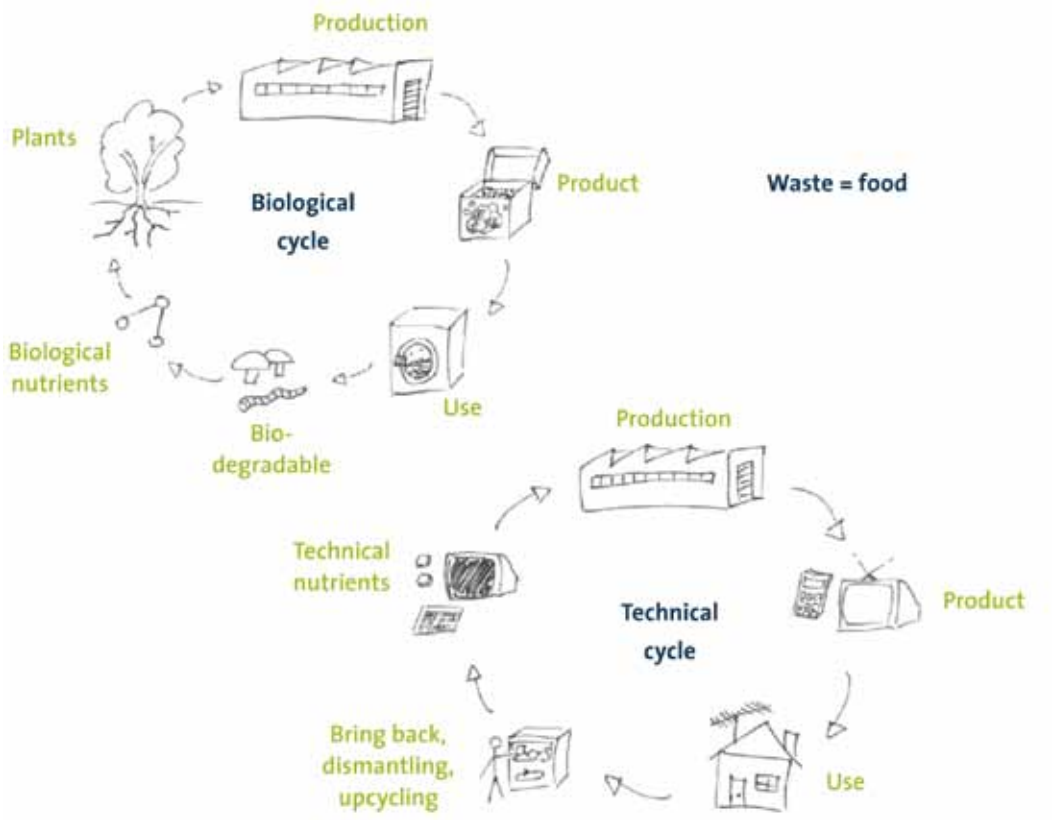

Figure 2.3: Biological (left) and technical (right) loops central to C2C thinking

Use of current solar income

Solar energy is an effectively eternal and abundant energy source. More energy reaches the earth from the sun in one hour than is used in a year – conceptually at least there is far more energy available than humans require. Although the current western paradigm is heavily based on energy derived from fossil fuels, Cradle to Cradle promotes the use of this renewable energy source for heating, electricity and lighting within buildings and for manufacturing processes within industry. In addition to direct use, wind and geothermal energy are also positive effects of solar energy and, whilst there are clearly currently technical challenges to overcome, the ambition is appropriate. The use of all truly renewable energy technologies is an accepted broadening of this second Cradle to Cradle principle. C2C would not consider, for example, recovering energy from waste (EfW) as a renewable energy since, whilst recognising that within current systems it may be a 'better' approach than landfill, it is not 'good'. Following the Cradle to Cradle approach there is no waste, and therefore EfW is not renewable.

Celebrate diversity

Healthy ecosystems are complex networks of living organisms, and diversity in nature builds resilience. Such diversity should serve as a model for human society, and this principle essentially promotes innovation based on adaptation to local conditions. 'Celebrate diversity' encourages bio-, cultural and functional diversity at a range of different scales. It also precludes a 'one-size fits all' approach to current challenges, requiring local solutions which address local challenges, and offer and make the most of local opportunities.

2.6.3 The Limburg Principles

These principles have been interpreted and supplemented with others based on local conditions and interests, leading to the development of the Hannover Principles for the World Expo in 2000, and the Almere and Limburg Principles. Developed by the Province of Limburg government in the Netherlands, lead partner within the C2CN, the Limburg Principles provide the inspiration for the Network. They are:

- We are native to our place;
- Our waste is our food;
- The sun is our income;
- Our air, soil and water are healthy;
- We design enjoyment for all generations; and
- We provide enjoyable mobility for all.

2.6.4 Delivering eco-effective, and Cradle to Cradle, solutions – certification and ambition

Products, processes, buildings, industry business models, spatial areas and other 'applications' can be inspired by the Cradle to Cradle concept and its three basic principles. Since it is an approach, rather than a solution, 'Cradle to Cradle' applications can be considered to be those which result from ambitions and approaches which align with the C2C concept.

Whilst not a consideration for the C2CN, there is a validation methodology which is used to certify that certain products are in line with the concept and principles of Cradle to Cradle. McDonough Braungart Design Chemistry (MBDC) issues certificates if it determines that products have been developed according to the Cradle to Cradle™ Design principles (see www.mbdc.com, 2010). These consider several criteria - material health, material reutilization, renewable energy use, water stewardship, and social responsibility – in assessing products and offer four levels of certification based on reaching required minimum levels. Thus the Basic certificate requires that:

- The product contains no PVC, chloroprene, or related chemical at any concentration;
- All materials and chemicals assessed for toxicity to human and environmental health;
- A strategy has been developed to optimize all remaining problematic chemicals; and
- All materials defined as technical nutrients can be recycled or biological nutrients can be composted.

Silver and Gold certificates are available, and the highest level, Platinum, requires that:

- There is a material reutilisation score of at least 80%;
- Renewable energy is used for 100% of manufacturing (final assembly) and 50% of supply chain manufacturing;
- Innovative measures are implemented to improve water conservation and water quality; and
- That a third party social responsibility certification is completed.

This certification aims to guide product design and manufacturing, but for other applications no Cradle to Cradle validation/certification system exists. With complex projects, such as with buildings, it could be that a strict certification would require only certified constituent parts to be used. However, in many other areas there are single or multi-issue assessment tools which consider 'sustainability' and may overlap with similar requirements to those of the Cradle to Cradle certificates. Several are considered in the following chapters.

The Cradle to Cradle Network project does not intend to develop a criteria-based evaluation tool to determine whether applications are Cradle to Cradle. It considers that C2C is an approach to come to better solutions (and ultimately to good solutions), rather than a scoresheet for compliance. It aims to help understand what the wider implementation of Cradle to Cradle principles could look like in the areas of industry, buildings, governance and spatial area development, and to disseminate and learn from current and emerging good practices.
As such, the Network acknowledges that where there are not yet C2C applications, ambition can be reflected by incorporating C2C elements, adding benefits to existing society and creating a showcase – and highlighting a way forward or a roadmap (see Figure 2.4) - for future projects.

Cradle to Cradle is a process, and understanding the process, and in particular the ambitions and benefits of the key stakeholders, is likely to be key to the delivery of eco-effectiveness. Setting an eco-effective ambition, and then a staged approach towards achieving it wherever possible, choosing eco-efficient alternatives where effectiveness is not currently viable, is central to this approach.

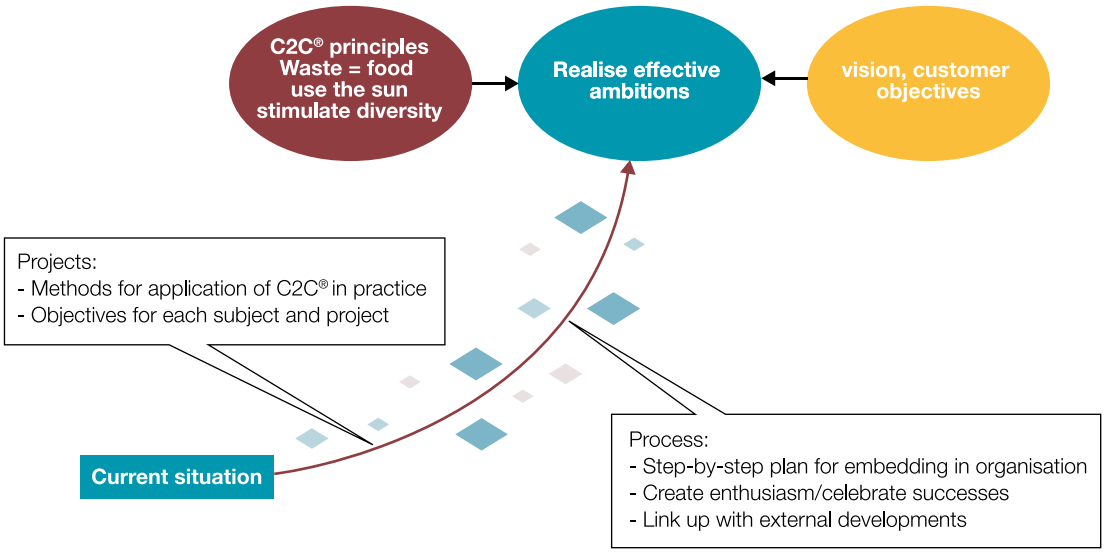

Figure 2.4: A conceptual roadmap towards implementing C2C thinking. ©Royal Haskoning

While this chapter has provided a short insight into the Cradle to Cradle principles and application, the following chapters elaborate on the specific application to the Build theme.

3 Cradle to Cradle and build – theoretical framework

3.1 Introduction

In this chapter a subsidiary theoretical framework is proposed to outline the application of C2C within the 'build' theme. This includes design and construction and considers both new and existing buildings. The application of Cradle to Cradle to this area is considered in relation to other existing principles.

3.2 The challenge

Not only do buildings consist of a multitude of products, and therefore technical and biological nutrients, they also have an important and wide-ranging impact on water and energy cycles, air quality (indoor and outdoor) and fauna and flora, as well as on social and economic factors. Current building activity tends to result in a large and net negative environmental impact, or footprint, including:

- The building and construction industry being responsible for 40% of fossil fuel consumption, one third of greenhouse gas emissions and 40% of raw material consumption worldwide;
- The building and construction sector is estimated to produce up to 40% of our solid waste (UNEP, 2007);
- In 2007 the housing sector was the biggest source of pollution – due to PM2.5, NMVOC, CO, SOx and NOx emissions from household energy use (European Community's air pollutant Emission Inventory Report (EEA, 2009));
- Pollutant concentrations within buildings (mainly stemming from finishes and paints) can be over twice as high – in some cases as much as 100 times as high – as concentrations outside (UNEP, 2003); and
- The loss of fertile land due to infrastructure development.

A fundamental difference between the building and construction sector with other industries is the long lifetime of the product, when compared with consumer products. Structures built in developed countries have an average lifetime of 80 years (UNEP, 2003). Research in the UK suggests that whilst 31% of 2050 building stock is not yet built, and 3.2 million buildings are estimated to be demolished between 2005 and 2050, 85% of the UK's building stock in 1996 will still be standing in 2050 (Boardman et al., 2005).
As a consequence of this many parts are replaced or repaired during use. Existing structures are also often rigid and difficult to adapt to changing circumstances and needs (e.g. to reduce energy consumption and greenhouse gas emissions, or to be resilient to the effects of climate change). Challenges include the need also to maintain and enhance historic buildings for their architectural heritage. From the start, therefore, this suggests that the complete implementation of a C2C approach will require a longer transition period than with, for example, the manufacture of simple products.

3.3 Efficient, or effective buildings

From an eco-efficiency approach 'green buildings' are those where the design seeks to reduce these negative impacts as much as possible, for instance by using less energy, less materials and less water. Whilst the negative footprint is reduced, such efficiency can result in a reduction in 'quality' (for instance because of an increase in cost above 'standard').
From an eco-effective or Cradle to Cradle approach it is not the size of the footprint that matters but the nature of this footprint. As illustrated in Figure 1.2, instead of a negative footprint buildings should be designed to have a positive footprint (eg healthy and productive buildings). Taking a holistic approach means that costs can be reconsidered as benefits realised elsewhere, but this requires a broadening of economic scope as part of C2C thinking. A focus on eco-effectiveness can create the maximum benefits for employees, management, local community, government and clients (added value). This illustrates one of the challenges, and highlights that for buildings, area design and economic development must be a central part of the move from efficiency to effectiveness from the start.
Braungart and McDonough again suggest drawing inspiration from nature, and introduce the concept of "houses like trees" and "cities like forests". Buildings should, just like trees, harvest energy from the sun, remove dust and CO2 from the air, etc. In their book they refer to the cherry tree metaphor:
"As it [the cherry tree] grows, it seeks it own regenerative abundance. But this process is not single-purpose. In fact, the tree's growth sets in motion a number of positive effects. It provides food for animals, insects and micro organisms. It enriches the ecosystem, sequestering carbon, producing oxygen, cleaning air and water, and creating and stabilizing soil. Among its roots and branches and on its leaves, it harbours a diverse array of flora and fauna, all of which depend on it and on one another for the function s and flows that support life. And when the tree dies, its returns to the soil, releasing, as it decomposes, minerals that will fuel healthy new growth in the same place."

An eco-effective or C2C building will therefore be a large source for nutrients, realised sooner or later (as shown in Figure 3.1), instead of a waiting room for materials to become waste.

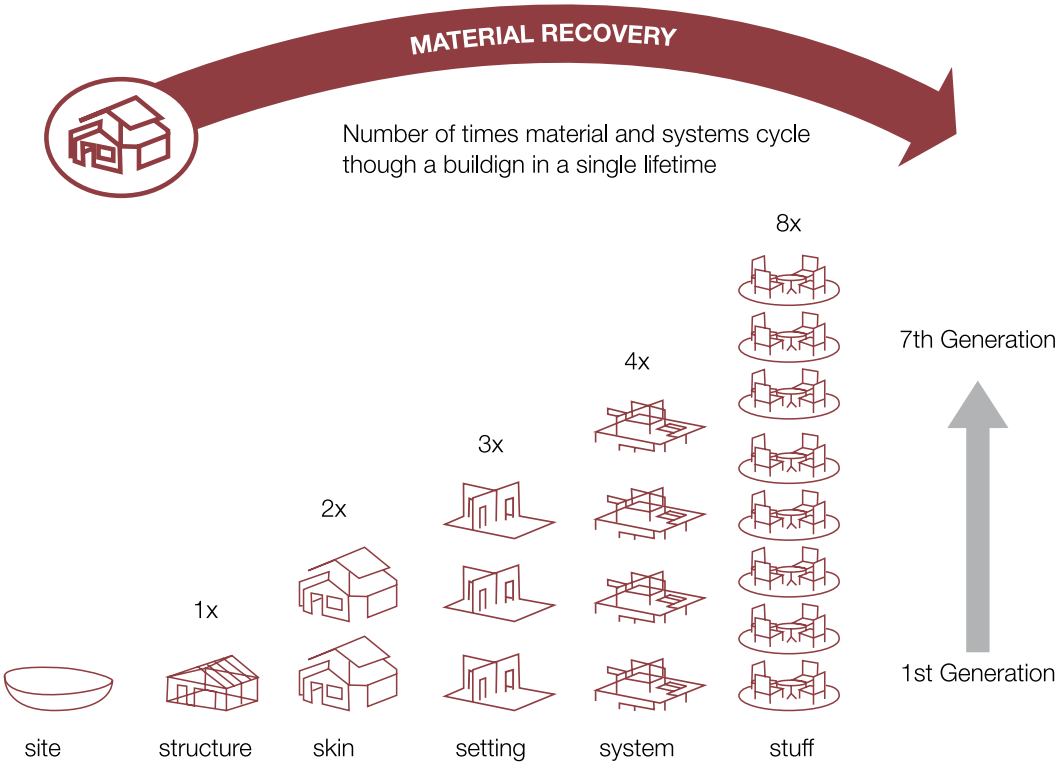

Figure 3.1: The flow of materials through buildings over their use period (Source William McDonough & Partners architects, but borrows from a description in an earlier book by Stewart Brand: How buildings learn: what happens after they're built. Viking, New York, 1994

3.4 Considering Cradle to Cradle principles in buildings

As above, in their book Braungart and McDonough describe how the three C2C core principles (section 2.6.2) can be applied at the level of products and even buildings, and such principles have been applied individually in various buildings for a long time.

As well as the three core principles, other documents have also explored the application of Cradle to Cradle to buildings with the aim of helping building designers to develop eco-effective buildings. The Limburg Principles (the reference principles for the C2C Network), the "Cradle to Cradle in architecture" manifesto and the Cradle to Cradle building charter signed by Braungart and McDonough are discussed below.

3.4.1 The Limburg Principles and building design

Since 2008 the Province of Limburg has expressed the ambition that buildings in the Province should be designed with respect for the needs and health of the people who live and work in it and with respect for the surroundings and the environment.
This is stated in the 'Policy Framework on Sustainable Development 2008-2011' which is inspired by the Cradle to Cradle concept. In it the Province combines the eco-effective Cradle to Cradle way of thinking (doing the right things) with eco-efficient use of resources and energy. These are included in recognition that a transition period is necessary before Cradle to Cradle can truly be realised in different areas such as energy production, resource management and building techniques.
The framework introduces the six Limburg Principles (presented in section 2.6.3), which are Cradle to Cradle based but also consider other aspects relating to the regional scale of their scope. The Province of Limburg therefore promotes the added value of using natural and healthy materials, sustainable energy sources and ensuring that a project is integrated into surrounding ecosystems at the design phase.

3.4.2 C2C in Architecture manifesto

In 2009 an international group of architects published the manifesto "C2C in Architecture" which identifies distinct and measurable characteristics or 'milestones', applicable at the design stage, that they suggest define a C2C built environment. These are set against the 'three Es' of sustainability (equity-ecology-economy (people, planet, profit)) and subdivided into categories similar to BREEAM and other models introduced below. They are shown in Table 3.1.

Table 3.1 C2C principles translated into milestones in relation to ecology (materials, energy and site), economy and equity/society

Ecology

Materials

- Eliminate waste: only use materials that will become resources for further biological or technical production loop.
- Only use materials whose impacts are measurably beneficial for human health and environment.
- Design buildings free of radioactive, hazardous and toxic off-gassing materials.
- If hazardous materials are necessary, they are not released in the environment and are completely recoverable in technical pathways.

Energy

- Use only energy from present solar income.

Site

- Create topsoil, clean water and clean air and improve biodiversity as a result of human intervention.

Economy

- Design buildings that can be mined for materials in the future. If waste is a resource, materials become the new currency.
- Promote building products leasing and by doing so make producers responsible for them.

Equity | Society

- Create a diverse environment of equal opportunity. Create a healthy, safe and inspiring environment.

3.4.3 Cradle to Cradle building charter

Following the C2C in Architecture manifesto, a further group of C2C practitioners coordinated by Braungart and McDonough prepared the Cradle to Cradle building charter (http://c2carchitecture.org). The charter describes guiding principles for buildings as well as 'innovation concepts' that a design team should actively use and specific intentions or goals for building and sites to strive for. As such they set ambition and encourage new ways of thinking which could focus a move away from existing structures and processes and enable the innovation which will be required to deliver Cradle to Cradle. These are all set out below.

Guiding principles

Cradle to Cradle buildings will:

- Incorporate materials that are technical and biological nutrients that can become safely reusable nutrients;
- Measurably use renewable energy. Examples of renewable energy include solar thermal, ground based and air-based heat exchange, wind, biomass, hydro and, photo-voltaic);
- Actively and measurably support biodiversity according to well-established biological tools for measuring species diversity; and
- Anticipate evolution and change, incorporating strategies and approaches that enhance the ability for the building to adapt to a variety of uses over time.

3 A number of these 'concepts' touch upon similar areas.

Innovation concepts

In applying these, design teams are encouraged to:
- Think of how to create beneficial impacts instead of how to be less bad;
- Think of how to have a big healthy footprint instead of a less bad minimized one;
- Think about eco-effectiveness instead of just eco-efficiency[3];
- Improve quality of building systems, products and processes in measurable steps;
- Partner with customers & suppliers to establish material partnership communities;
- Think "materials opportunity" instead of "energy problem";
- Design building systems and processes according to their intended use for building occupants and for biological and technical metabolisms;
- Improve indoor air quality so it contributes healthy air to the building occupants, and to the outdoors; and
- Design building areas and processes that are energy positive.

Cradle to Cradle intentions and goals for buildings and sites

Overall, building projects should aim to achieve the following goals:
- Using building materials whose contents are measurably defined in Cradle to Cradle terms of chemical contents, effects on air, soil and water, and effects on human health from manufacturing through use and recovery in biological or technical pathways;
- Integrating topsoil production and carbon re-use into structures and landscapes to produce more biomass and soil than before development. Topsoil is a main repository for carbon and for CO2 capture and storage. (Example: green roofs);
- Integrating renewable energy into buildings and area plans so that they produce more energy than they use;
- Integrating healthy air production into buildings and area plans so that they produce more healthy air than they use;
- Integrating measurable recycling of water and biological nutrients in buildings, landscaping, and spatial plans;
- Supporting measurable increases in species diversity (flora and fauna) according to accepted biological methods, so the area contains more diversity than before development of the building or site; and
- Achieving Social Fairness: define, quantify and practice social responsibility criteria. Adopt and make publicly available statements regarding social performance goals and demonstrate it through third party accreditation.

Elements of these principles and intentions overlap with the assessment criteria for C2C certification. In particular they focus on measurable enhancements – positive footprints – with respect to a range of assessment areas (eg energy, water, air quality).

3.4.4 Cradle to Cradle® criteria for the built environment

In October 2010 a further publication on the translation of the core C2C principles into measureable criteria for the built environment was produced. Michael Braungart and his colleague Douglas Mulhall (representing the Cradle to Cradle chair at Erasmus University in The Netherlands), produced this sequel to the Cradle to Cradle building charter which describes the guiding principles and other criteria in more detail. This booklet gives an insight in how the C2C concept could be applied to the built environment including principal criteria, implementation criteria and ways to measure intentions, milestones and roadmaps. It aims to provide planners with a basis for developing buildings with measurable C2C features, and also provides the following broad definition as their ambition for a Cradle to Cradle building:

A C2C building contains defined elements that add value and celebrate innovation and enjoyment by: measurably enhancing the quality of materials, biodiversity, air and water; using current solar income; being deconstructable and recyclable and performing diverse practical and life-enhancing functions for its stakeholders.

Within the context of this perspective study, and the C2CN project, whilst such a definition maintains a focus on the broad principles and ambitions the Network is driven by investigating the challenges and opportunities presented in delivery. As such the Network is not focussing on specifics, but rather on applications and potential blockers and enablers. This assessment is also informed by the comparison of C2C approaches with more established ambitions and tools within the field of sustainable buildings.

3.5 Cradle to Cradle compared with other concepts introducing and assessing sustainability in building design

3.5.1 Measuring 'sustainability' in the built environment

Since the 1990s, environmental assessment methods and accreditation systems for buildings have existed. These largely build on the established Buildings Research Establishment Environmental Assessment Methodology (BREEAM) from the UK, and include LEED (US), HQE (France), Green Star (Australia) and DGNB (Germany), as well as wider adoption, for instance, through BREEAM NL in the Netherlands. They have become applicable to a wider range of building types. For instance, under BREEAM there are specific assessments applicable to Retail, Offices, Education, Prisons, Courts, Healthcare, Industrial, and multi-residential, as well as a Bespoke method for specialised buildings. Similar schemes also exist for civil engineering, where CEEQUAL is used to assess the 'sustainability' of large industrial installations and public realm, among other, developments. The Code for Sustainable Homes, a development of the BREEAM Ecohomes standard, is now used as a basis for future amendments to elements of the UK buildings regulations.
These accreditation systems are comprised of sets of criteria, some mandatory, some voluntary or tradable, grouped into categories such as energy use, water, materials, waste, transport, land use and ecology. According to the overall score, the building under assessment is awarded an appropriate certificate (from pass to outstanding under the UK BREEAM system). Such systems are considered to have played a role in moving the market towards more sustainable building practices. However Cradle to Cradle or eco-effectiveness advocates such as the architect Thomas Rau have demonstrated that a building conceived according to Cradle to Cradle principles does not necessarily obtain a high score when being assessed under either BREEAM or LEED.
However these schemes have evolved over time, and will continue to do so, becoming more strict and introducing different considerations and weightings in line with the uptake of sustainability measures in building practices (as exemplified by the BREEAM 2008 update). Cooperation between the US GBC (LEED) and Braungart and McDonough on C2C building materials has already taken place. The U.S. Green Building Council (USGBC) announced in May 2007 that projects seeking certification under the LEED® Green Building Rating SystemT can now earn an "Innovation in Design" point by using the Cradle to Cradle program for certified building products. Innovation in Design points are awarded to LEED projects that develop new solutions, employ new technologies, educate, or realise exemplary performance in another area. There is also an interest by the Dutch Green Building Council to collaborate and incorporate C2C into their BREEAM-based systems (BREEAM-NL).

3.5.2 Advanced sustainability in the built environment

Several separate initiatives have developed which attempt, in a similar way to C2C, to conceive the most advanced measure of sustainability in the built environment. Two such schemes are discussed below.

One Planet Communities initiative

The WWF's One Planet Living initiative, and the related One Planet Communities initiative, attempts to limit the per capita ecological footprint of building occupants/residents to the "Earthshare", i.e. the available worldwide per capita 'bio-capacity'. Although still largely addressing the eco-efficiency approach to sustainability, the 10 One Planet criteria and principles are:

- **Zero carbon:** making buildings more energy efficient and delivering all energy with renewable technologies;
- **Zero waste:** reducing waste, reusing where possible, and ultimately sending zero waste to landfill;
- **Sustainable transport:** encouraging low carbon modes of transport to reduce emissions, reducing the need to travel;
- **Sustainable materials:** using sustainable healthy products, with low embodied energy, sourced locally, made from renewable or waste resources;
- **Local and sustainable food:** choosing low impact, local, seasonal and organic diets and reducing food waste;
- **Sustainable water:** using water more efficiently in buildings and in the products we buy; tackling local flooding and water course pollution;
- **Land use and wildlife:** protecting and restoring biodiversity and natural habitats through appropriate land use and integration into the built environment;
- **Culture and heritage:** reviving local identity and wisdom; supporting and participating in the arts;
- **Equity and local economy:** creating bioregional economies that support fair employment, inclusive communities and international fair trade; and
- **Health and happiness:** encouraging active, sociable, meaningful lives to promote good health and well being.

Living Building Challenge

In contrast to BREEAM and similar schemes this system, launched in 2006, has only mandatory criteria4. Developments, whether renovation or newbuild, landscape or infrastructure, buildings or neighbourhoods, are also only certified based on actual, rather than modelled or anticipated performance[4]. This avoids a situation previously possible where, for reasons relating to either delivery or occupation, a building which was highly sustainable on paper failed to live up to its ambitions. The 20 'imperatives' are:

- Projects may only be built on previously developed (brownfield) sites;
- All projects must integrate opportunities for agriculture;
- For each hectare of development, an equal amount of land must be set-aside as part of a habitat exchange;
- Each new project should contribute towards the creation of walkable, pedestrian-oriented communities;
- One hundred percent of occupants' water use must come from captured precipitation or closed loop water systems;
- One hundred percent of storm water and building water discharge must be managed onsite or on adjacent sites;
- One hundred percent of the project's energy needs must be supplied by on-site renewable energy on a net annual basis'
- Every space which can be occupied must have operable windows that provide access to fresh air and daylight;
- Projects must meet certain criteria to ensure good indoor air quality;
- The project must be designed to include elements that nurture the innate human attraction to natural systems and processes;
- The project cannot contain any of the materials or chemicals on the Living Building Challenge Red List;
- The project must account for the total footprint of embodied carbon (tCO2e) from its construction and projected replacement parts through a one-time carbon offset tied to the project boundary;
- The project must advocate for the creation and adoption of third-party certified standards for sustainable resource extraction and fair labour practices;
- Source locations for materials and services must adhere to certain restrictions to limit transportation distances to the building site;
- All project teams must strive to reduce or eliminate the production of waste during design, construction, operation, and end of life in order to conserve natural resources;
- The project must be designed to create human-scaled rather than automobile-scaled places, so that the experience brings out the best in humanity and promotes culture and interaction;
- All primary transportation, roads and non-building infrastructure that are considered externally focused must be equally accessible to all members of the public regardless of background, age and socioeconomic class;
- The project may not block access to, nor diminish the quality of, fresh air, sunlight and natural waterways for any member of society or adjacent developments;
- The project must contain design features intended solely for human delight and the celebration of culture, spirit and place appropriate to its function; and
- Educational materials about the performance and operation of the project must be provided to the public to share successful solutions and to motivate others to make change.

3.6 Concluding remarks

A close similarity between Cradle to Cradle criteria and some of the others relating to buildings is clear, and to a degree there is a mutual compatibility between elements of a number of the approaches. Although C2C is defined more as 'a way of thinking', instead of a way of assessing solutions, the ambitions of a number of these systems are complementary. The differentiator for Cradle to Cradle, at least from most of the other systems, is that the clear focus of C2C on redefining waste and materials is not so strongly represented in other models. Additionally, Cradle to Cradle in relation to building design is not only about using the right materials but about creating added value to the building, its surrounding and the people who live or work in it. These concepts are considered further below.

4 Two of the features of the BREEAM 2008 update were the introduction of a two stage, design and Post Construction stages, assessment process, and the introduction of mandatory credits.

4 Applying C2C in the Built Environment

4.1 Introduction

This section investigates how the eco-effective concepts introduced earlier can be reflected in the built environment. We particularly focus on how the holistic approach represented by the Cradle to Cradle principles can be achieved and delivered, and what Cradle to Cradle buildings might look or feel like.

4.2 C2C in practice in the built environment

Modern practices in 'green' or 'sustainable' construction have in the last few years involved a range of innovative and exciting practices. A wide range of approaches can be employed to come to similar outcomes. For instance: whether a building is large or small; hi-tech or low tech; off grid or part of integrated local networks; and whether the construction relies on lightweight, off-site modern methods of construction, or on the higher initial costs, lower operating costs and potentially longer lifetimes associated with more heavyweight high mass construction. Developing on these approaches, and as discussed above, there are clearly a range of ideas of what a C2C building might feature in terms of design, technologies or approach.
To a greater or lesser degree 'sustainability' is reflected in many if not all new buildings, although this may not be recognised. Primary considerations tend to be driven by legislation, for instance achieving set standards of energy efficiency or carbon emissions through higher standards of insulation and the use of double or triple-glazed windows, or for reduced water consumption whether in residential or commercial buildings. This is in line with tightening legislation following the eco-efficiency approach. Financial cost, or value, both in delivery and operation plays a role also for the developer and the consumer respectively. There are also clear differences between buildings delivered en masse, for instance by housing developers where compliance and efficiency would tend to be the key, and more individual units where an individual owner or designer's values can have more of an effect and lead to wider positive, but not necessarily financial, benefits.

Within the current system there are different benefits for different stakeholders from the development of more sustainable buildings. Users can benefit from low running costs, developers can realise a higher sale price and, since the buildings can be more attractive in the market, investors can see more stable income, and therefore more profitable contracts.
Within the current system this can highlight a conflict between eco-efficiency and eco- effectiveness, again identifying the need for a transition in the system. Such focuses can create an imbalance, driving the introduction of technologies to address one issue, whilst inadvertently creating others. Such unforeseen circumstances, possibly driven by perverse incentives, can be enhanced through a failure to consider impacts, or the potential for benefits, in the more holistic way encouraged by eco-effectiveness.
Smarter use is being made of water through the capture and reuse of rainwater and grey water, bringing benefits in terms of offsetting water bills and, where green roofs are used, benefits for biodiversity and potentially local air quality. Increasingly, renewable energy technologies such as solar thermal, photovoltaic panels and wind turbines – both small and large scale – are being used to contribute to home energy need or to power larger industrial and commercial premises, with excesses used to power local networks or fed into the national grid. The introduction of a 'Feed-in tariff' in Germany in 1990 supported more widespread installation of home energy generation across the country in a scheme that has since been emulated in many other European countries, including the UK. This highlights important elements of the transition stage introduced above, which are the role of the positive business case and the role of the public sector in incentivising change. This is considered more later.

However despite these positive trends the reality of actually delivering a true C2C building is that it is currently unachievable. Even when smaller-scale dedicated test or pilot developments are considered, the holistic view contained within the Cradle to Cradle approach precludes meeting such an ambitious standard. However buildings do lend themselves well to being considered according to the Cradle to Cradle approach, which draws such inspiration from nature. Buildings are highly complex structures with a multitude of components and systems and have flows and metabolisms in a similar way to natural systems (for instance energy, water, materials). They also interact significantly with their users, wider local society, and their local surroundings and environment (which could be considered as further metabolisms). Buildings also have, in many cases, a design life of many decades, and this can present a particular challenge to widespread adoption of eco-effective principles. Taking the C2C concept or aspiration and using it to deliver C2C buildings will require a number of wide-reaching changes: this will include new ways of thinking, new solutions, and a period of transition both in terms of process and delivery. Therefore at this moment, we should not focus solely on the whole building, but on considering buildings which are beneficial for all stakeholders, and which contain elements that can be considered C2C.

4.3 Considering current and future Cradle to Cradle buildings

In carrying out this assessment it is useful to have a framework within which to consider buildings. Cradle to Cradle can be considered an innovation-focussed model, albeit one which considers a far wider range of issues than just technological. The buildings assessment methods introduced in Section 3 provide such a structure, and this section is initially set out according to the technical (hard) elements considered by the BREEAM methodology. As discussed above, however, whilst C2C could be considered as a technically-focussed approach, the issues addressed mean that we must consider a number of important elements not formally addressed by BREEAM. Those, non-technical, elements follow below. Throughout this assessment, and differentiating the Cradle to Cradle approach from the BREEAM standards, is the ambition for a building to have the widest possible range of only positive outcomes.

4.3.1 Technical elements

This section of the study briefly considers the energy, transport, water, materials, waste, landuse and ecology and pollution elements of the BREEAM assessment tool, and of the built environment, and how each one could be addressed in the built world of C2C.

Energy

Sufficient sunlight falls on earth's surface to power all man's energy requirements with plenty to spare. C2C buildings will make maximum possible use of solar energy (and other forms of renewable power), so that not only will less energy be needed in the first place (efficiency, i.e. buildings have a south facing aspect for warmth and lighting purposes), but also that energy which is needed will be provided for (effectiveness).
The less energy a building needs, the less chance there is of wastage, with correspondingly lower running costs than a building constructed to minimum standards. Through a design which considers the planned use of the buildings and minimises the building's demand for power, for example through extensive insulation (using both existing and emerging low-impact or transitional technologies such as Insulating Concrete Formwork), maximising solar gain and natural lighting and ventilation, energy requirements can be fulfilled through solar thermal panels and photovoltaic cells, on-site wind turbine(s), ground and air-source heat pumps and emerging technologies for example energy piles (a type of ground sourced heat pump incorporated into the piles of large buildings). Much can be gleaned from the Passivhaus design and other examples including those case studies detailed later on within this study.

However, when designed from a Cradle to Cradle basis, the C2C building of the future will generate more energy than it requires since it also looks wider for potential additional benefits that might be realised. There may be the potential for the opportunity (a building with integrated renewable power generation) to be beneficial to others. Other potential stakeholders, not immediately associated with the building, might realise significant benefits if the building was designed to produce more energy than was needed to operate it - the excess could then be fed to nearby buildings or if not then to the grid. Larger scale industrial and commercial developments could install larger energy generation technologies, such as wind turbines, with any excess again being used beneficially. In the transitional period such an approach also brings increased resilience to rising energy prices, and a reduction in carbon footprint which would also offer benefits to a company and the wider society.
Depending on the type of building and its intended use or uses over its lifetime, larger technology such as an anaerobic digestion plant could provide energy for the site. This could again serve several beneficial purposes including community wastewater treatment and helping to close local biological cycles. Without looking wider at the potential benefits beyond the delivery of the building itself, such opportunities could be missed, Also, immediately, the possibility for interlinkages between energy, water and materials are clear, with one technology realising a number of benefits which might previously have been delivered by different solutions.

Traditional sustainable energy	C2C inspired energy
• Energy legislation and the energy hierarchy	• Awareness of the use of energy and make it beneficial • Integrate renewable energy so the building and site generate more energy than they use

Transport

Two primary elements related to transport are important in this analysis. The first concerns accessibility; the transport options that individuals and organisations have and how these dictate lifestyles and the added value created. This has strong links to health and welfare and other social issues, particularly in the case of residential developments, and is also discussed in the non-technical application section below. The second relates to modes of transport used.

There is no benefit in designing and building a C2C development that is almost totally dependent upon fossil-fuel intensive modes of transport. The consequence of such a development would be that it becomes a transport or journey generator with increased emissions of greenhouse gases that offsets much of the effort made in ensuring the building delivers a net benefit. Clearly a greater area than the building footprint itself will have to be considered if the goal of C2C is to be met. This 'footprint' will need to extend as far as benefits can be realised, potentially meaning greater integration into local or regional transport policy, and into infrastructure in the surrounding town or city. A C2C development would need to be situated in an area where the need to travel is limited (reducing pressures on time and location) and where transport using methods currently considered to be 'alternative' are encouraged so as to be the options of choice (supporting a transition from efficiency to effectiveness). Initially this will mean a focus upon providing excellent cycling and walking infrastructure, with widespread public transport provision that allows easy, efficient, reliable and regular travel with added value of people or diversity. The existing models in a number of European cities such as Freiburg, Groningen ('World Cycling City') and Copenhagen would be good ones on which to base C2C designs.
Additionally, the transport footprint of the development itself must be considered. Transport miles, whether by road, rail or air, form a significant proportion of the environmental footprint of many products. Consideration will have to be given to sourcing local products; helping to limit associated emissions and contributing to a building being 'native to its place'.

Traditional sustainable transport	**C2C inspired transport**
• Minimize transportation in the first place	• Optimize transportation with net contributing transportation • Enhance quality of transport, contributing to diversity and health

Water

Views on water have changed in recent years with a move away from the idea that it is an infinite resource that can be used (and especially wasted) with no regard of the consequences. It is also a resource with which significant savings can be made simply through raising awareness and changing behaviour. However, in large parts of the world, access to clean and safe water remains a significant socio-economic issue. The technical challenges associated with water use and management outside the developed world represent a particular challenge and one where the potential benefits are great, and widespread.
C2C developments will need to rethink the way in which water is used. Eco-effective use of water would rely on water being used without affecting its quality. There are many practical examples in existence today that can be incorporated into designs or developed further. Collection of rainwater is a simple and obvious element that can be incorporated into all buildings and used for toilets, for washing and cleaning (especially in commercial or industrial units), gardening and other non-potable applications. Whilst such uses are still, in the language of C2C, still considered to be down-cycling, integrating suitable treatment (for example UV treatment, where the power required is provided from renewable energy) into buildings would enable local collection of water and its use for drinking. The benefits of a widespread adoption of this approach, in terms of reduced pressure on aquifers and rivers, and on the energy and land currently required to store, treat and transport drinking water, could be significant.

The introduction of measures such as reedbed filtration and treatment systems can clean wastewater to the extent that it can be returned to nature without requiring industrial treatment. However, these considerations are again complicated when looking holistically by a need to consider what the 'pollutants' in that water might be. If a building is being operated, as well as designed, according to C2C principles, there will be nothing in the water which is not part of a biological cycle. If not treated through reedbeds, because of more limited availability of space, the anaerobic digestion approach introduced above has potential. Equally, nutrient-rich wastewater could be used to grow algae. This could then be harvested and used as a basis for materials or fuels - a future application despite only currently being a developing technology.

Sustainable Drainage Systems will feature in developments ensuring that periods of intense rainfall result in surface flooding as traditional systems are either unable to cope with the volume of water in an urban area, or that rapid drainage to larger waterways results in flooding as rivers burst their banks. Through their introduction wider scale benefits in terms of flood resilience – lessening the chance of the physical, mental and financial impacts of flooding – can be realised.

Traditional sustainable water	C2C inspired water
• Reducing water use • Improving waste water quality	• The building provides cleaner water than it takes, ensuring its safer use in biological nutrient cycles • Close water cycles and get out essential nutrients in wa ter for high value use (for instance to generate energy)

Materials and pollution

In nature, there is no waste, everything is put to use. It is a model upon which humanity must start to emulate as the true impacts of consumption and resulting waste are realised through ecosystem damage, the impact of the production of materials that are wasted, the pollution of watercourses and aquifers, and the direct health hazards of waste – especially an issue in developing countries.

According to the C2C approach also there is no waste, and as such there should only be a consideration of materials and their reuse. Only recently has the urgency of the situation been realised, leaving a substantial hurdle to overcome as society, having become a 'throwaway society', tries to rebalance. The impending scarcity of many important raw materials in the near future requires an immediate transition, at least to even more efficiency. The ambition therefore shouldn't be to use less, but especially using the right materials in the right way so that reductions in quality (downcycling) are prevented. Thus C2C buildings will require that their occupants, in both residential and commercial or industrial surroundings, adopt lifestyles and business practices where reuse is encouraged and supported (eco-effective living). Central to such thinking is the continual consideration of what the 'right' materials are in a given situation. Construction would have to consider the lifetime of all the components to be used and would in itself require a complete change in the design methodologies and the use of materials. Entirely different materials may have to be used, or used in (currently) unconventional ways. Both the nature of materials, and their anticipated 'future uses', should be defined at the outset of a project to ensure they accord well with the C2C principles. No materials within the C2C approach will have elements which are toxic to humans or the environment, and all will be reusable within the separate technical and biological cycles introduced above. Buildings themselves may certainly be simpler in design and construction, reflecting the need for their components to be easily re-used or 'up-cycled' following the useful life of the building itself (and according to pre-defined material pathways). For example, a building that makes full use of natural heating and cooling will not require air conditioning and the extensive infrastructure that it requires, eliminating components and immediately reducing the potential energy demand of the building. Materials would need to be selected according to the best properties in terms of re-use and components that can be more easily disassembled.
Consideration of materials and components and the energy embedded therein will require careful consideration. Through this transition phase this is a discipline that will evolve as the global manufacturing industry responds to the need to limit the embedded and lifelong environmental impact of a product, and presents in itself a unique set of challenges to be overcome.

Although not a focus of the C2CN, materials used within a building could be classified. Some companies have already developed C2C products, certified by McDonough Braungart Design Chemistry, which are used in the built environment. These range from coatings to carpets, insulation, furniture, and structural materials. However, aside from this certification assessments could build on more available and existing structures such as the Green Guide for Specification in the UK. This scores the reducing environmental impact of materials from D to A, but a further level, or levels, could be added (illustrated in Figure 4.1) illustrating how eco-effective building materials, whole buildings, or wider projects are. Individual materials could also be scored and then combined to give an aggregate score.

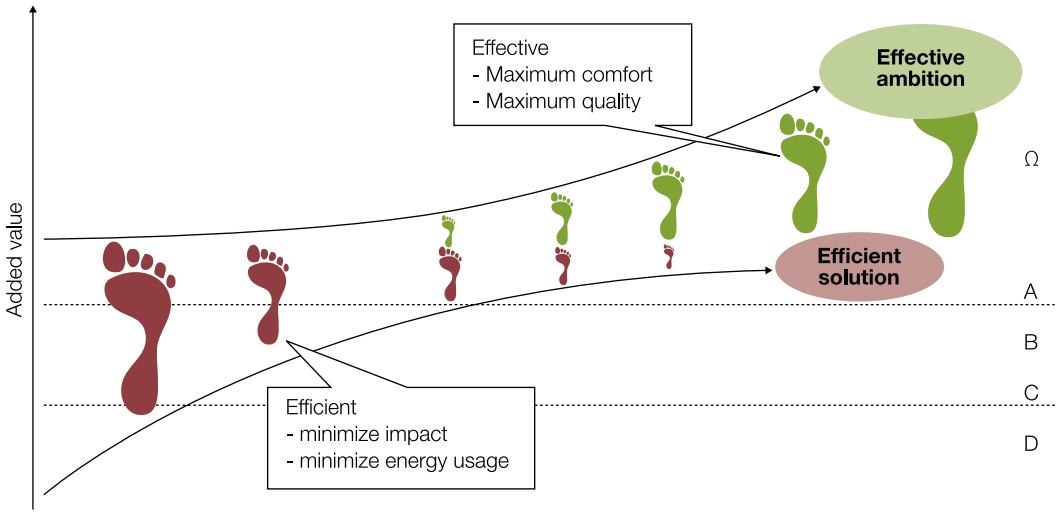

Figure 4.1: Conceptual assessment indicating levels of eco-efficiency and eco-effectiveness ©Royal Haskoning

Clearly also a building that is fully self sufficient in terms of energy will not be desirable if the processes involved in the construction of some of its components, have adverse environmental or social impacts. Thus a number of the technical solutions proposed above – for instance photovoltaic panels – will need to be substantially re-designed before they can play a part in the eco-effective future, rather than just in the transitional phase.
Finally a building should improve air and climate quality. Although not considered by assessment tools such as BREEAM, indoor air quality can frequently be worse that that outside. Cradle to Cradle buildings should contain and emit cleaner air than they take in, which will require integrated air management systems and techniques such as green walls and the use of plants (also contributing to local diversity). The management and reduction of pollution and, ideally, its eradication will need to be a core focus of progressing the C2C agenda in the built environment. Under a truly C2C approach there is no pollution - pollution is considered only to be an effect of ineffective and inefficient material, water and energy usage. However, starting from where we are now, pollutants will still arise during the construction of buildings, construction and assembly of components, transport to and from site, use and operation, and often once their useful life is over, for many years into the future.

Traditional sustainable materials	C2C inspired materials
• Reducing waste • Use local materials • Sustainable sourcing	• Improving quality of building for stakeholders: healthy materials for users which create a healthier indoor air quality than outside air • Separate bio- and technical cycle and prepare for upcycling • Use materials for their intended uses, and define their future pathways

Landuse and Ecology

In keeping with the core C2C aim of delivering net benefits, the importance of halting and reversing global trends of biodiversity loss cannot be understated. Areas of so-called ‘waste land’ which may offer little in terms of ecological diversity could be managed in such a way to ensure that species are able to thrive that previously had been unable to. Measurably increasing biodiversity in the built environment can be achieved by improving habitats for flora and fauna both within a building’s footprint and within the wider surroundings. Positive multiple uses of biodiversity-enhancing elements can include the use of green roofs and façades (green walls). Activity to encourage, enhance and increase biodiversity directly supports the core principle of Celebrate diversity.

C2C developments will have to deliver benefits locally to the site on which they are built in terms of diversity. There are substantial areas of land across Europe within urban environments that are the sites of former industrial works, factories, warehouses, flats and residential developments which have existing transport infrastructure links and potentially good links in regard to more sustainable modes of transport. These are ideal candidate sites for the progression of C2C projects. In particular they are areas where one of the considerations of the C2C in Architecture manifesto and the C2C Building Charter – that of the importance of topsoil as a substrate for healthy ecosystems and as a carbon sink, and the need to encourage and enhance its creation – is of greater local benefit.
The presence of such 'green lungs' in an increasingly urbanised landscape are also of great importance (often under-rated and overlooked) in terms of the social and mental wellbeing associated with having easy access to nature. This will be discussed in more detail in the following chapter.

An industrial or commercial C2C development would likely incorporate a green roof, whether in the form of a sedum/grass covering or rooftop gardens. Direct effects include maintaining top soil, increased biodiversity and water retention for effective reuse (which all create added value for stakeholders). Less direct effects include the enhanced insulation potential, and its effect on delivering against the energy requirements of a building, but also the less tangible publicity and reputational benefits.
Widespread planting of trees that form 'wildlife corridors' and more space around residential dwellings, both in terms of public space and allowing (and encouraging) bigger gardens. Building designs that offer nest and roosting spaces for birds and bats are very simple and effective measures that can be taken.
Again demonstrating the linkages inherent in adopting a holistic approach to buildings and development, Sustainable Drainage Systems and related or new developments in managing surface run off may result in the creation of ponds and wetlands, which, if designed with biodiversity in mind, can support large numbers of species and therefore as well improves the quality of life of humans.

4.3.2 Non-technical elements: Economy and society

Although the structure above provides a useful framework for considering elements of the built environment, the holistic approach requires a greater consideration of less immediately tangible issues. C2C (as with other sustainability approaches) aims to achieve a mutually-beneficial balance between social aspects, economy and ecology (people:planet:profit). Whilst later in the transition period this will include greater consideration and quantification of non-fiscal benefits, it is a fact that most current delivery is bound by traditional financial models. In this section we give an overview of equity elements in the C2C approach - issues related to human capital and societal wellbeing, including the extent to which the built environment is appreciated, identity and diversity - based on the C2C core and Limburg principles. Initially we consider the issue of economics, and the need to consider a business case for delivering Cradle to Cradle projects.

Economics

C2C, as detailed earlier, differs from conventional approaches to sustainability in that from the outset, a C2C project will not set out to minimise adverse impacts, but rather to deliver a net benefit for stakeholders environmentally, socially and economically. A fundamentally new look at building design, construction and use (including maintenance and operation of systems) will be necessary if C2C is to become a reality and the standard in modern construction. However, this should be seen as something to aspire to; in the meantime the focus must be on how the transition can be encouraged.
The current need for greater environmental stewardship means future communities will need to live 'smarter' than we do. It is likely that legislation will play a significant role in this, raising standards and ensuring or requiring that 'green' technologies are incorporated. Current building regulations vary across Europe, but in the UK do not require minimum standards that would see many of the technologies, detailed in the paragraphs above, included as standard.
The Code for Sustainable Homes, now mandatory for residential developments, combined with changes to Buildings Regulations and to Standard Assessment Protocol software will have positive effects on building design and construction. They should also support reductions in the higher costs often associated with more sustainable buildings, and help drive innovation. However, whilst these moves are very positive, they still largely support moves towards greater eco-efficiency.
Innovation in 'green buildings' can be held back by a lack of finances to fund research, development and production. In the short-term at least this can only be expected to have more of an impact, potentially delaying the development of standards for buildings that truly embrace C2C principles and undermining the achievement of future benefits. However there is a counter-argument. Necessity breeds innovation and, based on a market-driven approach, the added value of sustainable / beneficial / C2C-inspired buildings should stimulate the application of innovative solutions.
With a C2C inspired building, from the outset, the intention would be that the project would result in a net benefit for stakeholders: employees, users, banks and investors, neighbourhood, clients. Today's 'best practice' green buildings are showcasing many of the features that future C2C buildings might include, with the transition towards C2C likely to occur gradually as sustainability measures combine with C2C, developing the broader and more positive perspective regarding material, energy, and mutual benefits.

Growing consumer awareness combined with higher utilities bills will lead to home owners placing more emphasis upon the 'green' credentials of homes that they buy or rent. Supported at least in the short term by legislation and financial incentives, unit costs of, for instance, renewable energy equipment, should reduce. When combined with increasing fossil fuel-derived energy prices and material scarcity, doing the 'right' C2C-inspired things will become more affordable and the economics of beneficial buildings will become more favourable. Nonetheless, steps are being taken in the right direction as measures to reduce the environmental impact of modern buildings are being taken, albeit often at a small scale or driven by single individuals or organisations. However such steps can only be considered beneficial in a C2C sense in the short-term, through the transitional phase, if they are clearly part of a roadmap towards eco-effectiveness.

In order that eco-effectiveness is fully realised, a holistic and life-cycle approach to costing is required, and this must also consider indirect effects like resident/employee health, and company or individual reputation, as well as wider benefits to society. In the meantime, during the transitional phase, moves towards implementing the C2C philosophy in the built environment will be dependent upon a sound business case and one that incrementally takes into account all benefits (especially those not frequently considered), placing a greater emphasis on effective solutions and not only efficient ones. This also helps to ensure that C2C delivers projects with net benefits, rather than solutions that are simply less bad.

Human capital – social benefits and community enjoyment

Celebrating diversity, within the core principles, and native to our place, enjoyment for all generations, and enjoyable mobility for all within the Limburg Principles are areas where realising C2C ambitions are less about technical solutions and more about less tangible social or 'feel' benefits.
As in nature, the Cradle to Cradle promoters consider that diversity increases quality of life. Specifically this is usually taken to relate to biological diversity (biodiversity), cultural diversity and diversity in ideas and functions. Although biodiversity has been considered above (landuse and ecology), the two other areas are addressed below.

Within the built environment, cultural diversity can be achieved and enhanced by considering the potential and actual future users of a building, and promoting buildings and areas which people with different values, backgrounds, ages and abilities can enjoy. Through encouraging this diversity there is expected to be a more inspiring area for inhabitants and users. At the spatial scale this could include integrating social and spatial planning by mixing affordable homes with luxury homes, and although also related to spatial development – another theme within the C2CN – individual buildings within an area can support and encourage this diversity. The C2C inspired design of specific buildings, sites and interiors, should also enhance the well-being of employees/people, contributing to enjoyment for all generations.
Designing multi-functional buildings which serve a range of purposes (diversity in functions) – for instance education, healthcare, recreation, dining, manufacturing - enable better use of space and contribute to the wider social enjoyment of an area. The use of modular designs can ensure flexibility to changing user demands over time. For example, in the residential sector, standards such as Lifetime Homes in the UK ensure that homes are flexible to inhabitants' changing needs, and that they can continue to enjoy their homes into old age, rather than having to move. Multifunctional buildings also enable more local greenspace and a more enjoyable, and healthy local environment since such areas also contribute to improvements in local air quality, noise and resilience to the impacts of climate change (again bringing wider social benefits).

As well as the buildings themselves, the movement of people to, from and around buildings and their areas are a focus of the Limburg Principles, encouraging enjoyable mobility for all. In achieving this alternative means of transportation should be stimulated, along routes which are enjoyable for users and which are inclusive (for instance 'Living Streets' and shared-use routes where the dominance of one form of transport or another is broken down).
Within the Limburg Principles these approaches also support the idea of being Native to our place, by delivering the needs not only of the building developer but also the local community and local biodiversity. Alongside this, facilities can be shared with the community or support other local interests through linking with local partners in micro-networks for, for example, waste treatment, energy use and generation, as well as developing local supply chain networks. Particularly where others in the supply chain have similar C2C ambitions, such links help to build resilience and further contribute to the wider uptake of Cradle to Cradle. In so doing, building on earlier examples can accelerate the development of the C2C approach. Local partnerships and networks also increase the likelihood of using local materials and products, but the focus on the building's surroundings also encourage an approach which would create a better area than before. Although such approaches have been a focus of planning policy for a number of years, delivery has not always supported the ambition, meaning that more mutually-beneficial C2C approaches are missed.

4.3.3 Summary – achieving Cradle to Cradle

Although this section has drawn together consideration of a range of different issues relating to buildings, the holistic nature of C2C means that all issues should be considered together in assessing the best means to achieve eco-effectiveness in any given situation. Adopting a structure such as BREEAM for the discussion is necessary to give some coherence to the document, but at the same time we must be careful that such an approach does not force the more traditional thinking in silos approach which will prevent the identification of links and networks central to the C2C approach.

Cradle to Cradle is discussed as an approach, and a way of thinking which is necessary in order to achieve positive outcomes. It is not a set of techniques or solutions for designing and delivering C2C buildings. The most beneficial and most appropriate solution will depend on location and situation, and as such the key issues should be:

- Focussing on high ambitions and considering the potential for widespread benefits, rather than lower impacts;
- Identifying networks which might benefit, either through the construction, operation or deconstruction and upcycling phases of a building;
- Designing the building with a mind of achieving as many of those benefits as possible (for instance according to a beneficial effects matrix shown in Figure 4.2);
- Considering eco-effective solutions, in line with the principles of Cradle to Cradle, as well as more traditional efficient solutions where the business case for innovation is not suitable, and
- Building on and combining existing and emerging good practices, contributing to the transition to eco-effectiveness.

ROYAL HASKONING		VALUES							
		Ecology			Economy			Equity	
Aspects	Nature	Biodiversity	Health & Safety	Climate Change	Scarcity	Cost/Benefit	PR	Corporate Social Responsability	Fairness
Energy	Problems	SO_2 / Acid rain	NO_x / PM	CO_2 / GHG	Fossil Fuel	Pay Back time, Life cycle Analysis Total Cost of Ownership Life Cycle Costing Hard and soft costs and Benefits	"Net Positive"	Net energy positive buildings	Super grid
	Solutions	Solar, Wind, Environmental, Geothermal Energy and Biomass							
Materials	Problems	Waste exposure*)	Air quality exposure*)	GHG	Virgin materials		"Recycled"	Self cleaning buildings	Materials leasign
	Solutions	Non-PBT, non CMR, From down-cycling to up-cycling, Biobased materials							
Ecosystems	Problems	Loss, Degratation, Contamination	Adapatation erosion		Phosphate, Regenmeration, Agricolture		"Green"	Positive contribution to ecosystems	Eco fax
	Solutions	Closed bio-cycles, vegetations strategies, eoil organic matter management							
Water	Problems	Contaminated water	Contaminated water	Flooding	Fresh water, drought		"Clean"	Cleaner sdiscarge as intake	Water footprint
	Solutions	Algae, Zeolites, Memabrane technology, nutrition regeneration, Natural water storage, Decentralised sanitation							
Human Capital	Problems	Antibiotics	Allergies, Infectious diseases	Adaptation	Food security		"Healthy"	Enpowerment	Fair Trade
	Solutions	Health programs, (Industrial) Higyene programs, Micro credits, Food programs							

***) Persistent, Bioaccumulative, Toxic (PBT), Carcinogenic, Mutagenic, Reprotoxic (CMR)**

Figure 4.2: A beneficial effects matrix, developed to guide thinking about appropriate eco-effective solutions to a range of problems. ©Royal Haskoning

With this in mind the final section below briefly considers the role of governments, and in particular local/ regional bodies, in supporting the delivery of the Cradle to Cradle approach.

4.4 How (local) government can enable C2C buildings

The Cradle to Cradle approach cannot be forced, it can only be encouraged. Government at all levels has a strong potential role as a facilitator, drawing together the various groups involved in an area or a development and stimulating their ambitions, supporting the achievement of higher standards and more beneficial approaches.

One mechanism for this, represented by the C2CN, is to identify and share information about the Cradle to Cradle approach and about good practices which exemplify elements of that approach. Governments, particularly at the local level but with higher-level support, can encourage others to adopt similar approaches, building on the lessons learned and combining successful elements of previous projects.
In particular, the roles of government ideally place it to identify where developments might achieve a range of mutual benefits which might, at this stage, be beyond the 'traditional' scope of building designers and developers. Building on this, governments can develop and raise the profile of local networks, supporting the development of local continuous cycles for products and services.
C2C should evolve and therefore only be stimulated and facilitated by a government. It will also only be achieved where there is a supporting business case. But this can itself be encouraged through the development of appropriate legislation, encouraging and incentivising positive change. The transition from efficiency to effectiveness (C2C) is only really starting now and, certainly in the case of the built environment, will take a considerable period of time. However, governments normally focus on medium to long timescales, and the development of longer-term goals lends itself to the adoption of a Cradle to Cradle-inspired roadmap for buildings in an area. Such a roadmap is illustrated in Figure 2.4, but begins by establishing at the earliest stages the ambition for the future. Where this is 'positive' – or eco-effective – it enables shorter-term target setting, and various drivers and challenges to be identified. These will necessarily combine efficiency and effectiveness, at least at the start.

5 Current and near Future Good Practices in the Built Environment

Over the course of the project examples of good practices, green and sustainable buildings from across the partner regions, have been collated. At this relatively early stage in the C2C process, the focus has been on finding examples of buildings where in some way a building exemplifies one or more of the core principles of C2C. These good practice examples allow an analysis of the practices, technologies and designs that could well feature in dedicated C2C buildings of the future.
They serve as a foundation for C2C designs and projects, helping to bridge the gap between existing building practices and the aspirational developments that this project is looking towards.
The case studies detailed below are not projects that have been designed with C2C in mind. Therefore, they are not presented as living examples of how a building can encapsulate the philosophy of C2C. Instead, the examples are presented as existing projects that showcase technologies, designs and mindsets that could feature in C2C buildings of the future. These good practice examples have sought to go beyond minimising their negative impacts, and have tried to create a positive footprint. However they have also combined this with higher levels of eco-efficiency, demonstrating the early stages of the transition phase in practice.
The focus throughout the build element has been on taking good practice examples that are built and operational, as these of course allow a detailed assessment to be made and lessons to be learned. Projects that are still at the conception phase have not been considered in such detail simply because as they have not yet been built - there is no way of knowing if the aims and ambitions of the project will be realised. A number of these examples were discussed at the Cambridge conference – and considered within the question 'what should a good practice look like and is this one?'

5.1 Residential

5.1.1 Search Architects – Unity Gardens Social Housing Scheme, Long Sutton, UK

Detailed description of the case
There is an urgent need to address increasing greenhouse gas emissions. Residential properties make up a significant proportion of UK domestic energy demand, primarily through space heating. Thus there should be large level of interest, to governments and individuals, in reduced energy demand from residential properties and the associated lower running costs.

This development at Long Sutton became 'fully operational' in July of this year when the first residents moved in. Unity Gardens comprises of a number of earth-sheltered two and three-bedroomed homes built to extremely high standards of sustainability. The six single-storey dwellings are naturally ventilated, require almost no heating, and are self-sufficient in terms of their energy requirements. Each property features an array of photo-voltaic panels on its roof allowing each home to generate more electricity than it requires, with excess energy being sold to the national grid and generating income for the homeowner in the process. The homes are south facing and feature earth bunding on their east, north and west aspects. Space heating is provided in part by human occupants and by the equipment within the home, and also passively through the use of construction materials which absorb energy from the sun and slowly re-radiate it throughout the day. Underground water storage tanks form part of a rainwater harvesting system which provides water for toilet flushing whilst excess rainwater is directed to a balancing pond where reeds, sedge and mace are supported.
The access road is designed to encourage more sustainable modes of transport by ensuring that road users are not segregated, whilst parking areas double as play areas. Allotments are provided to encourage residents to grow their own produce, and native trees and plants have been planted throughout the development.
This development was designed by Search Architects and built by Lincolnshire Rural Housing Association with support from the Homes and Communities Agency (HCA). Search Architects set out with the aim to 'revolutionise social housing management' and in doing so have created one of the first social housing schemes to achieve a degree of autonomy in terms of energy. The development was supported by an affordable housing grant from the Homes and Communities Agency. Given the community approach but low levels of energy needed to run the dwellings, as well as the numerous other benefits they offer in terms of low impact lifestyles, they serve as excellent examples of what can be achieved to limit the environmental impact of new homes.

Relationship with the Limburg principles
This development sets very high standards for low carbon living and many comparisons can be made with the core C2C and Limburg principles. Unity Gardens are without doubt 'native to their place'; being homes with a low visual impact that are designed to make maximum use of the solar energy and rainfall expected of the area. This in turn brings associated benefits to biodiversity (through native tree planting and the balancing pond) and to air, water and soil quality. The architect is very proud of his local

base also, and the development is part of a community-wide approach to high levels of sustainability. Maximum use is made of current solar income through the design and siting of the properties, and the photo-voltaic panels that are fitted to the roof of each development. 'Enjoyment for all generations' is captured well as this is a modern, unusual design that brings significant benefits to its residents; greatly reduced running costs and offering the chance to be much more self-sufficient and resilient to future change. Taking the priority away from the car and realising the opportunity for alternative use of spaces that typically are dominated by motor vehicles will help to ensure 'enjoyable mobility for all'.

5.1.2 Public Residential Housing for senior citizens (BIRD), Sapolino, Brescia, Italy

Detailed description of the case

Aler Brescia (formerly IACP Brescia) is the public company that deals with the construction, rental and maintenance of public housing in the province of Brescia. The BIRD project (designed by Professor Ettore Zambelli and site engineer Danilo Scaramella) will create 52 apartments for elderly people plus a service centre in Sapolino, a town in the province of Brescia. The name of the project is an acronym: BIRD stands for Bioedilizia (bio-construction), Inclusione sociale (social inclusion), Risparmio energetico (energy saving) and Domotica (home automation).

The project focuses on the maximum achievable energy saving through the use of an innovative system combining use of geothermal heat pumps, photovoltaic equipment and solar heating to achieve a balanced budget between the energy produced and energy used by the buildings. The building does not use traditional masonry. The structure is metallic, while the inner shell consists of framed walls, coated with plaster and mineral fibres and wood fibres for insulation. The building has also a dual water distribution system in order to use non-potable water for watering the green and for the toilet cisterns.

When the building reaches the end of its useful life, the dry construction which characterizes it ensures that, instead of normal demolition, the building can be dismantled through an easy separation of materials used in construction, with the potential to use them in recycling processes and/or reuse. The steel frame is completely bolted together - it can simply be removed and steel can be reused; insulating materials used are not oil derivates but only natural insulators such as wood wool and mineral fibres, which can therefore be easily reused.

The building features a dual water distribution system in order to use non-potable water for watering the green spaces and for use in toilet cisterns. In agreement with the local authorities, the town plan has been changed to eliminate the penetration of roads throughout the area in the vicinity of the development, thus reducing the presence of vehicles and increasing the amount of available green space.

The works were completed in September 2009, after a three year construction period. The first apartments were occupied in January 2010 while the service centre became operational in July 2010.

BIRD is a public housing project, built in partnership by the Lombardy Region, Aler Brescia and the Municipality of Brescia, which set the original conditions for building a residential complex for the elderly, powered with geothermal probes and photovoltaics. The company Energy Resources was responsible for the design and implementation of the geothermal heating and cooling systems in collaboration with the enterprise LPG Construction, based in Ancona. Funding for the project was provided by the Region of Lombardy.

Relationship with the Limburg principles

This example from Sapolino features a key C2C characteristic insofar as the full life cycle of the building has been considered from the outset, ensuring a design which enables easier demolition and re-use of component parts than could be achieved in a conventional building; helping to view waste as food. The building utilises current solar income through photovoltaic panels and a design which offers the best opportunities for natural space heating from sunlight. The ground-source heat pumps reduce the demand that the building places on fossil fuel energy sources, with associated benefits on wider air quality. Similarly, pressure from this development (if it incorporated no 'green' innovations) upon water has been reduced through the installation of a dual water system which utilises both mains and rainwater; contributing towards the need for the air, soil and water to be healthy. The development exemplifies 'creating enjoyment for all generations' through a focus on a home that is not expensive to heat and run. Additionally, the provision of green space, and efforts to minimise the impacts of road traffic, will contribute towards a better place to live.

Aler Brescia was awarded with the recognition PALMARES Federcasa in 2009, in the category "Environmental sustainability and management". The project was awarded the "Innovazione Amica dell'Ambiente" prize in Italy as well as the Federcasa 2009 award for sustainability. The European Commission included the project among those exhibited at the international conference on "fuel poverty" held in Brussels in February 2009.

It is interesting to note the difficulties that were encountered in the project particularly the unpreparedness of the building system to cope with dry construction methods and the difficulty of getting residents to align their principles and habits with a home designed to have a low environmental footprint. This interaction with inhabitants or users is a key factor with C2C or sustainable buildings, where even if the ambitions of the designer are eco-effective, the building must encourage appropriate use, otherwise the positive benefits will not be maximised.

5.1.3 Project Tweewaters, Leuven, Belgium

Detailed description of the case

Tweewaters comprises the extensive redevelopment of a former industrial site (an area known as Vaartkom) into flats, retail, green space and offices that places a firm emphasis on low-carbon lifestyles; in essence a 'low-carbon' community for Leuven. Homes for approximately 5,000 people are to be built. Good transport links with key city infrastructure are planned and the development will encourage a move away from single-occupancy vehicle use and the uptake of more sustainable modes of transport such as cycling and public transport. A combined heat and power (CHP) system provides electricity and heating for the buildings with targets of providing 80% of heating and 100% of lighting from renewable sources. Construction began in 2010 and is expected to take a total of five years.

Low-carbon technologies/features that will feature in the Tweewaters development include:

- 40% less energy demand for dwellings compared to current national standards;
- Second generation biofuels (so no competition with food production) powering a site-wide Combined Heat and Power (CHP) system;
- Investigation into incorporating cutting edge technologies including thermo-active foundations, energy piles and thermal road collecting systems;
- Extensive provision of secure cycle parking to aid uptake of sustainable transport;
- Extensive insulation in all buildings;
- Rainwater recycling for use in toilets, dishwashers and washing machines; and
- Widespread facilities for recycling and waste minimisation.

Relationship with the Limburg principles

Being 'native to our place' is exemplified through the incorporation into the design of the iconic silos, formerly owned by Stella Artois, which are located on the site. Being firmly established as a feature of the city, they are going to be modernised and utilised in part by a new hotel development. The project will also take full advantage of being located alongside the River Dijle; having extensive green and open space for visitors and residents alike to enjoy. Residential units make maximum possible use of natural sunlight and helps the project to 'utilise solar income'. With extremely high targets in terms of renewable energy provision, the project is minimising fossil fuel emissions through a site-wide CHP plant. Additionally, rainwater harvesting will help to minimise the demand upon mains water made by the new development. 'Designing enjoyment for all generations' features strongly through the design of a city quarter that places an emphasis on open space; community and low-carbon homes that allow residents to minimise their impact on the environment. Being 'car-free', residents will benefit from not having the problems that historically impact 'car-centric' developments; roads are socially divisive, noise and air quality impacts, safety fears, etc. The project provides an excellent example of ensuring 'enjoyable mobility for all'. The entire site will be car-free; vehicles will park in underground car parks and will not be able to drive around the site. Maximum provision is made for sustainable modes of transport with a large network of cycle ways, secure cycle parking for all residents, large areas of green space for walking/recreation and public transport stops along the road at the edge of the of the quarter. A car-sharing network will be established to promote 'smarter choices' for those residents and employees who have to travel by road. The distance to key local infrastructure such as Leuven railway station and market place is minimal, thus making cycling and walking viable options.

5.2 Commercial

5.2.1 Littlehey Young Offenders Institute, Huntingdonshire, UK

Detailed description of the case

The United Kingdom Ministry of Justice (MoJ) has mandated that all new developments are required to meet the standard of 'BREEAM Excellent', with a view to reducing the carbon impacts of their estate and operations. With this in mind, a group of organisations set out to ensure that the works at Littlehey were completed to a high environmental standard. Littlehey Young Offenders Institute subsequently achieved a BREEAM Excellent award in 2010.

All in all, twelve buildings across the site were awarded a BREEAM Excellent rating. These included all of the house blocks, a sports hall, kitchen, administration building, education and multi-faith facilities, segregation unit, visitors' centre, reception and healthcare facilities, and workshops.

The project featured a range of sustainability measures including:

- Rainwater recycling to limit the sites demand on mains supply;
- Sustainable Drainage System;
- Making full use of natural lightning and ventilation;
- Landscaping across the site to encourage and enhance biodiversity;
- A biomass heating strategy for the whole site which provides in excess of 30% of the total heating demand of the site;
- Use of renewable energy and designing out of polluting refrigerants;
- Construction methodology employed result in significant reduction in material being sent to landfill; and
- The use of responsibly-sourced materials.

Relationship with the Limburg principles

The range of measures incorporated into the work carried out at Littlehey demonstrate a number of the core C2C principles and the Limburg principles. Maximising natural light and thereby reducing the demand of energy for lighting links closely to the Limburg principle of seeing the 'sun as our income'. One of the core C2C principles is celebrating diversity which encompasses biodiversity and recognises that the strength of a system is the sum of its component parts and that the more diverse a community is, the stronger and more successful it will be. Thus a landscaping plan that is designed to encourage and enhance biodiversity not only contributes towards this aim, it also links to the 'air, soil and water being healthy' as a healthy ecosystem provides clean water, soil and air. A significant proportion of the space heating needs for the development are being provided by biomass, utilising the waste products of certain systems as a fuel source for others; thereby realising the ambition that 'waste is food'. However the nature of the development, a centre for housing young offenders, challenges the adoption of some of the Limburg Principles, and in particular 'enjoyment for all generations'.

5.2.2 Innova complex Floriade, The Netherlands

Detailed description of the case

The Province of Limburg in the Netherlands is assuming the role of a property developer for this project which is taking a pro-active approach to 'building-in' C2C. The Province's intention was to use the project as an opportunity to investigate the potential for Cradle-to-Cradle to be incorporated into the design and build of a new development. An additional challenge is to try to apply C2C principles within a high-quality architectural design but whilst maintaining the appearance of a more traditional building. Furthermore, the project will provide valuable experience of applying the C2C formula within a European tendering process and developing innovative contractual agreements.

The overall goal is to develop, in the most sustainable way possible, an office and reception building for the Floriade 2012 World Horticultural Expo. This building will be the starting point, and after the Floriade 2012 event will be converted to form part of "Greenpark Venlo"; a business park/industrial estate for enterprises in the Agri, Food and Nutrition sector. The building will be the landmark for Greenpark Venlo and the identifying icon and access gate to Floriade 2012.

Construction began in April 2010 and is expected to be complete in April 2012. The project is a collaboration between a number of organisations including the Province of Limburg (client), the City of Venlo (landowner), Greenpark (site manager) and Floriade (tenant/user).

A wide range of features have been incorporated into the project including:

- A photovoltaic array will feature on the roof, providing electricity for the building's interior;
- A 'solar chimney' which is designed to reduce the need for mechanical ventilation by creating a natural updraft to transfer heat around the building;
- Creation of a green roof to capture rainwater and promote biodiversity;
- A rainwater harvesting system which collects rain water and uses it for flushing toilets and other functions within the building that do not depend upon mains water;

- Separation of grey and black waste water. Grey waste water will be sent for biological filtration prior to joining surface water channels whilst black water will be processed at a biomass fermentation plant being constructed on site;
- Construction methodologies that place a strong focus on the re-use of materials through easy disassembly once the useful life of the building has been reached;
- Installation of a full suite of energy and water monitoring technologies; and
- Extensive insulation and innovative 'double' wall design to minimise heat loss.

Overall, the building is expecting to demonstrate between 25% and 50% greater efficiency than a comparable office building built to standard regulations.

Relationship with the Limburg principles

With C2C forming one of the foundations of this project; i.e. having been considered from the outset, this case study is unique amongst those featured in this report. Seeing waste as food is demonstrated through a design which aims to maximise the potential for re-use of construction materials at the end of the useful life of the building. Ensuring components can be easily disassembled is key to achieving this aim. Solar income is maximised through the incorporation of solar panels and a 'solar chimney' to help ventilate the building naturally. The more efficient a building is, the smaller its impact should be on air, soil and water. Utilising renewable energy and rainwater as far as possible and minimising the energy requirements of the building are examples of how the development contributes to this Limburg principle. The building should also contribute towards 'designing enjoyment for all generations' through being designed with C2C in mind from the outset and therefore providing a unique space to be enjoyed by visitors to the 2012 Expo and eventually for the users and employees of 'Greenpark Venlo'.

5.2.3 Tesco Zero Carbon Store, Ramsey, Cambridgeshire, UK

Detailed description of the case

As part of a drive to achieve carbon neutrality by 2050, Tesco are increasingly looking at how to reduce the environmental impact of their operation. This store in Ramsey is Tesco's first zero-carbon store in the UK.

If features a range of energy-efficient technologies including:

- A timber framed design that utilises wood from a sustainable source. The timber makes a significant carbon saving over steel that would otherwise be used, and can be easily re-used in future;
- Maximum use being made of natural light through the use of sun pipes and roof lights to light staff areas and the shop floor. The roof lights contain a gel which controls incoming solar radiation to ensure internal temperatures are kept within desired limits. Internal lighting systems are automatically controlled using light sensors so that they are dimmed or brightened depending upon ambient light levels. Street lights are solar powered and internal lighting is controlled by movement sensors and features low energy (LED) bulbs (however as a demonstration of the complexity of delivering Cradle to Cradle within existing technologies and systems, the negative chemical implications of LED lights should be acknowledged);
- Space heating and cooling systems are using hi-spec energy efficient equipment. A mixed-mode ventilation system consumes only a small amount of energy and far less than traditional air conditioning systems. Additionally, the construction of a lobby reduces heat loss to outside;
- Rainwater harvesting is employed to supply toilets and the car wash;
- Renewable fuel powers a combined heat and power (CHP) unit that provides electricity for the site;
- Heating, ventilation and air conditioning systems do not use harmful refrigerants; and
- Low energy, highly efficient baking ovens. Freezers and fridges have doors which utilise a special type of film on the glass to stop them freezing up and thus obscuring the view of the products inside.

Over 80% of staff live within 3 miles of the store which helps to keep emissions associated with commuting to a low level. BREEAM guidelines were used during the design and build of the store, which opened on the 7th December 2009.

Figure 5.1: Tesco's first zero-carbon store in the UK – Ramsey in Cambridgeshire

Relationship with the Limburg principles

Utilising solar income is a key feature of the new Tesco's store in Ramsey, particularly in terms of the natural lighting. Through the widespread use of harvested rainwater, the project is helping to lower demands on mains water and deliver associated benefits such as reduced emissions and impacts upon biodiversity as water courses are over-extracted. Also helping to ensure that the 'air, soil and water are healthy' are the wide-ranging efficiency measures being taken to minimise emissions associated with the store's operation as detailed above.

5.2.4 Zuckerman Institute for Connective Environmental Research (ZICER), School of Environmental Sciences, UEA, Norwich

Detailed description of the case

The School of Environmental Sciences (Env) at the University of East Anglia is widely recognised as the leading school in its discipline in Europe. Env has expanded widely since its creation in 1967 and includes the world-renowned Tyndall Centre for Climate Change Research which is based in the award winning ZICER institute. The Zuckerman Institute opened in 2003 and comprises 2,860m2 of primarily office space spread over five floors. The building showcases some highly innovative environmentally friendly building design techniques and technologies. ZICER is naturally cooled by air which is circulated at night through the building's hollow Termodeck floors. Termodeck construction uses lightweight hollow-core ceiling slabs through which both incoming and exhaust air are able to circulate. The system offers a very high standard of insulation, good levels of air tightness (although it should be noted that whilst this is an effective means of reducing energy use and carbon footprint, it can contribute to reduced inside air quality) and an efficient heat recovery system. In the winter, heat that is generated by equipment and occupants is absorbed by exposed concrete walls which then re-radiate the heat during the night. In summer, absorbed heat is ejected outside the building by fans that run during the night. The building is extensively insulated to a standard far exceeding that specified in planning guidance.

The roof is covered with photovoltaic panels, which generate 33 kilowatts of electricity during peak conditions. This is then fed into the building, or other buildings on campus if an excess is being produced, reducing the demand on the national grid. Timber-framed triple glazed windows have low-emissivity coatings which help to limit heat loss.

ZICER won the 'Low Energy Building of the Year' award in the Building Magazine's 2005 sustainability competition. It was also short listed for the Times Higher Education Supplement's 'Outstanding Contribution to Sustainable Development' award in 2006.

Relationship with the Limburg principles

ZICER exemplifies a number of the guiding principles of Cradle to Cradle. The extensive use of photovoltaic cells as a source of energy for the building is an excellent demonstration of maximising solar income. This is also reflected in the way that the building widely utilises natural light to reduce the overall demand for power for lighting, particularly on the top floor which is extensively glazed and used as an exhibition and conference centre. Through a design which minimises demand for energy, the building demonstrates well the Limburg principle of 'the air, soil and water are healthy' by significantly reducing the greenhouse gas emissions associated with its operation. The design and layout of the building creates a high quality work and study environment; linking well to the Limburg principle of 'designing enjoyment for all generations'. High quality provision for cyclists is also a feature of the building; users ride down a ramp into the basement floor off a nearby access road, where they can access secure and sheltered bicycle stands, as well as showering facilities. This latter element of the ZICER building offers a good example of how to help provide for 'mobility for all'.

ZICER is also a very good example of how effective building monitoring and management can play a key role in reducing emissions, and keeping them low. The energy management policy allowed energy consumption related to heating to be reduced by a further 57%, although this again meets efficiency goals rather than demonstrating effectiveness.

Funding for the installed PV array was received from the Department of Trade and Industry (DTI) as a Major PV Demonstration Programme project. The project cost £5 million overall.

5.2.5 Autogrill service & Restaurant centre, Mensa di Ravenna, Italy

Detailed description of the case

Conceived as an on-going experiment in sustainability, the Autogrill development in Mensa di Ravenna incorporates a wide range of good practice design and technologies.

The 400m2 building structure is made up by over 600m3 of expanded polystyrene (EPS) blocks (that as well as functioning as an insulating material, have a dedicated canal system for the passage of electric cables and air shafts). The Autogrill development is a totally self-sufficient building in terms of its heating and air-conditioning needs, thanks to geothermal energy and a design which features modern technological and architectural solutions. The structure is covered by grass and ivy to maximize natural perspiration and keeping down the internal temperature. The roof, made of green and low growing grass, has a drop by drop watering system featuring rainwater recycling.

The interior design reflects an aspiration to incorporate 'green' measures as widely as possible: windows and light wells are orientated so that a considerable contribution of lighting for the building's interior comes from natural light. All furniture material is recyclable whilst the lighting system utilises LED lamps, working with photovoltaic panels for signs and external lighting. A geothermal system is used to heat the building. The building uses 75% less energy than a comparable development, and has substantially reduced the amount of water that it uses. The building has obtained Energy Class A Certification (4.26 kW/m3 per year), and is the first in Europe in its category according to information submitted. Water consumption has been reduced by 40% thanks to photocells with time-sensors and dry toilets.

Relationship with the Limburg principles

The Autogrill development is a good example of how a development can be 'native to its place' through the design that is sympathetic and unobtrusive to the surrounding area. With an expansive green roof, rainwater recycling and energy efficiency measures, the development is moving towards the C2C principle of ensuring air, soil and water are healthy. Additionally, through the use of ground-source heat pumps for space heating, the fossil fuel emissions associated with the development have been markedly reduced. Utilising the sun's income is made through a design that maximises the natural lighting as well as incorporating solar panels. Recycling and waste minimisation feature heavily in the day-to-day operation of the building.

It is expected that the design and technologies featured in this development will feature in a new service station development near Milan in the near future.

The building cost approximately 20% more to build than a comparable development built to building standards, but after an estimated 5 years will have saved the difference in terms of energy consumed.

5.2.6 Volker Fitzpatrick Headquarters building, Hertfordshire, UK

Detailed description of the case

Located in Hoddesdon in Hertfordshire, Volker Fitzpatrick's new offices (built in 2008) replaced the previous headquarters that was built in the 1970s and sits on an adjacent site. The new building sits in the position of the firm's previous plant compound and builder's yard.

Using BREEAM guidance from the outset to inform the design of the new building, the new building was completed within one year of the start of construction and achieved a BREEAM 'Excellent' rating. With double the floor space of its predecessor, the new building has slashed CO2 emissions by 70% due to the wide ranging efficiency measures that were incorporated into it:

- A total of 26% recycled material was incorporated into the design;
- A final BREEAM assessment score of 78.4%;
- CO2 emissions of 27.8kg per square metre which compares very well with the previous building's 175.53kg CO2 per square metre.
- A rooftop array of solar-thermal panels provides hot water;
- Ground-sourced heat pumps provide efficient space heating and cooling;
- Rainwater harvesting for use in toilets;
- Daylight sensors control lighting to minimise energy wastage;
- Photovoltaic array contributes towards total energy demand;
- Innovative waste management system featuring an on-site baler has reduced the volume of waste leaving the building by 80%;
- The incorporation of videoconferencing facilities as well as an on-site gym means the need to travel has been reduced, with associated cost saving benefits as well.
- Non-essential electrics are shut down at night using an automated system which saves an estimated 16 tonnes of CO2 annually.

The building's exterior is designed for maximum efficiency with a sun shade or 'brise soleil' featuring on its southern face. The designers tried to maximise the opportunities for natural lighting, with even the basement floor benefitting from its incorporation. In addition to the rainwater harvesting system as

detailed above, porous paving has been used around the building to aid the retention of rainwater and help to reduce the risks posed by pluvial flooding. Internally, electronic taps have been incorporated to further aid the reduction in use of water.
Outside the building, lighting is controlled automatically so that whilst being bright during a winter evening as staff are leaving the office, later on the lights dim to 50% where they stay until 6am when daylight sensors activate to either turn off the lights in the summer or turn them up to full intensity on dark days during winter months. As well as the obvious benefits in terms of carbon emissions and reduced energy consumption, the system also helps to reduce light pollution locally. The compactor and baler, which sit outside the building, have been extremely successful in minimising the volume of waste leaving the site. All non-recyclable waste is crushed which has reduced the total of weekly skip loads from seven to just one. The success this has achieved has resulted in Volker Fitzpatrick installing similar systems at a number of their other sites.
A desire to reduce the amount of travelling undertaken by staff or for other business-related tasks led to the introduction of a number of measures to tackle it. The building was designed to include plenty of meeting space and full videoconferencing facilities to minimise the need for travel to meetings. An onsite gym and dining area again help to reduce the need for staff to travel off site, contributing to diversity of use of the building, and to the enjoyment and wellbeing of its users.
It is with regard to building services that the building has made breakthroughs. Two electrical systems power the building meaning that essential services can be left on whilst non-essential services can be shut down completely over night and at weekends. This means that consumables like computers, monitors, printers and copiers are shut down by the system between 7pm and 7am unless over-ridden by an employee.
Space heating and cooling is provided by ground source heat pumps and a total of 36 boreholes, each around 100m in depth, which transfer either warmth or cold to a refrigerant which passes through narrow pipes running within the ceiling voids. The design has delivered CO2 savings in excess of 23 tonnes annually. An intake in the nearby wood transports air through a ducted system to the office, allowing pine-scented air to circulate around the office benefitting indoor air quality.
Based on energy prices in 2007, the payback period in terms of the energy efficiency technologies incorporated is 14 years. With the increase in wholesale energy prices over the past three years, this period will have reduced notably.

Relationship with the Limburg principles

Fitzpatrick's new headquarters building highlights a wide range of low carbon initiatives delivering benefits to the company and linking well to a number of C2C principles. The use of solar energy for water heating, space heating, electricity generation and as a source of natural light collectively form an excellent example of how a commercial building can maximise current solar income. The associated reduction in greenhouse gas emissions contribute towards improved air and water quality. Also helping to ensure that impacts on air quality are kept to a minimum is the ground-source heat pump system that has been installed. Viewing waste as food is a field which many developments have difficulty demonstrating to any significant extent. However, with 26% of this building made of recycled materials, Fitzpatrick have demonstrated good progress in this discipline. The installation of an in-house gym and dining area provide staff with more choice, hopefully enabling them to better strike the right work-life balance – creating a better workplace in the process.

5.2.7 Royal Society for the Protection of Birds (RSPB) Visitor Centre, Rainham Marshes, Essex

Detailed description of the case

A varied specification had to be met in order for this multi-award winning development to meet the requirements as set out by its owners, the RSPB. The specification included having high sustainability credentials, being resistant to vandals, and a desire to achieve BREEAM 'excellent' certification.
As the new visitor centre for the RSPB at Rainham Marshes, near Purfleet in Essex, the building also had to serve as an education centre for environmental awareness. A number of additional criteria had to be met including a design that would not adversely impact the integrity of River Thames wall; a concern raised by the Environment Agency.
Funding for the project was provided by a consortium that included the Heritage Lottery Fund, the Thurrock Thames Gateway Development Corporation, the Department for Communities and Local Government, and of course the RSPB.
A relatively unusual criteria which had to be met, as highlighted above, was to ensure that the site was as 'vandal proof' as possible due to concerns over the risks of vandalism/damage caused by people living locally. Thus surrounding the visitor centre is a dry moat with drawbridges as well as shutters on the first and second floor windows.
The building should achieve, or be very close to achieving, carbon neutrality with the addition of a 15 kW wind turbine that was installed in 2009. Installing a wind turbine on a site such as this, where turbines have the potential for adverse impacts on bird species, required careful consideration. A large (50m2) photovoltaic array on the roof of the visitor centre provides in excess of 50% of the building's energy requirements. Space heating is provided by a system of ground source heat pumps incorporating six 80m deep boreholes. The building is extensively insulated with sheep's wool while the building itself was

designed to minimise air leakages through trying to create a 'sealed building envelope'. A natural ventilation and passive heating system is employed, removing the need for any air conditioning and making full use of solar heating. Thus even in summer, the building is able to maintain appropriate internal temperatures. Natural lighting therefore makes a substantial contribution towards lowering the demand for lighting systems, providing sufficient lighting for as much as 80% of working hours. The forecast annual CO2 emissions (calculated during the design phase) are only 22kg/m2.
Extensive use has been made of rainwater harvesting, with almost all water required for flushing during the first year of operation expected to be provided by rainwater. Additional water efficiency measures include low flow taps with automatic turn off and waterless urinals.
The building has won a number of different awards including the Green Apple Award, RIBA (Royal Institute of British Architects) National Awards and RIBA East of England Award amongst others. The project cost just over £2.3 million from conception to completion

Relationship with the Limburg principles
Maximising current solar income is one of the C2C attributes of this development, with natural lighting and heating being key elements of the building design. The development goes some way towards being 'native to its place' through attempts to source locally sourced construction materials. The decision to paint the exterior of the building (which is made up of sawn timber boards) in a variety of colours while being unusual does create a distinctive character that sits well within the local area. The substantial reduction in emissions compared to a conventionally designed building along with the use of rainwater harvesting contribute strongly towards achieving the Limburg principle of the air, soil and water being healthy. The design can also be seen as being 'native to its place' through needing to have as low an environmental impact as possible (especially given the ecological importance of the habitat that it is showcasing) but also through a design including locally sourced materials.

5.3 Industrial

5.3.1 Adnams, Southwold, Suffolk, UK

Detailed description of the case
Covering 4,400m2, the multi-award winning Adnams distribution centre development near Southwold has received significant national and international interest as a flagship project in sustainability in the built environment. The building is rated BREEAM Excellent and underlines a company-wide pro-active approach to environmental stewardship.

The building was designed to meet three primary objectives. The success of the development reinforces that whilst often deemed to be incompatible, the objectives below can all be achieved as the outcome of a single project:
- Minimal environmental impact;
- Maximum operational efficiency; and
- Superior returns on investment

The building features the largest green roof in the UK which, as well as helping to regulate the temperature inside the building, also provides a substantial surface area for capturing rainwater which is used internally. Rainwater is collected in underground tanks which then supply toilets and washing facilities for the distribution vehicle fleet. The roof design incorporates clear panels enabling natural light to reach the warehouse floor thus reducing the demand for electrical lighting. The walls of the warehouse were constructed using Hemcrete which has 'locked in' over 150 tonnes of CO2. Hemcrete is a combination of lime, hemp, and waste quarry material. Hemp exhibits very high insulating and environmental qualities, as well as the mechanical qualities necessary in supporting a structure such as this. The hemp used was grown in East Anglia with over 90,000 Hemcrete blocks being used in the construction.
The roof itself is supported by timber beams that have been glued and laminated (glulam) giving a 'beam-free' span of 35m for the warehouse floor. The timber was sourced in Scandinavia from managed forests which are certified to guarantee legality of logging and a high level of environmental management.
Provision of solar thermal panels allows the site to generate 80% of its hot water requirements, whilst reed beds purify waste water and also double as features that encourage biodiversity locally.

In order to minimize the extent of concrete used, the car park has been constructed using a reinforcing mesh called Golpa which is made from low-density recycled plastic. Grass grows through the mesh whilst the mesh itself provides sufficient strength for parking whilst also supporting sustainable drainage and improved control of storm waters.

Relationship with the Limburg principles
Many parallels can be drawn between this building and how C2C developments may appear in the future. Solar energy is used to help light the building naturally as well as to provide the majority of its hot

water requirements, offering a high quality example of how a development can maximise solar income. The use of Hemcrete, utilising locally produced materials, contributes towards this development being 'native to its place'. By making substantial use of rainwater, the site is minimising demands on mains water (and the impacts associated with it), and helping to minimise local impacts of the development. Additionally, extensive insulation combined with appropriate building and energy management practices are ensuring that the greenhouse gas emissions associated with the building's operation are kept as low as possible. Collectively, these help to ensure that the building demonstrates well the Limburg principle that 'the air, soil and water are healthy'. This, along with the reed beds used to filter and clean waste water, will provide opportunities to improve biodiversity, thus linking to 'celebrating diversity'.
Adnams estimate that in the region of £49,000 is saved annually on energy prices (based on 2006 prices). Additionally, the use of Hemcrete blocks over standard concrete blocks is estimated to have saved in excess of 500 tonnes of CO2.

5.4 Retrofit

5.4.1 The Foundry, Green Light Trust, Lavenham, Suffolk, UK

Detailed description of the case
The Green Light Trust (GLT) is an environmental charity based near Lavenham in Suffolk. They are involved in community engagement, environmental education and business development. It occupies a single-story timber framed redundant traction engine shed which has recently been refurbished with a key focus in sustainable development and minimising the impact on the environment.
GLT is an environmental education charity that was established in 1988. It promotes the establishment of community woodland in the UK and is actively involved in rainforest conservation work in Papua New Guinea. The centre provides the necessary training space for theoretical and practical skills in community development and sustainable woodland management. It also provides meeting rooms and office space for community use as well as environmental education.
Driven by the urgent need to expand (for example they were receiving significantly more requests for training courses than could be accommodated) and modernise, and having been previously based in a pair of Portakabins, the GLT acquired The Foundry with works commencing in 2005.

Figure 5.2: The Foundry – carbon neutral refurbishment of a former traction engine shed.

Most of the original timbers were treated and re-used during the renovation. In fact, more than 80% of the original timber frame and brick plinth were recycled into the new building. Additional material was sourced from local demolition sites. Lime was used to treat the timbers and prevent attack from beetles or problems with fungi, rather than more commonly used chemical treatment processes. Impressively, no concrete was used in the renovation. Instead, the construction team (featuring volunteers and people already involved with the GLT) utilised lime which also doubles as a fire retardant in timber-framed buildings such as this. In addition, the use of lime also greatly reduces the 'embodied' carbon footprint of the project compared to energy-intensive concrete. A final benefit of using lime is that it allows the building to 'breathe', thus reducing the risk posed by damp and moisture that could cause problems in a building using regular bricks. Indoor walls are made using wattle and daub, utilising local clays and hazel from the adjoining woodland. Rather than regular building bricks, the project made and used hemp bricks which again have a significantly reduced carbon footprint compared to bricks or concrete blocks. They also have good thermal and insulating qualities. The floor, external walls and roof are insulated

using hemp and lime which removed the need for moisture and temperature controlling plastic and foil membranes or linings that feature as part of the insulation in a conventional property. Space heating is provided by a woodchip boiler which uses wood from the Trust's coppicing work in the adjoining wood. The only water that is brought onto the site is drinking water. All other services are catered for by rainwater through a rainwater harvesting system. The site is not connected to the mains drainage or sewage systems. Instead, bark rings and a reed bed break down waste through natural processes. Water is heated by solar-thermal panels that are located on the roof of the building.

Double glazed timber windows are painted with linseed oil paint as linseed oil paints have low environmental impacts compared to conventional paints. Using timber with natural paints means the windows can be recycled at the end of their life with no adverse impacts on the environment.

Powering the site is a 15m tall 6kW wind turbine. Initial estimates expect that The Foundry will produce an excess of around 6,000 kWh of electricity which will be fed back into the national grid. The GLT's 2009 CO2 emissions report shows that the site was able to export over 2,600kWh to the national grid during the course of the year, with the total amount generated by the turbine being less than expected. Technology combined with a wide awareness amongst of staff means that water consumption is extremely low in terms of per person use annually. The Foundry won the 2006 Royal Institute of British Architects East Sustainability Award. It is a carbon neutral building, looking to become carbon positive as the project progresses.

Relationship with the Limburg principles

The Foundry exemplifies a number of the C2C principles, and sets a very high standard for low-impact, high efficiency buildings. The refurbishment can certainly be considered 'native to its place' as it is not a new building. In addition, the project made widespread use of locally sourced materials, and was built using local expertise. The project includes a good example of seeing 'waste as food' through the re-use of the existing timbers. Viewing the 'sun as our income' is demonstrated well in this case through the utilisation of solar thermal panels for water heating. A number of the initiatives included align well with the desire for 'air, soil and water to be healthy' including:

- Generation of renewable energy through an on-site wind turbine;
- The renewable generation of heat for hot water; i.e. no associated greenhouse gas emissions;
- Rainwater harvesting reduces demand on mains supplies;
- Natural filtration through the on-site reedbed allows natural processes to deal with waste whilst at the same time not contributing towards the energy demand of water treatment processes;
- Use of natural, non-energy intensive construction materials, paints and wood treatments all contributing through reduced embodied energy and greater ease of re-use in future; and
- Space heating provided by woodchip boiler avoids need for gas or electrically powered heating.

The building also showcases 'designing enjoyment for all generations' through taking a highly responsible approach to construction and operation that minimises demand on fossil fuel resources and promotes environmental stewardship and protection.

6 Cradle to Cradle in Practice – Achieving the Network's Aims now and in the future

6.1 Introduction

The perspective study and Build theme conference in Cambridge serve as a platform for discussion on the application of the Cradle to Cradle concept within the field of building design and construction. C2C is a holistic concept, and encourages a network approach to achieving projects, seeking positive outcomes for all stakeholders at all stages of the project, from conception to deconstruction and upcycling. However, it is also an ambition and will require encouragement, facilitation and a significant period of time to enable its wider uptake in the built environment.

6.2 Current good practice - achieving Cradle to Cradle buildings

As described earlier, Cradle to Cradle buildings do not yet exist. Currently C2C is not the ambition of many developers, designers or project managers. Current legislation, assessment tools and market and consumer focuses continue to drive the efficiency agenda and many would consider achieving high levels of efficiency, through for example attaining carbon neutrality for a development, to be extremely challenging. Whilst not wrong from a sustainability perspective, this is where the efficiency agenda can stifle the more holistic thinking required to unlock Cradle to Cradle solutions.

Braungart and McDonough (2002) talk of buildings like trees and cities like forests – among other things, net energy exporters and areas which purilfy their own waste water and release more pure water back to the environment. Starting from the point we are at the moment, rather than with a blank canvas, a transition to this future is likely to take a long time.

Currently, and as shown in the good practice examples, eco-effectiveness is adopted piecemeal, but where there is a business case or ambition to go beyond minimising negative impacts and to generate positives a number of organisations and individuals can be considered to be the forerunners. Energy is an area where a positive footprint is most widely achieved, but the examples above also demonstrate the use of eco-effective materials, going some way to return clean water to the environment, and to deliver positive social outcomes also. Greater integration and 'mainstreaming' of Cradle to Cradle approaches is likely to be progressed through two parallel processes.

- Firstly, good practices such as those illustrated in this study will have their positive elements combined in future schemes. Through forerunners striving to achieve the positive, ambitious outcomes Cradle to Cradle can create greater momentum, once early concepts have been proven. The eco-effective elements of buildings can be defined and combined, gradually moving more completely from eco-efficient to eco-effective.
- True achievement of Cradle to Cradle in the built environment will require a more fundamental rethink about the roles of buildings in general, and whether the types or buildings delivered now are the best means of achieving the inter-linked and mutually beneficial goals enshrined in the Cradle to Cradle philosophy.

6.3 Current challenges

A number of issues associated with the current (or 'traditional') way of doing things could present particular challenges to the widespread and successful realisation of Cradle to Cradle in the built environment. Each of the three core principles of C2C is associated with particular technical or legislative challenges, and by way of example we address several here.

In the context of the built environment, reconsidering waste as food and treating all materials as nutrients within technical or biological cycles would be made difficult by current European waste regulations, and their implementation in the member countries. Similar challenges are also likely to be experienced in many other countries. The use of solely renewable energy is limited in many areas to a small number of technologies. Many of these are also still considered 'developing' or 'unproven' despite having been in use for several decades. Particular issues with renewable energy relate to the current reliance, again in many countries, on centralised grid systems, and the constraints this can impose on different technologies becoming a significant part of the energy mix, and on the 'intermittency' associated with many renewables also (for instance, wind turbines only generate electricity when the wind blows). Many of the constituent parts of renewable energy systems, for example photovoltaic (solar) panels, contain scarce materials, and although being used beneficially cannot be considered effective until alternative materials can be found, or systems for upcycling of these materials are fully operational.

In building terms, many areas will also find that the development of diverse, multifunctional buildings are challenged by local requirements for buildings to be in keeping with the 'local vernacular' or style, or by local communities' views on alternative designs. Multifunctionality can work very well where uses are easily compatible, but issues such as security, or the need for hours of use to be more flexible for the primary occupier, can in reality limit the ability to realise positive benefits for other stakeholders.

A key element of realising eco-effectiveness is identifying and maximising multiple benefits. This includes those which do not have value which translates easily into traditional financial terms, or where slight benefits are accrued by a large number of people. Within the prevailing financial system, and benefit:cost models, incorporating these into a business case requires careful consideration. Where a developer is just paying extra in order that others can benefit, a scheme is less likely to be progressed, but if the business case can be made positive for all it can enable the development. However this remains a current challenge. Linked to this, early-adopters to eco-effectiveness may also find that current financial systems stifle their ambition. Insurance and mortgage companies are traditionally averse to 'non-standard' buildings and approaches which they perceive as higher risk (within a traditional economic sense). As such there is a potential blockage, or at least disincentive to being in the early transition phase. Here again there is a potential role for government encouragement and intervention.
Traditional views on the roles and responsibilities of developers remain a potential blockage. For instance, developers do not generally want to become involved in ongoing energy production or utility provision. They therefore have no incentive for paying the capital costs for the embedded infrastructure that would be required to enable this in a cost-effective way.

Mechanisms such as Energy Services Companies (ESCos) and Multi-utility Services Companies (MuSCos) do exist, and can enable partnerships between developers and inhabitants/occupiers. Through these developers will incorporate the infrastructure necessary in an area for a private or community-owned organisation to subsequently produce and sell energy or other utilities, paying back the capital investment whilst also benefiting from local supply and control. However such schemes are in their early stages and, whilst providing a potential model for the future, are receiving only limited support from the market place
Finally, and whilst it is not the ambition of the Network to establish means of determining, or even quantifying, how Cradle to Cradle something is, this may be a consideration for the market. Consumers with the ambition of being eco-effective or Cradle to Cradle will either need to be well-informed about the principles and the ways in which they can be adopted, or will look to third-party verification. Several broad frameworks do exist, including the recently-released qualitative criteria for the built environment produced by Michael Braungart and Douglas Mulhall. However, assessment criteria, particularly when considering complex issues such as building design, seem also to go against the ethos of Cradle to Cradle. Certainly at the present time, achieving a C2C development is as much about the ambition and the process as it is about the actual building. It is about seeking the direct and indirect positive outcomes that can be achieved from a project, and focusing on achieving these wherever possible. Quantitatively comparing one development against another, of a different type, in a different location, with different potential and realised benefits will be a significant challenge.

6.4 Opportunities

This study and the initial phases of the C2CN activity have highlighted several further principles or considerations which we feel can help to enable the uptake of eco-effective approaches.
First among these is simply the critical importance of setting out with the positive ambition – aiming to be 'good', and to create benefits, rather than to be 'less bad'.
Secondly, there is no one size fits all approach. Although this study has highlighted a range of good practice studies one of the clear conclusions is the range of ways in which they achieve similar broad ambitions. Within C2C diversity should be celebrated – as a result it is not possible to identify the way in which C2C can be delivered. In order to realise the greatest benefits from a building it must be designed, constructed and operated with a mind to its local situation and the networks it can draw upon, benefit and create.

Linked to this, whilst C2C encourages innovation, some of the solutions presented at the conference and in this study may be more traditional, low-tech approaches. However, they need not necessarily be so, unless that is the most positive approach in a given situation (native to place).
It is therefore important to think of C2C in terms of systems and processes rather than products. C2C buildings are therefore those which accord with the principles, rather than one which is necessarily built with C2C-certified products. Such certification or other form of validation may yet have a role, however, since benefits and disbenefits throughout the supply chain must be considered to ensure the overall outcome is positive. This fundamental need to consider multiple potential areas of benefit indicates the strong need for collaboration between different sectors and for a range of different disciplines to be represented within individual project teams. At the start of a project client/developer objectives and constraints should be identified, to define realistic and acceptable boundaries to the project. Within this multi-disciplinary teams can identify and work to realise a wide range of positive outcomes.

Finally, and as suggested throughout this document there is general acceptance that efficient and effective solutions can be complementary through a period of transition, but that this transition will increasingly require a focus on different and new processes, encouraging greater ambition and realisation of benefits by demonstrating and updating good practices.
A strong output from the Cambridge conference was the importance of inspiring cases to lead the way for others and encourage their high ambitions. The successes of forerunner projects should be highlighted widely to provide such inspiration and guidance. These could include not only architects and designers, but also policy-makers and others whose remit includes elements which could enable and encourage eco-effectiveness.
The C2CN itself can play a role here, through the production of this study and those looking at other thematic areas, and the overarching good practice guide. It also has the intention to inform and influence future legislation both at the European level and at national level, through the development and implementation of regional action plans, as summarised below.

6.5 Beyond the perspective study – what now

Following the completion of the Theoretical Framework document, the perspective studies linked to each of the four C2CN themes, and the accompanying good practice handbook, the Network's activities move into the next phase.
Through 2011 Network members will focus on the transferability of the good practice examples presented, or elements of them, and identify ways in which different regions might benefit from each others' experience and learning to date. Alongside transferring good practice between the ten partner regions, each Network member will also be developing a regional action plan for C2C, building on the findings of the perspective studies and providing a basis for supporting and driving the ambitions of the Network within the individual member states.

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The Cradle to Cradle Network (C2CN) is an Interreg IV C capitalisation project consisting of ten partners from ten European regions which aims to reduce raw materials' utilisation, to generate less waste and less environmental pollution, as well as to enhance innovation and economic development.

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