Translate the Cradle to Cradle Principles for a Building

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Abstract
Various guidelines for Cradle to Cradle in the built environment were established since 1992. However, it's not clear how the Cradle to Cradle principles can be translated to the realization of a building. This paper contains information from literature with a focus on applying the Cradle to Cradle principles in building design and -construction. Also results of interviews with experts and directly involved stakeholders, about applying the Cradle to Cradle principles in the built environment will be provided. Specifically a number of aspects and desired results will be addressed, which seem to be essential in the realization of a building.

Keywords:
Cradle to Cradle, building, eco-effectiveness, continuous cycle, built environment

1 INTRODUCTION

For several decades there has been a discussion in the scientific literature about sustainable development in the built environment. Even today there is still a lot of confusion about what sustainable development really means, and how developments in this category are interrelated. The same applies to the more recent Cradle to Cradle approach. In the book Cradle to Cradle, Remaking The Way We Make Things, an approach is introduced that distinguishes biological- and technological cycles without quality loss of raw material [Braungart and McDonough, 2002]. Residues become raw materials for a subsequent metabolism. By distinguishing biological - and technological material cycles, Cradle to Cradle introduced a unique form of closing material cycles, with the elimination of waste.

Braungart and McDonough have defined three basic principles that are essential to make a true transition towards sustainable society. The following three basic principles are being applied:

1. Waste equals Food, Everything is a Nutrient for Something Else;
2. Use Current Solar Income, Energy that can be Renewed as it is Used;
3. Celebrate Diversity, Species, Cultural and Innovation Diversity.

Various guidelines for Cradle to Cradle in the built environment were established since 1992 through published declarations such as the Hannover Principles and more recently in The Netherlands, the Almere Principles and the Floriade Venlo Principles.

The Cherry Tree is often used as a metaphor for a Cradle to Cradle building: Imagine buildings that harvest the energy of the sun, sequester carbon, make oxygen, distill water, provide habitat for thousands of species as well as generate more energy than they consume.

However, it's not clear how the Cradle to Cradle principles can be translated to the realization of a building. Specifically, in this paper a number of criteria that seem to be essential in the design and realization of a building will be addressed. The findings of this paper result in a further concretization of the Cradle to Cradle principles into aspects and desired results for the design and realization of buildings. This paper focuses on the Cradle to Cradle development and implementation in the built environment in the Netherlands.

2 LITERATURE

Warnings have been sounded around the world since the 1960s about the deterioration of the environment. Partly because of these warnings, numerous proposals have been made from the 1960s onwards for a worldwide approach to existing and predicted environmental problems. The first examples of these are the World Conservation Strategy by the International Union for Conservation of Nature (IUCN) in 1980, and the Brundtland Report by the World Commission on Environment and Development (WCED) in 1987. Both reports advocate a departure from non-sustainable consumption and production in favor of sustainable development. The Brundtland Report defines sustainable development as a form of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Since then, awareness of the global environmental problems has clearly increased. Among the results has been the formation of a number of lines of thinking aimed at contributing to the reduction – and ideally the complete elimination – of environmental problems. Figure 1 gives a chronological overview of important schools of thought in relation to sustainable development. The timeline also refers to major environmental disasters in the same period.

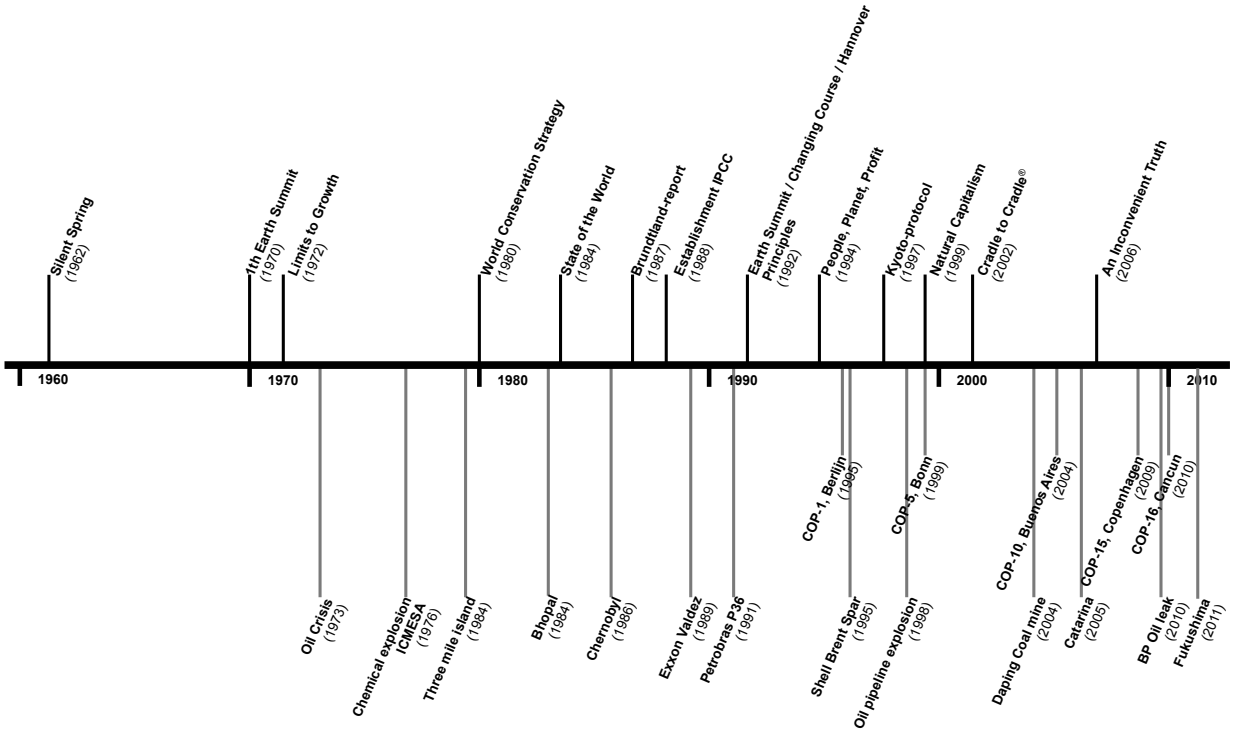

Figure 1: Overview of important schools of thought in relation to sustainable development, including major environmental disasters.

2.1 From eco-efficient towards eco-effective and eco-efficient sustainable development

Following the Earth Summit in Rio de Janeiro (1992), the question arose of what the possible contribution of industry could be to achieving sustainable development. Eco-efficiency aims to reconcile environment and economy by producing more from less: using minimal resources to work at lower cost and in a more environment-friendly way. The core of eco-efficiency can be summarized as: 'get more from less'. More products or services with less waste, less use of materials and lower harmful emissions.

After this Earth Summit, fifty of the world's largest companies analyzed the applicability of the concept of sustainable development. In the book Changing Course, these companies introduced a strategy to achieve this sustainable development. This strategy followed an eco-efficient approach, defined as companies that continuously create more usable products and services – that add value – while also continuously reducing the consumption of resources and the production of emissions [Schmidheiny, 1992]. In line with the above definition, the World Business Council for Sustainable Development (WBCSD) investigated the application of eco-efficiency in industry and reached the following definition: eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity [WBCSD, 2000]. Based on the strategy of eco-efficiency, innovative strategies have been developed focusing on reduction and compensation of harmful effects on the environment.

Out of concern about the lack of completeness of the concept of eco-efficiency, McDonough and Braungart came up with a response with the introduction of the concept of eco-effectiveness in 2002. Eco-efficiency delays environmental pollution and the exhaustion of natural resources. An eco-efficient approach would allow the use of fossil fuels to be minimized, but it will never be possible to eliminate their use completely. A total solution requires a new paradigm. Simply reducing the problem will never solve it completely, and will also limit freedom of trade and growth opportunities. Less bad is still not good, according to McDonough and Braungart. Eco-effectiveness is based on a continuous-cycle approach, in which materials are used in new products, processes and objects in a way that they are 100% recyclable or even upcyclable, and in which the energy for all activities must be renewable. Eco-effectiveness causes no adverse effects in relation to a sustainable development. To work effectively towards sustainability, an eco-effective approach is essential to achieve positive effects in a range of areas. A certain level of eco-efficiency can certainly be valuable in an effective system. Eco-efficiency can also be valuable as a transitional strategy towards an eco-effective system.

2.2 Application of the Cradle to Cradle approach in the built environment

The past decades have seen repeated scientifically based warnings about the deterioration of the environment. A number of scientific studies have by now made it clear that – with 90% certainty – greenhouse gas emissions resulting from human actions are having a negative impact on the environment. As a reaction to these warnings, numerous initiatives have been taken around the world to achieve sustainable development.

As far as the built environment is concerned, these initiatives have focused primarily on finding alternative solutions for ways to generate- and use energy, the selection and use of resources and materials, and the development and implementation of alternative principles in the design of buildings.

The application of the Cradle to Cradle principles however would require a paradigm shift in the way designers, builders and owners understand the future value of the building and materials, as well as ownership and life cycle processing. The application of the Cradle to Cradle principles and an eco-effective approach in the built environment is taking off very slowly. One important reason for this is the lack of government policy to promote the use of materials in continuous cycles, without harmful effects on the environment. There is also still a lack of awareness in the building industry of ecological and/or economic aspects (see e.g. European Commission, 2010). These are important prerequisites for the successful implementation of the continuous-cycle principle in the building industry. A third factor is the lack of design knowledge and experience, and possibly also the will, to design a building based on the needs of the user that meets the Cradle to Cradle requirements. This would mean a design of a building that can be adapted or deconstructed with full re-use of the materials (of which it is made), and in which the energy supply is based on renewable energy, and has value for the stakeholders.

To make these changes in the building process, a change in the mindset of designers is the most important requirement. As William McDonough says: We need to take the filters from our pipes and put them in our designers' heads (McLennan, 2004).

2.3 Cradle to Cradle Criteria for the Built Environment

The various guidelines for Cradle to Cradle in the built environment, such as the Hannover Principles, Almere Principles and Floriade Venlo Principles, give direction to the implementation of Cradle to Cradle principles in practice, but will only be effective when they can be measurably demonstrated.

In 2010, Mulhall and Braungart introduced Cradle to Cradle criteria for the built environment. The following definition of a Cradle to Cradle building is given: A Cradle to Cradle 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 [Mulhall and Braungart, 2010]. The three basic principles of Cradle to Cradle and the definition of a Cradle to Cradle building have been translated into criteria for the built environment by Mulhall and Braungart (Table 1).

A critical note that should be made is, that based on the criteria in table 1, it will not be possible to determine to what extent a building meets the Cradle to Cradle principles. A first reason is the lack of a practical and specific expression of the Cradle to Cradle principles for a building. Without such a concretization it is not possible to make an informed decision whether a building is, or is not, designed according to the Cradle to Cradle principles. The criteria are more general guidelines and recommendations that can be used during the design and realization of a building, whereby it is unclear whether a building complies the Cradle to Cradle-principles or not.

It is also unclear to which qualities or quantities a building can be measured. How can be demonstrated if a building meets the Cradle to Cradle principles? These observations have given rise to the practical translation of the Cradle to Cradle principles for a building.

3 METHODOLOGY

In the first phase, an inventory was made of the most important aspects, that are appointed in literature, to realize a building according to the Cradle to Cradle principles. The literature survey focuses on the period from 1992 to 2012. The Hannover Principles: Design for Sustainability, were formulated in 1992 by McDonough and Braungart as development guidelines for the World Expo 2000 in Hanover. Studies on the application of the Cradle to Cradle approach has frequently occurred in recent years. Different contributions are presented in publications by McDonough and Braungart (1992, 2003a, 2003b, 2006, 2009) and Mulhall and Braungart (2010). Developments in the Netherlands are presented in publications of Build Desk (2009), Royal Haskoning (2009), SenterNovem (2009), Ministry of Transport, Public Works and Water Management (2010), Delta Development Group (2010) and TNO Building and Construction (2010).

Secondly, interview sessions with nineteen professionals in the field of Cradle to Cradle applications were conducted. The respondents were asked to reflect on their experiences with implementing the Cradle to Cradle principles in practice and what they considered as the main challenges for realizing a building in line with the Cradle to Cradle principles. Besides being experienced in the design and building process, respondents satisfied at least one of the following criteria:

- Has successfully completed an official Cradle to Cradle training, or;
- Is Cradle to Cradle Certified Consultant, or;
- Is sustainability manager at a company that produces or markets Cradle to Cradle Certified products, or;
- Participates in a building project with defined Cradle to Cradle ambitions.

Table 1: Criteria for the built environment based on the defining Cradle to Cradle Principles.

C2C Principle	Criteria
Waste = Food, Everything is a Nutrient for Something Else	Define Materials and Their Intended use Pathways
	Integrate Biological Nutrients
	Enhance Air and Climate Quality
	Enhance Water Quality
Use the Sun, Energy that can be Renewed as it is Used	Integrate Renewable Energy
Celebrate Diversity, Species, Cultural, and Innovation Diversity	Actively Support Biodiversity
	Celebrate Conceptual Diversity with Innovation

The literature study and interviews resulted in a further concretization of the Cradle to Cradle principles for a building and the development of a framework with aspects and desired results that seem to be important to realize a building according to the Cradle to Cradle principles.

4 RESULTS

In this section the identified aspects will be translated into desired. A result is considered as a desired outcome of the defined aspect. The aspects and results that seem to be important to realize a building based on the Cradle to Cradle principles are summarized in table 2. The aspects can be used to provide guidance to design- and construction teams to gain focus by the implementation of the Cradle to Cradle principles into practice.

According to professionals there is a need to translate the Cradle to Cradle principles into practice, by developing practical guidelines for the built environment. These guidelines should give direction to the decision making process in both the design and realization process.

4.1 Aspects based on C2C-Principles 1: Waste equals Food

Consider aspect 1; define materials and their intended pathways. From a Cradle to Cradle perspective, materials and products are conceived for either a biological- or technological pathway. A product or material can be analyzed based on the Cradle to Cradle Design Protocol to define the quality and content from manufacturing through use and recovery. These analyzed products and materials are selected for application in a building. The use of recycled or renewable content is only desirable when the quality and content of materials are defined. Cradle to Cradle assumes recycling in case the reuse of raw materials has positive impacts on the environment without loss of quality; nutrients become raw materials for something else. Finally, products and materials need to be selected based on their intended use and impact for the users and the surrounding.

The second aspect concerns the integration of biomass production in a building, landscape or spatial plan. From an eco-effective point of view, a building has a positive impact on it's surrounding. Biological nutrients can be integrated to generate more biomass, topsoil and clean water than before the development of the site.

Enhance both the quality of air and water are complementary, and follows from the Waste equals Food principle of nature's design. A building should measurably improve outdoor air quality, so the air becomes healthier than before development and uses climate changes gasses as nutrient. Also, a building enhances interior air quality to provide a healthy and comfortable climate for occupants and users. The building will measurably improve the quality of water, so the water becomes healthier for biological metabolisms than before it entered the building.

4.2 Aspects based on C2C-Principles 2: Use the Sun

Nature thrives on the energy of the sun. Despite recent warnings and developments, human energy systems can hardly be called effective. The Cradle to Cradle approach is based on current solar income. Forms of renewable energy are wind, geothermal, biomass (as long it has no adverse effect on the foods supply), hydropower, and solar energy. To create a positive impact on the environment, the building and its site should generate more renewable energy than the building uses. Energy-efficiency can be used to introduce renewable energy rather than reducing the use of fossil fuels; exergy can be used as a way to guide energy effectiveness. In case a building and its site can not meet the energy demand with renewable energy sources, the possibility should remain to integrate innovative solutions in the near future to work towards an energy positive building. Monitoring the energy consumption and –production of renewable energy can be used for further development towards the defined goal.

4.3 Aspects based on C2C-Principle 3: Celebrate Diversity

Healthy ecosystems are complex communities of living things. When a building is realized according to the Cradle to Cradle principles, it should be tailor designed to maximize the added value on the surrounding. Consider the aspect of actively supporting biodiversity. This aspect can be described as a building that supports more species diversity than before development. A second form of diversity that can be distinguished is conceptual diversity. Conceptual diversity can be demonstrated by focusing on special beneficial features of a building and integrating innovative elements that are beneficial for the well being of occupants and the environment.

Buildings that are designed based on the Cradle to Cradle principles have positive impacts on it's surrounding and stakeholders. This can be achieved through a description of what Cradle to Cradle elements practically do for the users and stakeholders.

4.4 Other appointed aspects

From both the literature as well as the interviews can be concluded that, in addition to the principle criteria, at least four aspects seem to be important to realize a building according the Cradle to Cradle principles. Firstly, organize *reverse logistics* of defined products and materials, whereby a material pool is developed with diverse industries. Hereby, materials can safely return to a biological- or technological cycle after the use-time or lifecycle without quality loss. To create continuous metabolisms, the building should be adaptable and deconstructable from use through recovery without demolition waste, also known as *Designed for (Dis)assembly*. Therefore, a plan to deconstruct building elements, products and materials is necessary. During the use-time of a building several transformations are made or functions will change. A study of Brand [1994] shows the number of times that materials and systems are adjusted during the use-time of a building. Brand suggests that during the use time of a construction the facade will be adapted at least once, while the furniture is replaced up to seven times. To safely return all products and materials in a biological- or technological pathway, the intended *use-time* of the building, product and material has to be defined. A fourth aspect that seems to be important in realizing a building according to the Cradle to Cradle principles is enhancing *environmental qualities*. How can a building have a measurable positive impact on the surrounded area? Through the realization of a building, the quality of the surrounding is healthier than before predevelopment conditions.

Table 2: Aspects and desired results that seems to be important by realizing a building.

	Aspects and Desired Results
Waste equals Food	**1. Define materials and their intended pathways**
	1.1 Materials and products can safely return in a biological- or technological pathway, without quality loss;
	1.2 Cradle to Cradle Certified Products and Materials are applied in the building;
	1.3 Material contents come from renewable or recycled materials;
	1.4 The design- and construction team assessed applied products and materials in the building on their intended use and impact for its users and the surrounding.
	2. Integrate Biomass Production
	2.1 More biomass, topsoil and clean water is generated by the building than before the development of the site.
	3. Enhance Air and Climate Quality
	3.1 The outdoor air quality is improved by the building so the air becomes healthier than before development and climate change gases are used to produce biomass;
	3.2 The indoor air quality is healthy and comfortable for occupants and users.
	4. Enhance Water Quality
	4.1 The quality of water is improved by the building and healthier than before it entered the building;
Use the Sun	**5. Integrate Renewable Energy**
	5.1 More renewable energy is generated by the building and it's site than the building uses;
	5.2 Energy-efficiency is used to introduce renewable energy rather than reducing fossil fuels;
	5.3 Exergy is used as a way to guide energy effectiveness;
	5.4 Innovative techniques to produce renewable energy are integrated;
	5.5 A monitoring system that measures the energy consumption and -production is used.
Diversity	**6. Biodiversity**
	6.1 Biodiversity is increased by the building.
	7. Conceptual Diversity
	7.1 Innovative elements of the building are beneficial for the well being of occupants and the environment.
Other appointed Aspects	**8. Organize Reverse Logistics**
	8.1 Supply and discharge of defined materials and products is organized.
	9. Design for (Dis)Assembly
	9.1 A plan to deconstruct building elements, products or materials without demolition waste is made;
	9.2 The building can be adapted without demolition waste.
	10. Define Intended Use Periods
	10.1 Intended Use Periods of the Building, Products and Materials are defined.
	11. Enhance Environmental Qualities
	11.1 The building improves the quality of the building surrounding;
	11.2 The quality of the Top Soil is improved by the building (including green roofs).

5 DISCUSSION

The previous sections have outlined the development of increasing attention for the Cradle to Cradle implementation in the built environment. The Cradle to Cradle approach takes an important step towards the transition from a linear to a cyclic system of resource use, without adverse effects for the environment. To grow towards sustainability, an eco-effective approach is essential to achieve positive effects in a range of areas. A certain level of eco-efficiency can certainly be valuable when it is implemented in an effective system. Eco-efficiency can also be valuable as a transitional strategy towards an effective system. However, the application of eco-effectiveness and the continuous cycles principles takes off very slowly in the built environment. One important reason is the lack of knowledge about the application of the Cradle to Cradle principles into practice. If eighty percent of the negative consequences on the environment can be foreseen in the early design stage [Thackara, 2005], the practical translation of the Cradle to Cradle principles can play a fundamental role in the design- and realization of buildings with positive impacts on the environment.

In this paper a practical framework is developed that translates the Cradle to Cradle principles for the design and realization of a building. In 2010, Mulhall and Braungart introduced a first attempt to translate the Cradle to Cradle principles in criteria for the built environment. The proposed approach contributes in the transition of the building industry towards continuous material cycles without quality loss and the use of renewable energy only. However, based on the defined criteria, it will not be possible to determine whether a building is designed and build according to the Cradle to Cradle principles. Without such a concretization it is not possible to make an informed decision whether a building is, or is not, designed according to the Cradle to Cradle principles. These observations have given rise to the practical translation of the Cradle to Cradle principles for a building. An inventory of literature and interviews with professionals show that the defined guidelines and recommendations of Mulhall and Braungart are a first step towards building criteria, but requires a further practical translation.

Therefore, the Cradle to Cradle principles are concretized in a framework with aspects and results that should guaranty desired design and construction outcomes when developing a building. However, based on the described aspects and desired results, it is still impossible to indicate whether the building is designed or build according to the Cradle to Cradle principles. When does a building complies with the described aspects and desirable outcomes? In further research we will translate the described aspects and results into performance indicators and measurable units. A measurable unit is a dimension, size or quantity of the concerned result related to the Cradle to Cradle principles.

In further research, case studies will be used to analyse to what extent they meet the aspects and desired results. The new City Hall Venlo (the Netherlands) will be used as one of the case studies. The design of City Hall Venlo is inspired by the Cradle to Cradle principles. The purpose of further research is to investigate to what extent the framework is seen as accurate, complete and practical in the design and construction of a building.

To determine whether a building complies with the Cradle to Cradle principles is just a first step. Further on the implementation of the aspects into practice is a second important step. Subsequently a strategy will be developed and tested to integrate and implement the aspects and desired results in the design- and building process.

6 REFERENCES

[1] Braungart, M., McDonough, W., 2002, Cradle to Cradle: Remake The Way We Make Things, New York, North Point Press.

[2] Braungart, M., McDonough, W., 1992, The Hannover Principles, Design for Sustainability. Charlottesville, McDonough and Partners.

[3] Feddes, F., Duijvesteijn, A., 2008, The Almere Principles, Bussum, Uitgeverij Thoth.

[4] Regio Venlo, 2009, The Venlo Floriade Principles, Venlo, Drukkerij Knoops.

[5] Westerlo, B. van de, 2011, Sustainable Development and the Cradle to Cradle-Approach, Venlo, Océ Technologies.

[6] IUCN, 1980, World Conservation Strategy, Switserland, Union for Conservation of Nature and Natural Resources.

[7] WCED, 1987, Our Common Future, Oxford, Oxford University Press.

[8] Johnson, S.P., 1993, The Earth Summit, Dordrect, Kluwer Academic.

[9] Schmidheiny, S. 1992, Changing Course, London, MIT Press.

[10] WBCSD, 2000, Eco-Efficiency: creating more value with less impact, Switserland, WBCSD.

[11] Metz, B., et al., 2007, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press.

[12] European Commission, 2010, Critical raw materials for the EU, European Commission Enterprise and Industry.

[13] McLennan, J.F., 2004, The philosophy of sustainable design, ECOtone publishing company.

[14] Mulhall, D., Braungart, M., 2010, Cradle to Cradle for the Built Environment, Venlo, Knoops Eco-Printing.

[15] McDonough, W., Braungart, M., 2003a, Towards a sustaining architecture for the 21st century.

[16] McDonough, W., Braungart, M., 2003b, Applying the principles of green engineering to Cradle to Cradle design.

[17] McDonough, W., Braungart, M., 2006, Cradle to Cradle design: creating healthy emission.

[18] Braungart, M., McDonough, W., 2009, Cradle to Cradle Building Charter.

[19] Hoogers, A., Veldhuisen, S., 2009, Ontwerprichtlijnen volgens de Venlo Floriade Principles.

[20] Royal Haskoning, 2009, Leading by Example

[21] SenterNovem, 2009, De Cradle to Cradle kaart voor de bouw.

[22] Ministry of Transport, Public Works and Water Management, 2010, Ambities vernieuwing Rijnstraat 8.

[23] Delta Development Group, Volker Wessels, Reggeborgh Group, 2010, Towards A Cradle to Cradle Park 20|20.

[24] TNO Bouw en Ondergrond, 2010, Aanzet tot C2C gebouwprestatiecriteria.

[25] Brand, S., 2004, How Buildings Learn: What happens after they're built, Viking Press.