SUSTAINABLE DEVELOPMENT AND THE CRADLE TO CRADLE® APPROACH

A literature study of the opportunities to apply the Cradle to Cradle® approach in the built environment

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UNIVERSITEIT TWENTE.

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Contents

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. This review aims to provide a literature study of sustainable development in the built environment, and to identify the most important underlying principles.

The literature study contains information from articles published in scientific and professional journals searched using ScienceDirect, Google Scholar and the 3TU catalog. The review focuses on the period from 1962 to 2010. 1962 was the year in which, in an important scientific contribution, Rachel Carson published her concerns about the increasing pollution of the environment.

This review provides a literature study of sustainable development in the built environment, including the associated reference framework and basic principles of the different lines of thinking. Attention will be given specifically to the most recent Cradle to Cradle® approach, which takes an important step towards the transition from a linear to a closed-cycle system, without harmful effects on the environment.

This literature study formed part of the Construction Management and Engineering research program at the University of Twente. This research program has an interdisciplinary approach, focusing on the development of innovative solutions for building. Attention for sustainable development in building forms an essential part of the research program. The subject-oriented approach, close links with practice and emphasis on the integration of disciplines are important distinguishing features of this research program to improve the performance of the building industry.

1.1 Research questions

This literature study focused on the following research questions:

1. What have been the most important lines of thinking in sustainable development during the past 50 years?
2. Which basic principles and reference framework are associated with efficient sustainable development?
3. Which basic principles and reference framework are associated with effective sustainable development?
4. What are the principles of the Cradle to Cradle® approach?
5. Which policy initiatives to promote a sustainable society have been taken in the past 50 years by the United Nations, the European Union and the Dutch government?
6. Which methods, techniques and policy instruments are now available in relation to the realization of sustainable development in the built environment?
7. What are the scientific challenges to the realization of efficient and effective sustainable development in the built environment?

1.2 Methodology

In the first phase a literature study was carried out into the most important lines of thinking in sustainable development. Much research into sustainable development has been performed in recent decades. Important developments are presented in publications by Carson (1962), Meadows (1972), WCED (1987), Johnson (1993), Greadel (1995), Elkington (1998), Hawkens *et al.* (1999), Braungart & McDonough (2002) and Gore (2006).
The keywords which sources in the literature study had to contain are: sustainable development, sustainability, Eco-Efficiency and environmental problem, in the period from 1962 to mid-2010.

Secondly, a literature study was carried out into which policy initiatives to promote a sustainable society have been taken by the United Nations, the European Union and the Dutch government. A literature study was also carried out into the available methods, technologies and policy instruments for a sustainable built environment.
The keywords which sources in the literature study had to contain are: sustainable development, sustainability, policy and built environment, in the period up to 2010.

Thirdly, a literature study was carried out into the essential principles of the Cradle to Cradle® approach. This literature study covers relevant publications and related conference proceedings. Important Cradle to Cradle® development are presented in the publications by Braungart & McDonough (1992; 2002 & 2007).
The literature study allows the basic principles and reference framework of Cradle to Cradle® approach to be investigated. The keywords which sources in the literature study had to contain are: Cradle to Cradle®, Eco-Effectiveness and built environment, in the period from 1992, the year in which the Hannover Principles were published, up to mid-2010.

The findings of this literature study lead to an overview of sustainable development in the built environment. Finally, this literature study is analysed. The analysis leads to scientific challenges for the implementation and development of the closed-cycle approach in the built environment.

2 Sustainable development timeline

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 1980s 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 problem 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.
Using a timeline (see fig. 2.1), this section gives a chronological overview of the most important lines of thinking in relation to sustainable development. The timeline also refers to major environmental disasters in the same period.

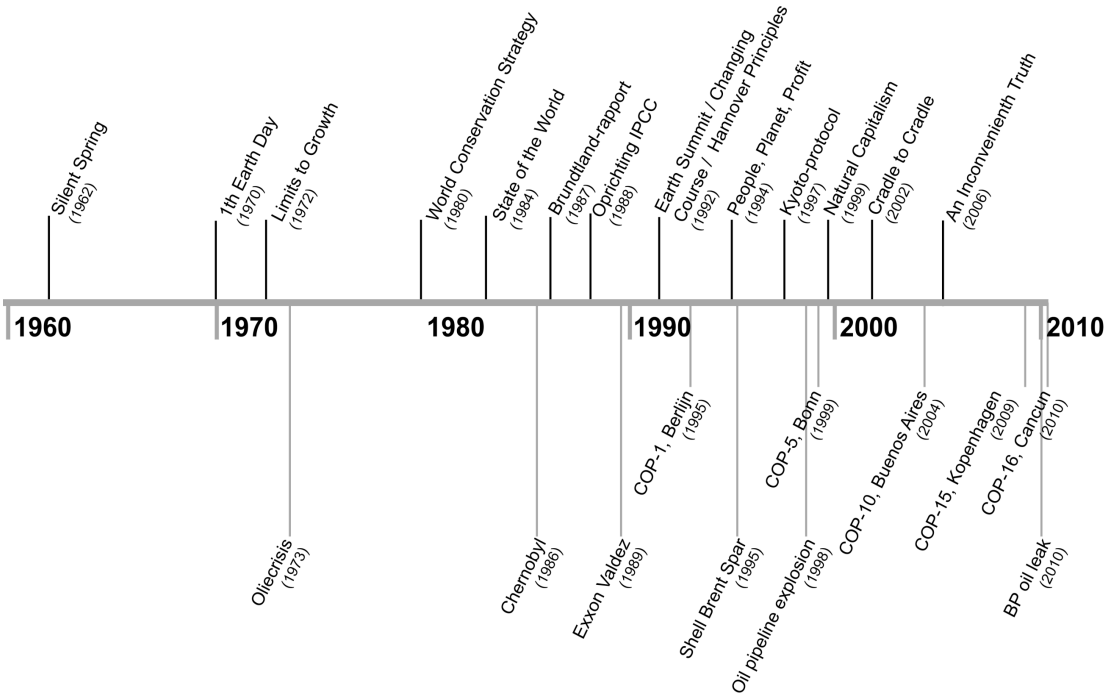


Fig. 2.1. Overview of the most important lines of thinking in relation to sustainable development.

1962 Silent Spring – Rachel Carson.
The book *Silent Spring* made an important scientific contribution to public concern about environmental pollution, caused mainly by the use of pesticides. The book describes and documents the harmful effects of pesticides on the environment (Carson, 1962).

1970 1st Earth Day – Gaylord Nelson.
The former US senator Gaylord Nelson started the idea of making the world population aware of its own consumer behavior and the resulting impact on the environment. Since 1970, Earth Day has been held in more than 175 countries on 22 April each year (World Resources Institute, 2010).

1972 Limits to Growth – Club of Rome.

This publication, ordered by the Club of Rome, focuses attention on topics including the problem of depletion of the earth's resources. The study is based on information from the period 1900 to 1970, and shows the consequences of growth trends in areas including population, pollution, industrialization, food production and depletion of fossil fuels. *Limits to Growth* suggests that if the present growth trends continue the earth will no longer be able to meet demands for natural resources by around 2100 (Meadows, 1972).

1980 World Conservation Strategy (WCS) – International Union for the Conservation of Nature and Natural Resources (IUCN).

The aim of the WCS is 'to help advance the achievement of sustainable development through the conservation of living resources. The concept of sustainability arose in the context of fisheries and forestry. The concept was first introduced by the IUCN as 'sustainable development' during an international forum (IUCN, 1980).

1984 State of the World – Worldwatch Institute.

Each year the Worldwatch Institute publishes a new *State of the World* book. The Worldwatch Institute is a renowned interdisciplinary research institute, and reports annually on the state of the environment (Starke, 1984).

1987 Brundtland Report – United Nations.

The UN commission, chaired by the then Norwegian Prime Minister Gro Harlem Brundtland, published the report *Our Common Future* in 1987. *Our Common Future* is better known as the Brundtland Report, and gives the following definition of sustainable development (WCED, 1987):

> 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

1988 Formation of the IPCC – United Nations.

In 1988 the United Nations set up the Intergovernmental Panel on Climate Change (IPCC) to assess the risks of climate change and, based on scientific data, to publish these impartially. Its published reports are considered as works of reference for policy-makers, scientists, specialists and researchers (IPCC, 1990).

1992 Earth Summit – United Nations.

The United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro in June 1992. The Earth Summit resulted in the climate and biodiversity treaty. Also drawn up at the first Earth Summit – and of a less binding nature – were the Forest Principles, Rio Declaration on Environment and Development and Agenda 21. Agenda 21 states international actions towards sustainable development in the 21st century. The most important decision-making body in the climate treaty is the Conference of the Parties (COP), in which all parties to the convention meet annually to discuss progress (Johnson,1993).

1992 Changing Course – Stephan Schmidheiny.

Following the Earth Summit in Rio de Janeiro, the question arose of what possible contribution industry could make to the achievement of sustainable development. The book *Changing Course* authored by Stephan Schmidheiny together with the World Business Council for Sustainable Development (WBCSD) presents the concept of eco-efficiency. In many cases ecology and economy are regarded as opposites. As a result, decisions are frequently taken that benefit the economy and employment, but are highly environment-unfriendly. The opposite is also the case: measures are sometimes put forward that are intended to benefit the environment, but do not take into account either cost price or economically better alternatives. Eco-efficiency therefore 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 (Schmidheiny, 1992).

1992 Hannover Principles – Braungart & McDonough.

The *Hannover Principles of Design: Design for Sustainability* was written in 1992 by Braungart and McDonough as a guide to development for the Expo2000 World's Fair in Hannover. It presents guidelines for the design of the built environment, taking into account future effects on the environment, society and sustainable growth in the longer term (McDonough & Braungart, 1992).

1994 People, Planet, Profit – John Elkington.

John Elkington introduced the Triple Bottom Line (TBL) in 1994 in which equal emphasis is placed on the social, ecological and economic dimensions, better known as People, Planet, Profit (Elkington, 1998).

These three factors have been adopted by numerous companies as a guideline for Corporate Social Responsibility. For the 2002 Earth Summit in Johannesburg, the P of Profit was changed to Prosperity, to include not only profit in the economic sense but also the benefit to society at large.

1997 Kyoto Protocol – United Nations.

Following the first Earth Summit, the Kyoto Protocol was drawn up by 179 countries in Japan during COP-3. Preparations for this were made during COP-1 (1995, Berlin) for further development, and during COP-2 (1996, Geneva) the scientific basis was laid for the protocol by means of a second IPCC report. The protocol forms part of the climate treaty, which sets out the goals for further reduction of greenhouse gas emissions (United Nations, 1998).

1999 Natural Capitalism – Hawken, Lovins & Lovins.

In *Natural Capitalism, creating the Next Industrial Revolution*, the authors emphasize the interrelationship of ecology and economy. According to *Natural Capitalism* the earth can only continue to function properly by recognition of the essential relationship between ecology and economy. Ecological economics is an academic research area that focuses on investigating the influence of and the interrelationship between ecology and economy. An important scientific challenge in the ecological economy is the question of how to build up a functioning economy in a specific ecosystem without damaging that ecosystem (Hawken *et al.*, 1999).

2002 Cradle to Cradle® – William McDonough & Michael Braungart.

In the book *Cradle to Cradle®: Remaking the Way We Make Things*, the authors present a 'Cradle to Cradle®' approach in which biological and technical cycles are closed without damaging effects on the environment. in this approach, waste materials are turned into 'nutrients' for a following cycle. To achieve this, the Cradle to Cradle® approach uses the following principles:

1. Waste is food, Everything is a Nutrient for Something Else;
2. Use the Sun, Use Renewable Energy Only;
3. Enjoy Diversity, Species, Cultural and Innovation Diversity.

This approach introduces the concept of eco-effectiveness to address the shortcomings of eco-efficiency. Eco-efficiency aims as far as possible to reduce and compensate the harmful effects on the environment. Eco-effectiveness aims for development without harmful effects on the environment. The aim of the Cradle to Cradle® approach of Braungart and McDonough (2002) is: 'A delightfully diverse, safe, healthy and just world, with clean air, water, soil and power – economically, equitably, ecologically and elegantly enjoyed'.

2006 An Inconvenient Truth – Al Gore.

An Inconvenient Truth is the movie in which former US Vice President Al Gore tours the world to ventilate his concerns about climate change and the dismissal by politicians of the associated risks. To do this he uses high-impact images of the effects of hurricanes, glaciers falling into the sea, drought and desertification. He shows on a map that around half of the

Netherlands would disappear under water as a result of global warming. Gore also wrote a book of the same title. The book and the movie succeeded in bringing the expected climate crisis and climate change to the attention of a very broad public audience (Gore, 2006).

2009 United Nations Framework Convention on Climate Change (UNFCCC) – United Nations

Following the first Earth Summit and the subsequent COPs, COP-15 was held in Copenhagen in 2009 to reach a new international climate treaty. The aim of the UNFCCC is to make binding agreements for a new international climate treaty from 2012, which is when the binding agreements in the Kyoto protocol expire. The conference was attended by 192 countries, although it did not result in binding agreements (UNFCCC, 2009).

2010 United Nations Framework Convention on Climate Change (UNFCCC) – United Nations

After the failed negotiations during the climate summit in Copenhagen (2009), the discussions about a new international climate treaty were continued in Cancun, Mexico. At the UN Climate Change Conference in Cancun 190 countries reached a new agreement on measures against climate change. The most important agreements are on measures against deforestation and the setting up of a Green Climate Fund to enable developing countries to fight climate change. New agreements were also reached about reducing CO_2 emissions. The agreements were intended to form the basis for a finalized treaty to be signed the following year in Durban, South Africa (UNFCCC, 2010).

3 From eco-efficient to 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. This section addresses the basic principles and the reference framework of efficient and effective sustainable development in the built environment.

3.1 Defining Eco-Efficiency

After this *Earth Summit*, 50 of the world's largest companies analysed 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.
Governments and companies have adopted eco-efficiency as a guiding strategy. Table 3.1 shows the definitions of (eco-)efficiency used by some of these organizations:

Table 3.1. Definitions of Eco-Efficiency.

Source	**Definition**
*Australian Government**	*Eco-Efficiency is a management process that is designed to 'produce more from less'. Eco-efficiency can be achieved by increasing mineral recovery, using fewer inputs such as energy and water, recycling more an reducing emissions.*
*European Environmental Agency**	*Eco-Efficiency is the amount of 'environment' used per unit of economic activity.*
*Global Development Research Center**	*The relationship between economic output (product, service, activity) and environmental impact added caused by production, consumption and disposal.*
*Joseph Fiksel**	*The ability of a managed entity to simultaneously meet cost, quality, and performance goals, reduce environmental impacts, and conserve valuable resources.*
*Klaus North**	*Eco-Efficiency, cleaner production and lean production are based on a common philosophy: to reduce 'waste' in all steps of a production process. Eliminating waste will lead to improvements in eco-efficiency and thus contributes to: less energy consumption, less waste materials, less materials handling, and less intermediate storage.*
*Laurent Grimal**	*This strategy induces the integration of cleaner production technology into the production process, aiming at a reduction in materials and energy consumption and thus at a decrease in pollution.*
*LEAN Advisors**	*The means by which more and better goods and services are created using fewer recourses and minimizing waste and pollution. In practice, eco-efficiency has three core objectives: increasing product or service values, optimizing the use of resources, and reducing environmental impact.*

*Nokia**	*Eco-Efficiency means producing better results from less material and energy. For us this means: minimizing energy intensity, minimizing the material intensity of goods and services, extending product durability, increasing the efficiency of processes, minimizing toxic dispersion, promoting recycling, and maximizing the use of renewable resources.*
*PrintNet**	*Eco-Efficiency is a concept that links environmental and financial performance. It does this by focusing on the development, production and delivery of products and services that meet human needs while progressively reducing their environmental impact throughout their lifecycles. Eco-efficiency essentially means doing more with less-using environmental resources more efficiently in economic processes. The application of eco-efficiency is undertaken, but not limited, by approaches and instruments such as cleaner production and environmental management systems.*
*Toshiba Group**	*Eco-Efficiency is calculated by dividing the value of a product by the product's 'environmental impact'. The smaller the environmental impact and the higher the value of the product, the greater the eco-efficiency. The value of a product is calculated based on its functions and performance, taking the voice of customer into consideration. The environmental impact is calculated, taking into consideration various environmental impacts throughout its life cycle.*
*WMC Resources Ltd.**	*Maximizing efficiency of production processes while minimizing impact on the environment. Eco-efficiency can be achieved by using new technology, using fewer inputs per unit of product such as energy and water, recycling more and reducing toxic emissions. In summary doing more with less.*
* Source: Braungart & McDonough, 2006	

Critics respond to eco-efficiency by calling for effective, instead of efficient, options. They believe that eco-efficiency results in the development of short-term solutions. WBCSD recognizes that effectiveness goes further than simply improving existing systems. But according to WBCSD the concept of eco-efficiency is not intended as an all-encompassing panacea. It is therefore all the more important to emphasize what, according to the WBCSD, eco-efficiency is *not*. See Fig. 3.1.

What eco-efficiency is not:

- *Not a take-it-or-leave-it approach*
- *Not an either-or (but much more a both-and-and) approach*
- *Not a solution to all the problems on the way to sustainability*
- *Not a rigid framework*
- *Not anyone's single strategy*
- *Not a management system*
- *Not a certifiable standard*
- *Not a reporting format*
- *Not a cook-book with recipes*
- *Not something one can buy off the shelf*
- *Not an assurance against failure.*

Fig. 3.1. What eco-efficiency is not (WBCSD, 2000).

Efficiency can certainly be valuable if it is implemented as a tool in an effective system that is intended to create a positive effect in a range of areas. Efficiency is also valuable when it is applied as a transitional strategy to delay current systems that are harmful to the environment in such a way that they can lead to change. Steelcase (2001) uses the *Environmental Strategies Scale* as a tool to classify practical solutions in relation to overall progress towards achieving sustainability.

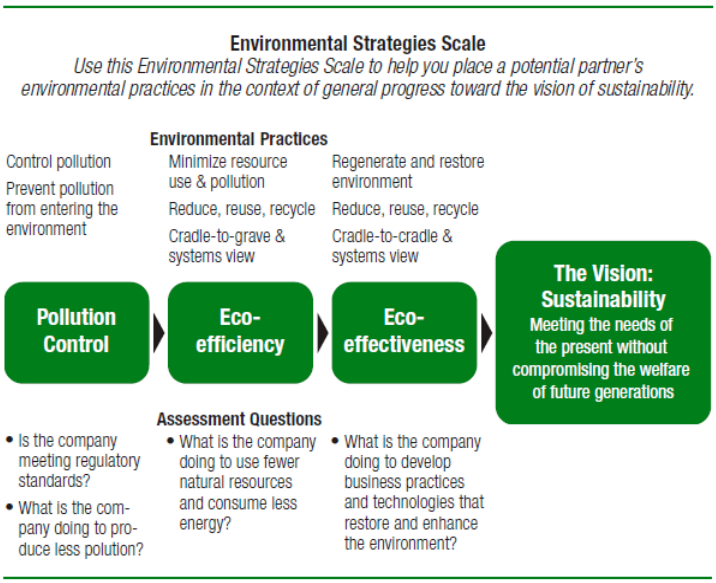


Fig. 3.2. Environmental Strategies Scale (Steelcase, 2001).

3.2 Triple P

In 1994 John Elkington introduced the strategy of the *Triple Bottom Line (TBL),* better known as *People, Planet and Profit (Triple P)*:

- *People*: individuals within and outside the enterprise;
- *Planet*: the effects on the environment in which we live;
- *Profit*: the production and economic effects of goods and services.

With this idea, the author responded to the Brundtland Report and the concept of sustainable development. In Elkington's view the ecological, economic and social factors had to be brought into a direct and balanced relationship to each other to achieve sustainable development. The P of *Profit* was replaced by the P of *Prosperity* at a World Summit on Sustainable Development held in Johannesburg; in other words profit was replaced by welfare.

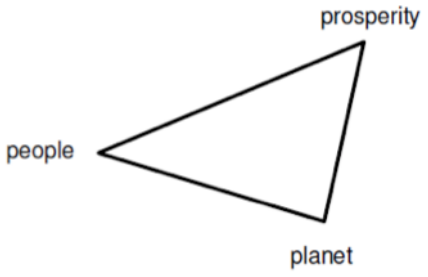


Fig. 3.3. The interrelationship between People, Planet and Profit / Prosperity (Elkington, 1994).

According to Elkington, sustainable development is a vague idea that is often understood incorrectly. The *Triple P* focuses on economic growth, ecological qualities and, in Elkington's view, the term that to some extent was not taken into account at the Earth Summit, social justice. None of these terms is new in the sustainable development discussion. *Our Common Future* clearly states that the factor of social justice forms part of the sustainability agenda (WCED, 1987). The treaty reached at the Earth Summit in Rio de Janeiro provided little clarity about the logic behind these three factors in sustainable development (Johnson, 1993). The enterprises that have been putting the treaty into practice since the Earth Summit are focusing on efficient operation and reduced costs. In Elkington's view the underlying message of eco-efficiency will never ensure completely sustainable development (Elkington, 1998).

3.3 Defining Eco-Effectiveness

Out of concern about the lack of completeness of the concept of eco-efficiency, William McDonough and Michael 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. Eco-effectiveness is based on a closed-cycle approach, in which materials are used in new products, processes and objects in a way that they are 100% re-usable or can be recycled, and in which the energy for all activities must be renewable. Eco-effectiveness causes no adverse effects in relation to sustainability.

Eco-effectiveness has been adopted by a number of enterprises. Table 3.2 shows the definitions of (eco-)effectiveness used by different organizations:

Table 3.2. Definitions of Eco-Effectiveness.

Source	**Definition**
Oxford References	***effective*** *adjective; 1 successful in producing a desired or intended result : effective solutions to environmental problems. • (esp. of a law or policy) operative : the agreements will be effective from November. 2 [attrib.] fulfilling a specified function in fact, though not formally acknowledged as such : the companies were under effective Soviet control.* • *assessed according to actual rather than face value : an effective price of $176 million.* • *impressive; striking: an effective finale.*
Steelcase	*All the products and materials manufactured by industry must after each useful life provide nourishment for something new.*
Van Gansewinkel	*Eco-Efficiency is about doing less harm, in other words produced less pollution. But 'less harm' isn't necessarily good! Cradle to Cradle® is about eco-effectiveness and therefore about 'doing good' – for example by eliminating pollution completely, without sacrificing economic, ecological and social value.*
DSM	*Cradle to Cradle® is about eco-effectiveness. Efficiency is a great was to optimize systems – but those systems first have to be effective before they are optimized, otherwise the result will be perfectly optimized but wrong (destructive) systems.*
Océ	*Océ uses the term eco-effectively to indicate that the business strives ultimately to achieve a closed cycle for industrial products (Cradle to Cradle® philosophy). The materials used in Océ products should be developed in such a way that they can be fully reused and/or recycled, and the energy used in all Océ activities should be derived from sustainable sources. For activities where eco-effectiveness is not yet feasible, Océ works eco-efficiently to minimize any undesirable impact Océ products may have on the environment.*
Shaw	*We are committed to being an industry leader in creating eco-effective ways to produce carpet – it's the right thing to do for our business and the environment. Through eco-effective technology, we will continuously redesign our products, our processes and our corporation.*

Desso	*At DESSO all polypropylene waste is recycled back into other industrial processes.*
E-commerce	*It leads to an industry which is regenerative and not destroying, which means products shall be reused rather than thrown away (recycling).*
Herman Miller	*Eco-effectiveness is modeled on nature, where nothing goes to waste. One organism's waste is another's food. Because the 'take-use-dispose' (or 'cradle to grave') approach to products has been predominant, most products and the processes used to create them have not been designed with end-of-life considerations in mind.*
Giancarlo Barbiroli	*Eco-effectiveness is the degree of natural resources rational utilization in any economy, that can be measured through a loss function that measures the distance between the real state (material and energy intensity to GDP or per-capita) and the ideal state (or state of Bliss).*

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 effective system.

3.4 Triple E

Inspired by Elkington's *Triple P* approach, Braungart and McDonough (2002) introduced the strategy of the *Triple Top Line (TTL)*, better known as *Economy, Ecology and Equity (Triple E).*

- *Economy*: the production and economic effects of goods and services;
- *Ecology*: the environment in which we live;
- *Equity*: equality of people, animals and plants;

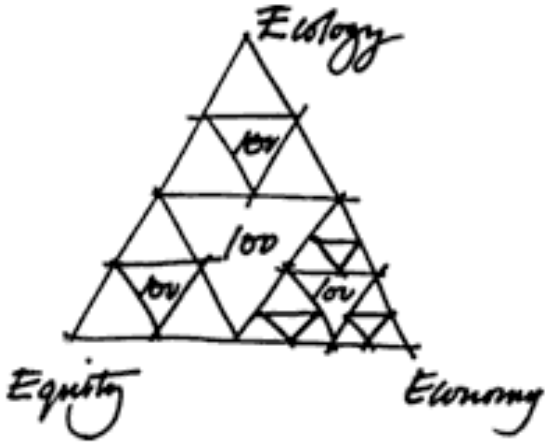


Fig. 3.4. Ecology, Economy and Equity (EEE) fractal (Braungart, 2007).

Both these approaches bring ecological, economic and social factors into a direct and balanced interrelationship. An important difference between the two approaches is in the concepts of *People* and *Equity*. The *Triple E* strategy is not only about people, but about equality of people, animals and plants.
According to Braungart and McDonough, sustainable development is a concept that in today's situation is interpreted on the basis of the strategy of eco-efficiency. Also, in the view of Braungart and McDonough, the eco-efficiency message will never ensure completely sustainable development. In response to this, they introduced the idea of eco-effectiveness in 2002. The TTL approach shown in the above fractal diagram aims for development without harmful effects for the environment (Braungart & McDonough, 2006).

4 Cradle to Cradle®: principles and design criteria

Braungart and McDonough's book *Cradle to Cradle®: Remaking the Way We Make Things* was published in 2002. In 2006 and 2007 the Dutch TV station VPRO presented the documentary *Waste is Voedsel* (Waste is Food) in the program *Tegenlicht*. This led to an outburst of reactions in the Netherlands (Hattum, 2006 & 2007). Subsequently, a Dutch translation of the original Cradle to Cradle® book was published in 2007, entitled *Cradle to Cradle®, Waste = Voedsel* ('Cradle to Cradle®, Waste = Food') (Braungart & McDonough, 2007). This section discusses the essential principles of the Cradle to Cradle® approach.

4.1 Principle 1: Waste equals Food; Everything is a Nutrient for Something Else

Nature works in continuous cycles in which there is no such thing as waste. The closed-cycle biological system of Cradle to Cradle® has for millions of years led to a flourishing planet with a varied abundance of food. Every being on the planet has formed part of it, and it provided good conditions for growth. The balanced natural system of resources on the planet has changed. Resources are extracted from the earth's crust and concentrated, changed and synthesized, leading ultimately to unlimited amounts of waste. This process means that valuable resources are lost (Cohen, 2007).

Example 4.1 Earth Natural Wealth: an audit

To get a feel for the scale of the problem, we have turned to data from the US Geological Survey's annual reports and UN statistics on global population. This has allowed us to estimate the effect that increases in living standards will have on the time it will take for key minerals to run out. How many years, for instance, would these minerals last if every human on the planet were to consume them at just half the rate of an average US resident today?
The calculations are crude - they don't take into account any increase in demand due to new technologies, and also assume that current production equals consumption. Yet even based on these assumptions, they point to some alarming conclusions. Without more recycling, antimony, which is used to make flame retardant materials, will run out in 15 years, silver in 10 and indium in under five. In a more sophisticated analysis, Reller has included the effects of new technologies, and projects how many years we have left for some key metals. He estimates that zinc could be used up by 2037, both indium and hafnium - which is increasingly important in computer chips - could be gone by 2017, and terbium - used to make the green phosphors in fluorescent light bulbs - could run out before 2012. It all puts our present rate of consumption into frightening perspective (see Fig. 4.1) (Cohen, 2007).

The decline in reserves of natural resources around the world is alarming. According to estimates by the European Commission (2010), demand for resources may more than triple in the coming 20 years. On top of that is the fact that most raw materials are only found in limited numbers of countries – for example graphite in China, cobalt in Congo and lithium in Chile. Cobalt and lithium are essential for the new generation of electric cars. An explosive increase in demand for lithium could mean that stocks will be exhausted after something over 40 years. The impending scarcity of lithium will also depend on the dependency of the exporting countries. Around 568 tons of the high-gloss metal indium, a by-product of lead and zinc production, are used each year in solar panels and LCD displays. That may rise to more than 1,700 tons within 20 years, three times the amount mined today. This increase could mean that stocks of indium will be exhausted in only 14 years. Nickel, which is used in making rotor blades for wind turbines as well as in many other applications, will be used up in just over 40 years if demand continues to increase. While if demand continues to grow, stocks of hafnium, used in integrated circuits, will be exhausted in less than 10 years (Cohen, 2007; European Commission, 2010; Centre for Strategic Studies, 2010). All these materials are important enablers for the high-tech industry to make the transition to sustainable applications with today's technologies.

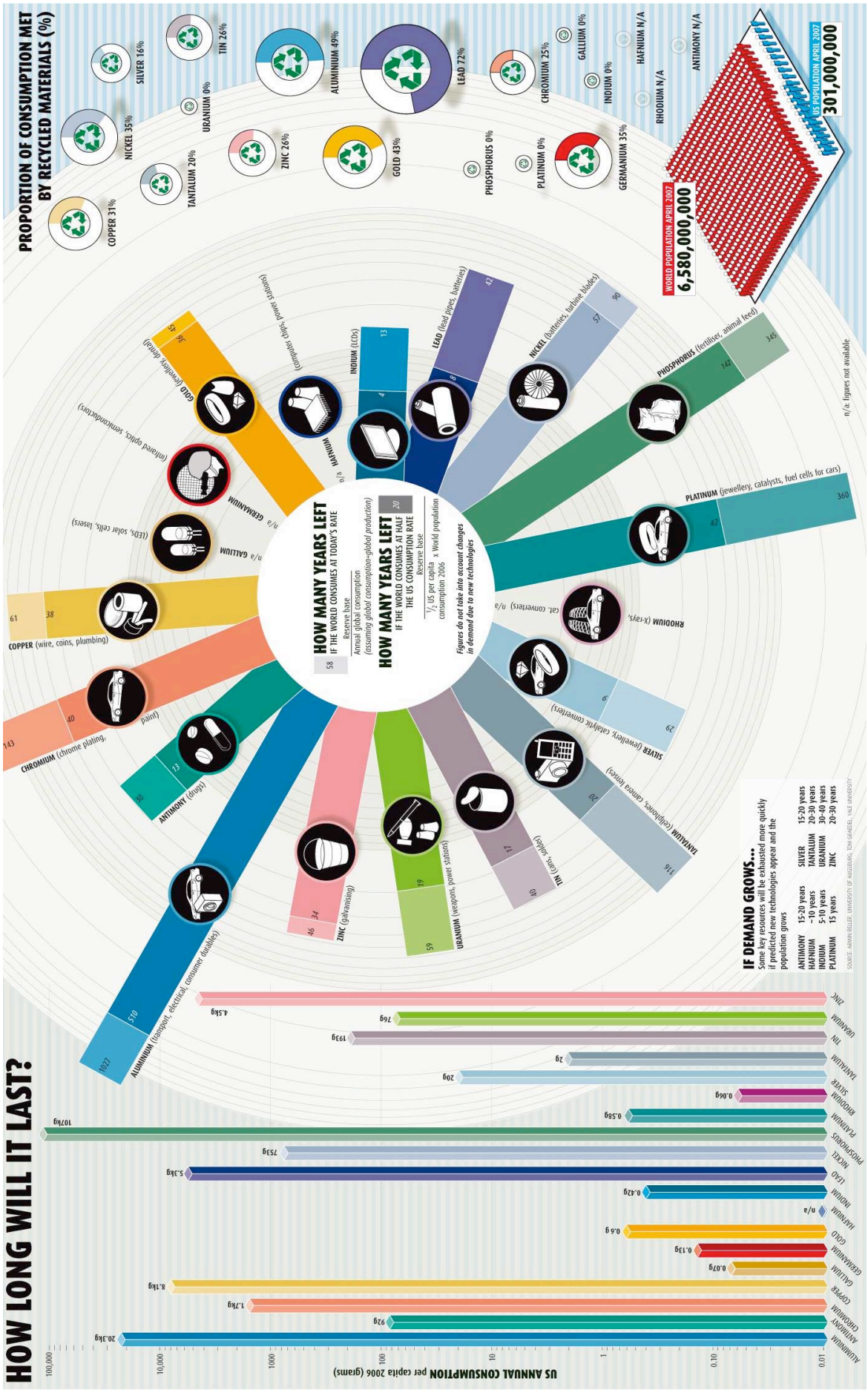


Fig. 4.1. 'How long will it last' shows the consumption of raw materials, see Example 4.1: Earth Natural Wealth – an audit (Cohen, 2007).

In the Cradle to Cradle® approach, material flows are divided into two cycles: a biological cycle and a technological cycle. The biological products are valuable for the biosphere, while technological materials are valuable for the technosphere.
With today's strategies and applications, unlimited re-use of technological products that have completely reached the end of their life cycles is not possible. Even if the product still consists of valuable materials, these are no longer used and they are lost as waste (*downcycling*). This is because the products are designed as part of a linear process which does not allow for unlimited re-use (*recycling*). In fact, industries even make products with built-in ageing. That means products last almost exactly until the time when users usually want to replace them. Ideally the materials could be a source for new, high-grade applications in a closed-cycle process (*upcycling*).
The amount of waste has increased greatly in recent decades (CBS, 2009). This is worrying, although the amount of waste and the space it takes up is not the biggest problem of traditional 'cradle-to-grave' designs. Much more worrying are the contaminated, wasted or lost raw materials. With a Cradle to Cradle® approach, these materials could form part of technological or biological cycles.

Example 4.2

A collection of strange objects floating in the Pacific Ocean between San Francisco and Hawaii covers an area at least as large as France, Spain and Portugal combined. The rotation of the earth and the trade winds bring plastic waste from beaches together in this area. The result is a huge maelstrom in which potential raw materials are lost, and which also has adverse effects on the local flora and fauna such as birds and fish (*Volkskrant*, 2008).

A further reason why materials are not re-used is the fact that there are no suitable systems to recover them. This is because many products are 'hybrids', using combinations of both technological and biological materials that cannot be separated for re-use.

Example 4.3

An example of mixed waste streams is sanitary waste. Until the 19th century people simply dumped their sanitary waste outside, sometimes even upstream of their own drinking water sources. The link between hygiene and public health was first understood at the end of the 19th century. Engineers saw that the discharge of rainwater through pipes into rivers also made it possible to get rid of sanitary waste in the same way. However this was still not a complete solution to the problem. Discharge of sanitary waste water into rivers caused an unbearable stench, for example during the Great Stink in London in 1858. It was finally decided to combine the rainwater and waste water flows and to transport them through large pipes to waste water treatment plants. This could be handled on a small scale by means of microbial and bacterial breakdown of the waste. But the increasing volumes of waste water meant that the process could only be continued by using chemical treatment. At the same time new products were introduced for household use that were never designed for disposal in waste treatment plants. This meant that substances like bleach and other chemicals, paint and even antibiotics and oestrogen ended up in the waste water! Add to that a wide range of industrial wastes and the result was a highly complex cocktail of chemical and biological substances (Braungart & McDonough, 2002).

4.1.1 Continuous cycles

The overall system in which we live consists of two essential elements: mass (the earth) and energy (the sun). Whatever people make, it never 'disappears' even when it is disposed of.

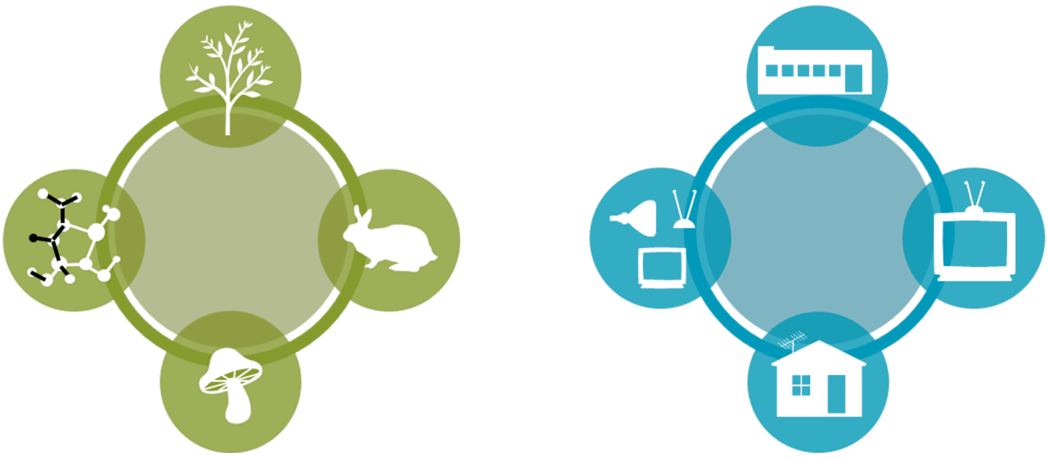


Fig. 4.2. Schematic of the biosphere or biological cycle and the technosphere or technological cycle (Braungart, 2006).

There are two separate types of cycle. The first are the biological cycles, or the biosphere – the cycles found in nature. The second are the technological cycles or the technosphere, the cycles of industrial production (see Fig. 4.2.). If these latter processes are to work in a cycle, they will have to emulate nature – also known as 'biomimicry'. Eliminating the concept of waste means that objects and products have to be designed right from the start on the principle that the materials used must not be allowed to end up on rubbish tips. That means it is no longer a question of *downcycling*, but instead it is about *recycling* or *upcycling*, in which materials and their qualities are at least maintained or even wherever possible improved.

4.2 Principle 2: Use the Sun; Use Renewable Energy Only

Diversity makes an ecosystem more resilient, so that it is better able to respond well to change. Decentralized energy generation also creates a stable system with more resilience. Nuclear power stations and other large-scale energy-production facilities often disturb the surrounding ecosystems and release huge amount of waste heat which is not used. Why should we remain dependent on large-scale utilities that keep energy prices for peak loads high? Why use and deplete non-renewable energy sources like gas, coal and oil? These are sources that will soon be exhausted if the present consumption levels are maintained.

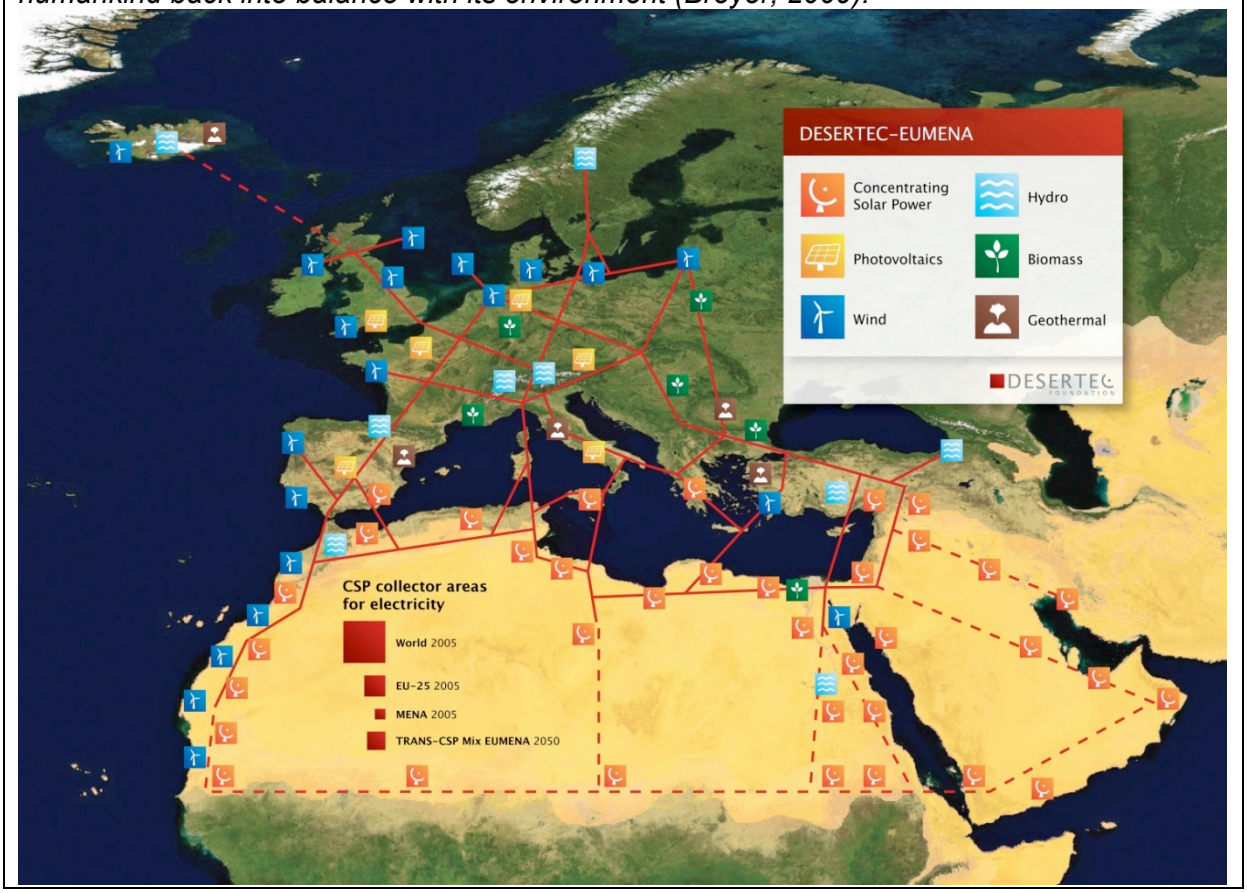
In the Cradle to Cradle® approach, as much use as possible would be made of renewable energy from unlimited sources (such as water, wind, the sun and geothermal energy). It is also recommended to use the waste heat that is released as an energy source. That provides a lot of advantages in terms of both cost and convenience.

Renewable energy sources have the potential to provide a thousand times more energy than what is used today (Breyer, 2009). This can be done by using local energy sources, for example at the level of an individual home, but also at national level. Research has shown that cooperation between African and European countries in the DESERTEC Model (see Example 4.4) would require a total area of no more than 280x280 kilometers to meet the current energy needs of 90% of the earth (Breyer, 2009). This provides ample opportunities to become independent of non-renewable energy sources.

Example 4.4

Global energy supply potential of concentrating solar power (DESERTEC Model)

Based on global datasets for direct normal irradiance and population density the energy supply potential of concentrating solar power (CSP) was estimated. There are clear indications that 90% of world population connectable per grid to deserts could be supplied only by CSP via high voltage direct current (HVDC) power lines not longer than 3,000 km. Less than 0.4% and 2.8% of the electricity potential of worldwide potential CSP areas would be required for electric and non-electric energy needs, respectively, on the today's European energy consumption level. Therefore, only a small fraction of 0.4% to 2.8% of global CSP energy supply potential would be needed to cover global energy demand. In reality an even smaller fraction will be needed due to the energy supply contribution of all locally installed renewable energy technologies and energy efficiency improvements. The DESERTEC concept for the EUMENA region is close to become a real interregional project for energy, water and climate security and might act as a blueprint for other regions in the world, to bring humankind back into balance with its environment (Breyer, 2009).



4.3 Principle 3: Enjoy diversity; Species, Cultural and Innovative Diversity

The vitality of ecosystems depends on the relationships between species, and the way they use and exchange materials and energy at specific locations. Diversity means strength and monoculture weakness. Diversity means a healthy and healing environment. But if diversity declines, the ecosystem becomes less stable. The more diversity there is, the more productive functions there will be, both for the ecosystem and for the planet. Each individual in an ecosystem depends to a greater or lesser extent on the others. Some people, such as followers of the Gaia principle put forward by James Lovelock (1978; 2000), even regard the earth as a single huge organism.

Biodiversity is just one aspect of diversity. Environments that respect diversity use local species, materials and energy sources, as well as local cultural, social, ecological and economic forces and innovation.

4.4 Cradle to Cradle® design criteria

Based on the Cradle to Cradle® approach and the dual cycle principle, design criteria can be derived for the creation of new products, processes and objects. The following 10 design criteria are regarded as crucial (derived from NL Agency, 2010):

1. Design all products, processes and objects so that after their initial use all materials can be fully re-used in a biological or technological cycle. Avoid hybrid material streams that are very difficult to separate. Define the materials and their associated life cycle usage paths.
2. Make sure that no harmful or toxic substances are released or used in the production process and during the usage phase of the product or object.
3. Make sure that the production process and the use of the product or object create added value for the stakeholders.
4. Design on the basis of a Triple E (Economy, Ecology and Equity) approach.
5. Use renewable energy sources such as the sun, wind and (ground) water.
6. Respect the diversity of the location, species, innovation and culture.
7. Protect and maintain the quality of water reserves.
8. Carry out the production process with social responsibility. That means no child or forced labor, no unhealthy workplaces, no discrimination and with freedom of association.
9. Follow a local approach in the production process.
10. Make intentions transparent and translate them into measurable targets. Concrete targets can be reached by drawing up a roadmap with milestones.

A Cradle to Cradle® building adds value and celebrates 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.

–Douglas Mulhall, Congress Cradle to Cradle® 2.0 Apeldoorn.

5 Cradle to Cradle®: old wine in new bottles?

A frequent criticism of the Cradle to Cradle® approach from both science and practice is that it is 'old wine in new bottles'. This section discusses the predecessors of the principles put forward in the Cradle to Cradle® approach. It is clear that the Cradle to Cradle® principles are in themselves not new, but they are a synthesis of sustainability concepts that have been described and applied earlier.

5.1 Principle 1: Waste equals Food; Everything is a Nutrient for Something Else

One of the predecessors of cycle-based thinking is Industrial Ecology (IE):
…In so doing, the now conventional cradle-to-grave approach to product design, development and analysis is replaced by a renewing cycle of Cradle to Cradle® analysis, transforming the industrial capitalism model for linear thinking to a closed loop system. This thinking resonates with early principles put forward by proponents of Industrial Ecology and Natural Capitalism (Young, 2006).

The most important aim of Industrial Ecology is to eliminate the concept of waste, in which waste is regarded as unusable and worthless materials. In nature nothing is thrown away, but all materials are re-used with great efficiency and effectiveness (Graedel, 1995). Graedel and Allenby propose an industrial and biological metabolism, both of which should be separated as far as possible (see Fig. 5.1.).

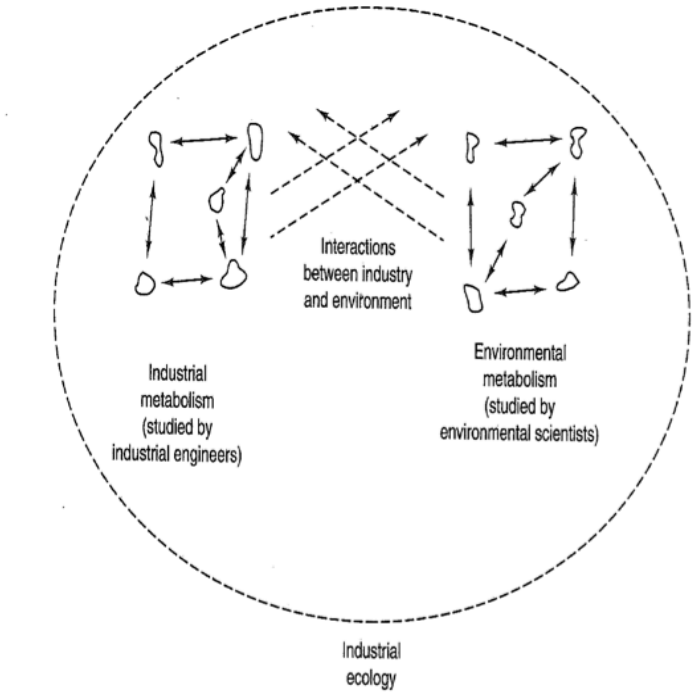


Fig. 5.1. The elements of Industrial Ecology, Industrial metabolism and Environmental metabolism (Graedel, 1995).

The authors define the concept of ecology as *the scientific study of the interactions that determine the distribution and abundance of organisms*. According to Industrial Ecology Type III in Fig. 5.2. is the optimum situation, in which only the sun is used as an external energy source. In Types I & II external sources are converted into an, ideally minimized, amount of waste.

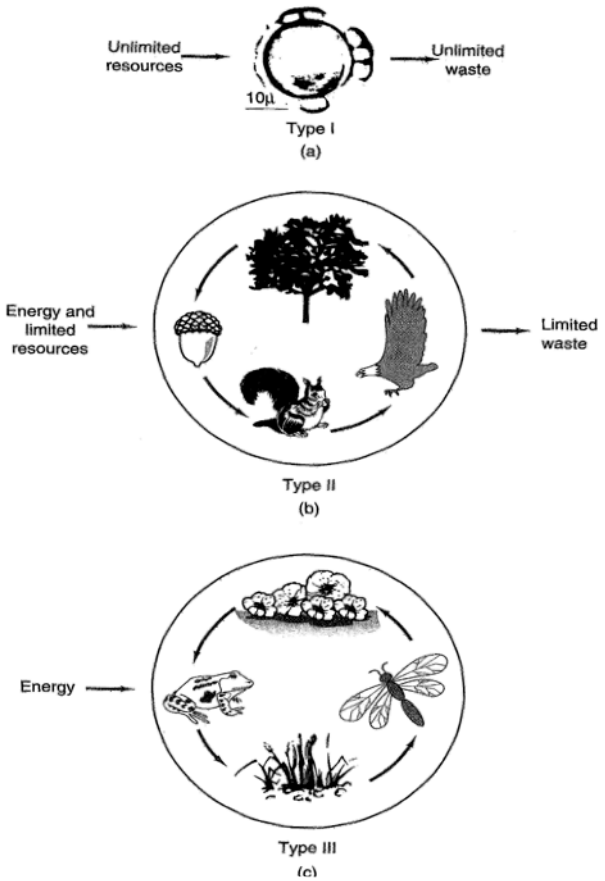


Fig. 5.2. (a) Linear material stream. (b) Quasicyclical material stream. (c) Closed-cycle material stream (Graedel, 1995).

The conceptual model of Industrial Ecology is based on the article *Strategies for Manufacturing* published in *Scientific American* by Robert Frosch and Nicholas Gallopoulos in 1989. The subtitle of the article was: *Waste from one industrial process can serve as the raw materials for another, thereby reducing the impact of industry on the environment*.
The authors regard the system as follows: *…The traditional model of industrial activity should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process serve as the raw material for another process* (Frosch, 1989).
When the designers do not take the final situation of the product into consideration, the dismantling and re-use of the product can become so complex, labor-intensive or hazardous that it automatically becomes waste (Harper & Graedel, 2003).

Others regard nature as the biggest example, in which there is no such thing as waste. In her book *Biomimicry: Innovation Inspired by Nature*, Benyus states that there are more things to be discovered in nature than to be invented.
Biomimics are fascinating people, working at the edges of their disciplines, in the fertile crests between intellectual habitats. Where ecology meets agriculture, medicine, materials science, energy, computing and commerce they are learning that there is more to discover than to invent. They know that nature, imaginative by necessity, has already solved the problems we are struggling to solve. Our challenge is to take these time-tested ideas and echo them in our own lives (Benyus, 1997).

5.2 Principle 2: Use the sun; Use Renewable Energy Only

In 1839 Edmond Becquerel discovered that metal plates in a conducting solution produce a voltage and a current when light shines on them. This is called the photovoltaic effect. Based on this phenomenon discovered by Becquerel, Charles Fritts developed the first real solar cell in 1883, with an efficiency of 1%. The first 'modern' solar cell, developed by Russell Ohl, was introduced to the market in 1941. This solar cell had an efficiency of only 4% in 1954 (ECN, undated). After the first oil crisis in the 1970s, there was a big acceleration in research into ways to significantly increase the efficiency of solar cells, and as a result to make commercial applications of solar cells possible (Weingart, 1974). More recently researchers at the Fraunhofer Institute for Solar Energy Systems announced that they had developed a solar cell with an efficiency of 41.1% (Guter *et al.*, 2009).

The potential of renewable solar energy in relation to today's energy consumption was investigated by Gommans (2009). In Fig. 5.3 the outer cube represents the total energy radiation reaching the earth each year. It has also been shown that the energy needs of 90% of the world population could in principle be met by concentrated solar energy from a total area of 280x280 kilometers (Breyer, 2009; Gommans, 2009; Labyrint, 2010). These findings demonstrate the potential of the sun as a renewable energy source on a global scale.

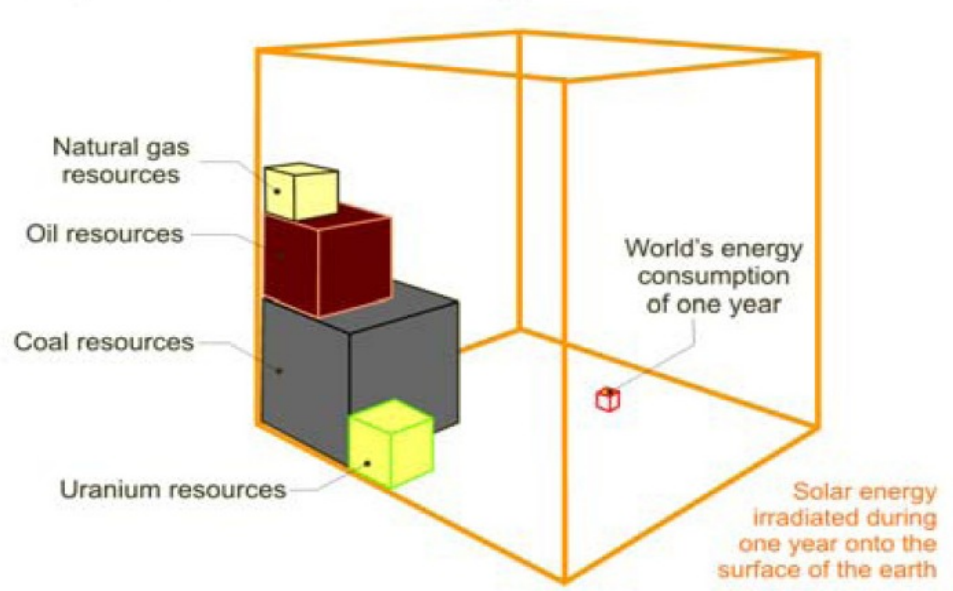


Fig. 5.3. Annual energy consumption in relation to all fossil fuels and irradiated solar energy reaching the earth (Gommans, 2009).

5.3 Principle 3: Enjoy diversity; Species, Cultural and Innovative Diversity

Paul Hawken (1992) describes biodiversity in his book *The Ecology of Commerce,* in which he regards biodiversity as the source of all welfare. The author also predicts that in the 20 years following publication of his book, many species will disappear if man continues to use natural resources in the same way as at present.

The biodiversity treaty was signed in Rio de Janeiro in 1992. The aim of the treaty is described as follows: *The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant Technologies, taking into account all rights over those resources and to Technologies, and by appropriate funding* (Johnson, 1993).

However biodiversity is only one aspect of diversity (see also Fig. 5.4.). Industries and populations that respect diversity use local materials and energy sources, as well as local cultural, social and economic forces (Braungart & McDonough, 2002).

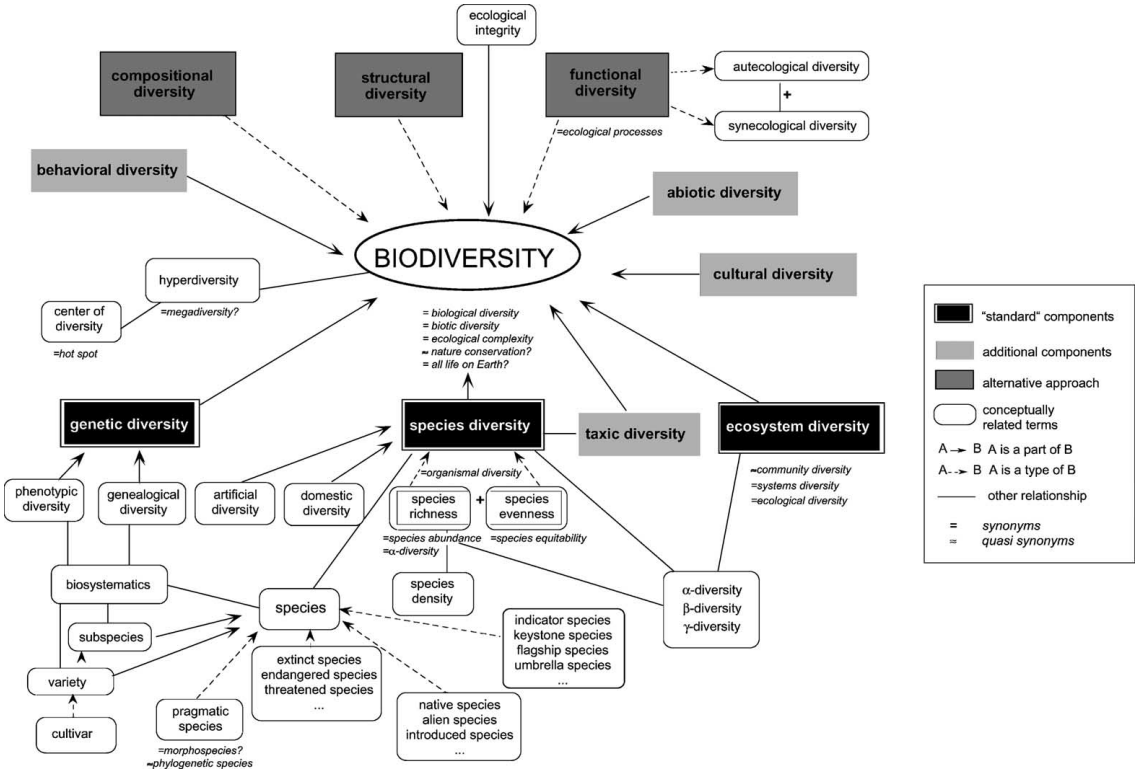


Fig. 5.4. Domain of biodiversity based on 125 text documents. The concept of biodiversity is defined in different ways by different authors (Duelli & Obrist, 2003).

6 Policy to promote sustainable development

This section gives an overview of policy in relation to sustainable development as developed and applied by the United Nations, the European Union and the Dutch government. The aims of the available instruments for the policies applied are also discussed.

6.1 Strategies to achieve sustainable development

6.1.1 Global strategy developed by the United Nations

The first Climate Treaty was concluded during the Earth Summit in Rio de Janeiro in 1992 under the responsibility of the United Nations. The aim of the treaty is to reduce greenhouse gas emissions, and by doing so to prevent the undesired results of climate change. The Climate Treaty took effect on 21 March 1994. Since then 192 countries, including the Netherlands, have signed and ratified the treaty. Agenda 21 is a detailed action plan for the implementation of the climate treaty signed in Rio de Janeiro. This action plan must be observed by all signatory countries to the Rio de Janeiro Climate Treaty. The figure 21 in Agenda 21 refers to the 21st century.

United Nations: Agenda 21

Agenda 21 addresses the pressing problems of today and also aims at preparing the world for the challenges of the next century. The developmental and environmental objectives of Agenda 21 will require a substantial flow of new and additional financial resources to developing countries, in order to cover the incremental costs for the actions they have to undertake to deal with global environmental problems and to accelerate sustainable development. Financial resources are also required for strengthening the capacity of international institutions for the implementation of Agenda 21. An indicative order-of-magnitude assessment of costs is included in each of the program areas. This assessment will need to be examined and refined by the relevant implementing agencies and organizations.
The program areas that constitute Agenda 21 are described in terms of the basis for action, objectives, activities and means of implementation. Agenda 21 is a dynamic program. It will be carried out by the various actors according to the different situations, capacities and priorities of countries and regions in full respect of all the principles contained in the Rio Declaration on Environment and Development. It could evolve over time in the light of changing needs and circumstances. This process marks the beginning of a new global partnership for sustainable development (United Nations, 1994).

The most important decision-making body in relation to the Climate Treaty is the Conference of Parties (COP). All signatories to the Climate Treaty meet each year to discuss progress on the agreements that were made. The COP is responsible for maintaining pressure on the international activities to prevent the undesired effects of climate change. An important task of the COP is to have the reports of the parties on progress in the implementation of the agreements assessed by a group of independent experts. The Kyoto Protocol was agreed during the COP held in Japan in 1997. The Kyoto Protocol includes agreements to reduce emissions of greenhouse gases – including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and a number of fluorine compounds (CFKs, PFKs and sulfur hexafluoride [SF6]) – by an average of 5.2% relative to the 1990 level in the period 2008-2012. The reduction percentages differ from country to country; economically weaker countries were given lower reduction targets.

6.1.2 Strategy of the European Union to achieve sustainable development

The climate treaty concluded in Rio de Janeiro in 1992 has been endorsed in full by the European Union. With the Treaty of Amsterdam, which was signed in 1997, it made sustainable development into one of the core goals of the European Union. In 2001 the European Union approved its own strategy for sustainable development in Göteborg. During the meeting of the European Council in 2001, an environmental dimension was added to the strategy agreed by the European Council in Lisbon for employment, economic reform and social cohesion. The strategy includes an annual evaluation during the European spring summits. The actions to be evaluated relating to sustainable development include attention points for climate, energy, transport, consumption and production, natural resources, public health, social inclusion, demographic development, migration and poverty.

European Union: Strategy of Sustainable Development

This strategy provides an EU-wide policy framework to deliver sustainable development, i.e. to meet the needs of the present without compromising the ability of future generations to meet their own needs. Members States must draw up national strategies and regularly review progress accomplished. They must carry out impact assessment before adopting their policies or committing public funds.
All the instruments available to the public authorities must be used to contribute to sustainable development. This includes regulations, but also incentives or market based instruments.
The Commission evaluates the implementation of the strategy once every two years on the basis of sustainable development indicators that it has adopted and, where necessary, updated. This evaluation forms the basis of another, carried out once every two years by the December European Council. Other bodies and institutions also examine what has been achieved and establish links with Member States and the public if required. The strategy must also be comprehensively reviewed at the beginning of each new Commission's term of office (European Union, 2001).

6.1.3 Strategy to achieve sustainable development in the Netherlands

In the Netherlands the *Duurzaam moet je doen!* ('Sustainability – just do it!') policy program of the Balkenende IV cabinet was laid down on the basis of the European Union strategy.

Netherlands: *Duurzaam moet je doen!* (policy program Balkenende IV cabinet)

Sustainable development demands a coherent effort for the development of the economy, social development and careful use of natural resources. Sustainable development also means taking into account longer-term developments and the effects of our actions on them. Many societal issues demand a 'sustainable approach', and this leads to a specific challenge for each policy initiative. By developing this policy program, the cabinet has acted on the ambition to take a significant step forward on the road to sustainable development. An innovative economy, the quality of the environment in which we live, social participation and coherence, a well functioning judicial system and governance, in the Netherlands and other countries, together form the cornerstones of sustainable development. The cabinet will monitor this interrelationship in the implementation of the policy program, and will periodically report on significant achievements.

As well as this translation of sustainability into policy, the government's own operations will also become more sustainable. This applies not only to Sustainable Procurement, but also for example to energy saving, mobility policy for employees, sustainable building and a balanced personnel policy aimed at diversity and against discrimination and exclusion on the labor market (Ministry of Housing, Spatial Planning and the Environment [VROM], 2008).

The European targets for sustainable energy supplies were a leading element in the coalition agreement between the VVD (People's Party for Freedom and Democracy) and the CDA (Christian Democratic Appeal) formulated in October 2010. This means 20% CO_2 reduction and 14% sustainable energy. To achieve the CO_2 reduction and reduce dependency in energy supplies, the new cabinet aims to increase the proportion of nuclear energy. It also plans to enter into a 'Green Deal' with society by continuing and strengthening the national approach to energy saving. Sustainable energy will in future be financed as in the German model by a surcharge on energy costs. In Germany this form of financing has led to a major increase in the share of sustainable energy (Dutch government, 2010).

6.2 Targets for sustainable development

Sustainable development can also be translated from a strategy into concrete targets. These are expressed mainly in terms of climate, type of energy supply, water consumption and mobility. This paragraph describes the sustainable development targets formulated by the United Nations, the European Union the Netherlands.

6.2.1 Sustainable Climate

The United Nations

A number of scientific studies have shown that – with 90% certainty – greenhouse gas emissions resulting from human actions are measurably influencing the environment leading to climate change (see e.g. Metz *et al.*, 2007). Combating this undesired climate change will, according to the United Nations, require measures to both reduce greenhouse gas emissions (mitigation) and to address the effects of climatic change (adaptation).

The Earth Summit climate treaty referred to earlier is intended to reduce greenhouse gas emissions, and thereby to prevent undesired climate change. The concrete aim of the treaty is to stabilize the concentration of greenhouse gases in the atmosphere at a level such that threats to the climate are avoided (Johnson, 1993).

The European Union

From 2001 sustainable development has been one of the overall aims of European policy. In December 2008 the EU leaders approved an extensive package of measures to reduce greenhouse gas emissions. This plan calls for greenhouse gas emissions in the European Union in 2020 to be reduced by at least 20% relative to 1990. The share of sustainable energy is also intended to increase to 20%, and total energy consumption to be reduced by 20%, relative to the projected trend (European Union, undated).

The Dutch government

The Dutch government is striving to achieve the 2020 climate targets through mitigation. To protect against flooding, climate change has forced a start to be made on raising the dykes and improving the drainage of cities. However making buildings climate-proof is not keeping pace.

The *Schoon en Zuinig* ('Clean and Economical') program of the Balkenende IV cabinet describes the concrete policy measures. Specifically for the built environment, the ambition is to achieve a major CO_2 reduction for the entire built environment in 2020. This will be based on two important pillars: achieving the targets of the *Meer met Minder* ('More with Less') covenant, and tightening the Energy Performance Coefficient (EPC) (CE Delft, 2008).

As stated earlier, the present Rutte cabinet has endorsed the European targets for sustainable energy supplies.

6.2.2 Sustainable Energy

Energy plays a central role in our lives. We need energy for transport and mobility, to heat and cool our homes, and to keep our factories, farms and offices running. A number of surveys show that the reserves of fossil fuels are finite (Gommans, 2009). In addition, these fossil fuels are partly to blame for global warming. It is therefore no longer self-evident that these sources will continue to meet our energy needs.

The United Nations
According to the United Nations (United Nations, 1994) we need an integrated energy and environmental policy based on clear goals. However no binding targets in relation to energy have been agreed within the UN. There is not even any single body that is responsible for the energy problem. This is why the World Summit on Sustainable Development was held, with the aim of promoting large-scale cooperation on sustainable energy generation (United Nations, 1994). The Agenda 21 action plan is the driving force to achieve this.

The European Union
More than 50% of the energy used in the European Union comes from countries outside the EU. The EU is therefore preparing for future energy shortages. The top priority is preparing the energy grids for sustainable energy sources and more efficient use of energy. The target for 2020 is to meet 20% of energy needs by renewable energy and to reduce total energy consumption by 20% (European Union, undated).

The Dutch government
The Dutch government follows the policy laid down in the *Trias Energetica* (see text box). The *Trias Energetica* was developed by the former SenterNovem agency to reach climate and energy neutrality in three steps (Ministry of Housing, Spatial Planning and the Environment [VROM], undated).

The *Trias Energetica*:
1: Use as little energy as possible;
2: Use sustainable energy, such as solar or wind energy;
3: Use energy from finite sources (natural gas, coal) as intelligently as possible.

The first step in the *Trias Energetica* is to reduce energy consumption. Good design can save energy, partly through good building orientation and insulation. The second step in this approach is to use renewable sources – energy that is not produced from fossil fuels but instead from clean, inexhaustible sources like solar and wind energy. The use of sustainable energy in the Netherlands is increasing steadily year by year: in 2008, 3.4% of total energy consumption was sustainable; a year earlier the figure was 2.9% (CBS, 2006).
The third step is to use non-renewable fossil energy sources as intelligently and efficiently as possible. The aim of the cabinet is to reduce energy consumption by 2% per year with a total sustainable energy share of 20% in 2020.

6.2.3 Sustainable Water

The United Nations

Agreements have been made at the Earth Summits about the water and sanitation program. Providing everybody with safe water and improving sanitation facilities have the highest priority. The following target was defined at the COP-6 in 2000: '*Reduce by half the proportion of people without sustainable access to safe drinking water by 2015*'. The following target was added at the COP-8 in 2002: '*To halve by 2015, the proportion of people who do not have access to basic sanitation*'. More than 830 million people in the Asia Pacific region in 2000 had no access to safe drinking water, and more than 2 billion people had no sanitation facilities (United Nations, 2009).

The Dutch government

An important initiative of the Dutch government is to promote more rational and economical use of clean (drinking) water. The current average water consumption in the Netherlands is 127.5 liters per person per day. The percentage of this water consumption that needs to be of drinking water quality is marginal (approx. 3.5 liters p.p.p.d.). This means that by far the largest proportion of consumption could be met by water of lower quality. With the same aim, efforts are being made to promote improvement of the production and distribution system and to increase the use of rainwater for purposes for which less pure water is suitable.

A second initiative by the Dutch government the *Nationaal Bestuursakkoord Water* (National Administrative Agreement on Water). This agreement became necessary as a result of the changing climatic conditions, with increasingly extremer periods of drought and rainfall. Fluctuations in river levels are increasing, and the sea level is rising. The agreement does not automatically aim for excess water to be pumped away (into rivers or the sea), but instead to be captured or stored in the affected regions (Ministry of Housing, Spatial Planning and the Environment [VROM], 2003)

6.2.4 Sustainable Mobility

The United Nations

A following attention point in (inter-)national sustainability policy relates to mobility. In developed countries mobility is the largest and one of the fastest-growing energy end-users. Efficient and effective transport systems are vitally important for access to markets, employment, education and basic services for fighting poverty. Urgent measures are needed in this area, varying from the promotion of an integrated policy and the accelerated phasing-out of leaded gasoline to the development of partnerships at (inter-)national level (United Nations, undated).

The European Union

Fast, efficient and low-cost transport of people and goods is vital for the efforts to reach a dynamic economy and social cohesion within countries. In the EU, the transport sector accounts for 10% of welfare, in terms of GDP, and provides employment for more than 10 million people. The European Commission presented a 10-year plan for the transport sector in 2001. An interim evaluation in 2006 found that the emphasis in this action plan should be placed on making the railways competitive, introducing a ports policy, developing intelligent transport systems, introducing charges for use of the infrastructure, increasing biofuel production and solving the problem of traffic congestion in cities (European Union, undated).

The Dutch government

The Dutch government has launched a subsidy scheme entitled *Proeftuinen voor duurzame mobiliteit* (Sustainable mobility incubators). This subsidy scheme focuses on a number of areas, such as the use of electric and hybrid vehicles and natural gas, biogas and hydrogen fuels. Attention points for project proposals are based on aspects such as CO_2 reduction potential, energy savings and transition routes. The first phase of the program is aimed at the use of electric and hybrid vehicles (Ministry of Transport, Public Works and Water Management, undated).

The Rutte cabinet intends to continue the present fiscal support for the purchase and leasing of environment-friendly cars with more transparent tariffs and a focus on absolute environmental performance. However the plans of the Rutte cabinet to increase the maximum speed on highways from 120 km/h to 130 km/h will have a negative impact on the environment. According to the independent research and consultancy organization CE Delft, this increase will have two effects: CO_2 emissions per kilometer will increase, and the use of cars will become more attractive, leading to increased use in the longer term. This will result in extra CO_2 emissions totaling 0.3 Mton – an increase of 1.3% relative to the present emissions by passenger cars. In this calculation CE Delft has taken into account the fact that the increase applies only to 120 km of highways, and that it is not always possible to reach the permissible maximum speed (for example at peak times).

6.3 Dutch policy instruments for a sustainable built environment

In the Netherlands, government initiatives have been taken in recent years to promote sustainable development in the built environment. The government uses a number of instruments for this purpose. This section gives an overview of the frequently used instruments, together with the associated targets.

6.3.1 Energy

The government has strongly promoted energy saving for a number of years. The instruments used have included: the Building Code, Energy Performance Standard, Environmental Action Plan, Regulatory Energy Tax, Energy Labels, Sustainable Building covenant and local climate policy. Some of these instruments will be discussed below.

The Building Code defines minimum energy performance specifications for newly built homes. Until 1995 the code defined requirements for aspects including the minimum thermal resistance of the building shell (Rc value for the walls, roof and floor, and U value for glass). From 1995 the Energy Performance Standard was introduced with the main aim of optimizing cost for a specific energy performance level. The requirements placed on newly built homes by the Building Code were tightened in 1991. The Energy Performance Standard specifies the Energy Performance Coefficient (EPC) (Jeeninga, 2002).

The EPC has been applied in Dutch climate policy since 1 January 1995. The use of fossil fuels is being limited by energy savings, efficiency improvements and the use of sustainable energy, which at the same time reduces CO_2 emissions. From 1 January 2006 new homes had to have an EPC of no more than 0.8, while from 2011 this is no more than 0.6. The aim of the EPC is to reduce the energy consumption of new homes and other buildings by 50% in 2015 relative to 2008 (Menkveld, 2002).

Sellers and renters of homes in the Netherlands have since 1 January 2008 been required to hold an Energy Performance Certificate for Homes and Buildings, better known as the Energy Label. The Energy Label classifies the energy performance of homes. The energy consumption of a home is compared with that of similar homes, showing how energy-efficient or inefficient a particular home is in relative terms and whether it complies with the Energy Performance Standard. The label encourages energy saving (Meijer, 2009). For homes with building permits not older than 10 years, an Energy Performance Certificate can also be used instead of an Energy Label.

6.3.2 Materials

The Life Cycle Analysis (LCA) was developed to show the environmental effects of products and human activities. The LCA analyses the life cycle of a product or activity. This means it is an investigation that extends from obtaining the raw materials, production and (re-)use right up to disposal and waste processing after use, in other words from cradle to grave. The outcome of an LCA is a scoreboard of environmental effects and consequences. The LCA is used for a variety of purposes by the target group, from consumers to policy-makers (RIVM, 2010):

- Product comparisons: which product alternative is the most environment-friendly?
- Environmental approval: does a product meet the minimum environmental requirements?
- Product design: how can a product be designed for the lowest possible environmental burden over the life cycle?
- Product improvement: how can the environmental burden of a product be reduced efficiently?
- Environment policy: how can policy measures be implemented?
- Compliance with European regulations: what do companies have to do to meet the latest environmental regulations?

6.3.3 Environment

The *Hinderwet* (Nuisance Act) in the Netherlands was replaced by the *Wet Milieubeheer* (Environmental Management Act) on 1 March 1993. The latter act provides for the issuing of environmental permits. The aim of this act is not only to prevent nuisance, but also to protect the environment. The transition to a sustainable society requires far-reaching social changes and measures. The fourth National Environmental Policy Plan (NMP4) identifies seven large environmental problems requiring timely action (SER, 2001):

- Loss of biodiversity;
- Climate change;
- Depletion of natural resources;
- Threats to health;
- Threats to external safety;
- Deterioration of the living environment;
- Possible uncontrollable risks.

7 Towards sustainable development in the built environment

There have been a number of initiatives in recent decades to realize a sustainable built environment. A number of important developments are discussed in this section.

7.1 Designing with both short-term and long-term focus

Building history shows that transformations of the built environment are always accompanied by demolition and waste. Conventional building processes of this kind have an impact on all the related systems. The traditional focus in a building project is on the management of three important aspects: cost, quality and time. In general, architects, builders and developers visualize buildings as static, permanent objects, and make little if any allowance for possible transformations that may be desired in the future. In a sustainable development approach, attention needs to be given not only to the short-term project goals, but also to the expected longer-term effects. Important aspects to be considered will then include the environment (emissions and biodiversity), the economic conditions and social-cultural facilities (Durmisevic, 2006). See Fig. 7.1.

Tackara (2005) pointed out that 80% of the final negative effects of a design on the environment are the result of incorrect decisions taken during the design phase of a building. These involve not only the realization of the object, but also the usage phase and the ultimate demolition of a building.

It is therefore important that consideration is already given in the initiation phase of a building project to the realization, the use and the possible demolition of the building.

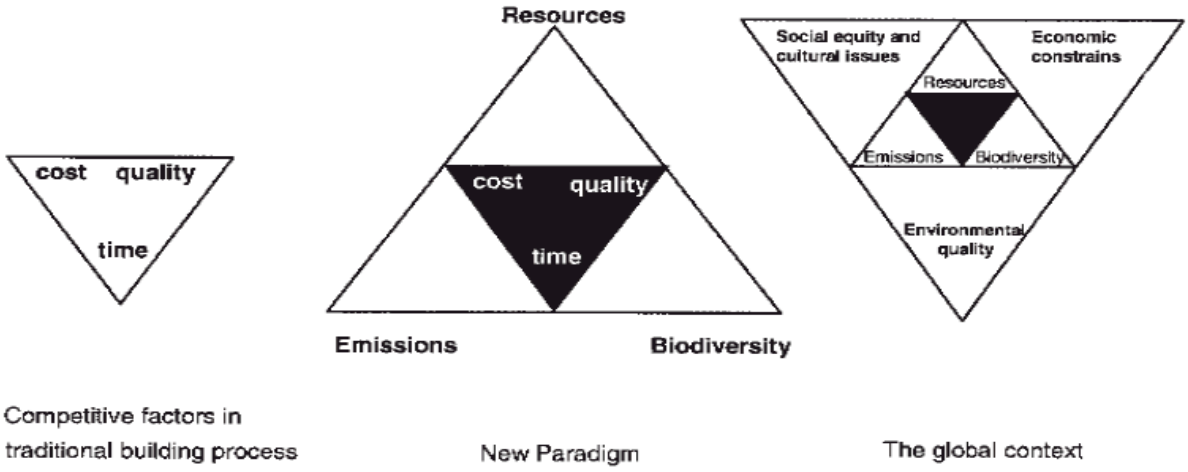


Fig. 7.1. Development towards a sustainable approach to the building process (Durmisevic, 2006).

7.2 From Triple P to Quadruple P

Duijvestein (1993) also indicated the need to consider the long-term effects when taking design decisions. Sustainable Building is based on the definition of sustainable development given in the Brundtland Report. In sustainable development the three Ps – People, Planet and Profit (Prosperity) – stand for social, ecological and economic qualities. In Sustainable Building Kees Duijvestein adds the P of Project, representing spatial quality. Spatial quality includes concepts like beauty, robustness, (bio)diversity and the relationship through the different scales (see also Fig. 7.2.).

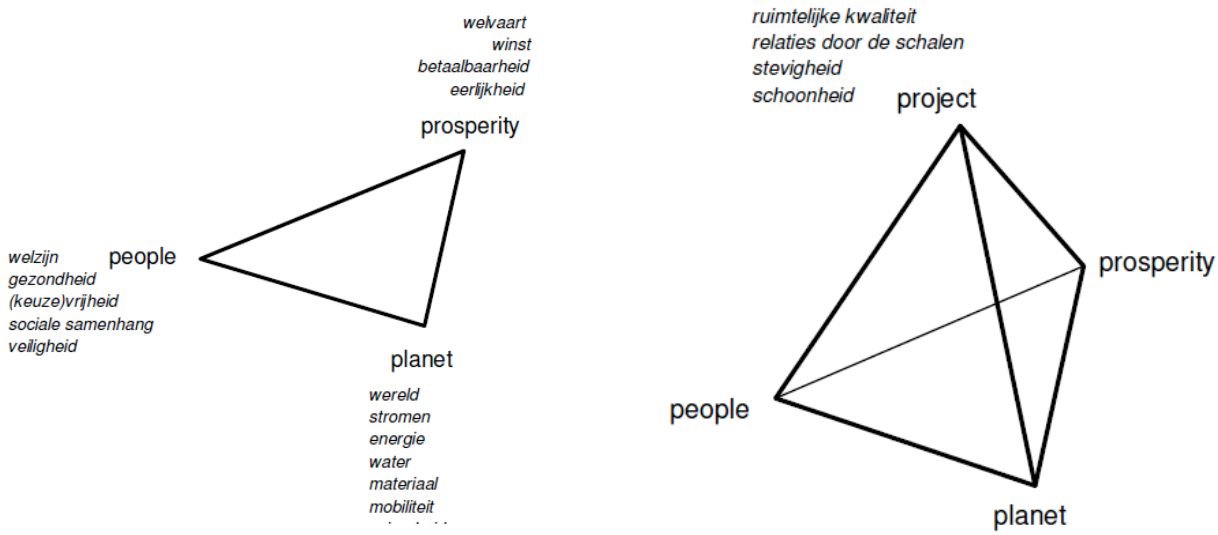


Fig. 7.2. Development of the Triple P (People, Planet, Prosperity) into the tetrahedron of Quadruple P (People, Planet, Prosperity, Project).

7.3 Sustainable Building

In the Sustainable Building approach, efforts are made to minimize the environmental burden during the realization, the use, the renovation and the possible demolition of buildings. in this way Sustainable Building is intended to contribute to reducing the environmental problem. It therefore means more than just saving energy by opting for the measures causing the lowest environmental burden. To achieve this, a number of criteria are applied in Sustainable Building (Ministry of Housing, Spatial Planning and the Environment [VROM], undated):

- Build healthy, safe and comfortable buildings and areas that will be able effortlessly to accommodate the changing wishes of users over time.
- Match the design and the choice of materials to both the function and the desired lifetime of the building. For buildings with a long intended lifetime, make allowance for possible changes in function and usage.
- Choose energy-saving measures and sustainable energy sources, and match these to the management of the building.
- Choose materials / products with a low environmental burden (pollution of air, water and soil) and that cause as few problems as possible in the usage and waste phases.

This development of Sustainable Building has gained international recognition in ‘Green Buildings’. Green Buildings offers an integrated approach to existing practices and techniques to reduce the impact on the environment and human health, and ultimately to eliminate those effects. To do this Green Buildings applies a number of criteria (U.S. Environmental Protection Agency, 2010):

- Efficiently using energy, water, and other resources;
- Protecting occupant health and improving employee productivity;
- Reducing waste, pollution and environmental degradation.

7.4. Industrial, Flexible & Demountable (IFD) building

IFD Building is an approach to design, development and building in which industrial, flexible and demountable aspects are taken into account together through an integrated approach. IFD aims to reduce the environmental burden of the physical building, as well as to shorten the building process and the associated organization. To achieve this an IFD Building checklist has been drawn up to assess whether a system and/or building method qualifies for the IFD label. This label can be awarded if no more than two of the questions below are answered by 'No' (SEV, 2007):

- ✓ Industrial building: building becomes assembling.
  - More than 80% of the system is factory-produced;
  - The system is of constant quality;
  - The production process is manageable;
  - The building time is relatively short;
  - The producer offers a factory guarantee;
- ✓ Flexible building: changing becomes moving.
  - The system offers a high level of design freedom;
  - The solution can be used both permanently and temporarily;
  - The volume can be changed simply;
  - The interior layout can be changed simply;
  - The solution is transportable;
- ✓ Demountable building: changing becomes moving.
  - The solution can simply be demounted;
  - The complete solution is re-usable;
  - The components are re-usable;
  - The technical lifetime can be matched to the period of usage.

In the IFD approach, a large part of the realization process takes place in the factory, thereby reducing the use of people, materials and machines. The reasons for an industrial building process are twofold: on the one hand the shortage of labor, and on the other hand the increasingly stringent occupational health requirements. These changes have the aim of improving the price, quality and speed (in terms of time) of the building process. The important basic principle of flexible building is that the building and its components are designed and realized in a way that changes are possible during both the present and future usage periods. This relates to technical flexibility, and not to financial and organizational flexibility.
The important basic principle of demountable building is that all the connections between the components are designed and realized to be demountable. The decoupling of components means there is less building and demolition waste, and promoting the re-use of materials makes a direct contribution to reducing the use of primary materials.
IFD building reduces the environmental burden by extending the life of materials and components, so it takes much longer before they become waste. Industrial production under controlled conditions creates around 30% less building waste than a traditional building process. The flexibility and demountability mean that an average of 80% of the materials and components are suitable for re-use.

7.5. Bio-Ecological Building

Bio-Ecological Building is a strategy aimed at saving energy and water in the building process, while using as few chemicals and harmful materials and substances as possible. It makes allowance for the supporting capacity of the earth and with the rightful needs of present and future generations worldwide. Bio-Ecological Building uses local and inexhaustible natural raw materials to create a healthy living environment for the user. The term 'ecological' often means: 'with respect for the natural balance'.

A Bio-Ecological building is compact, with an optimum orientation and buffering, is well insulated and ventilated, and is produced using natural building materials with high environmental and health scores. Inside the building, energy and water supplies use economical and energy-saving installations and technologies to reduce harmful effects. The buildings are preferably situated in a compact built environment to limit individual motorized transport (Weterings, undated). A more detailed description of the principles of Bio-Ecological Building, and how to gain a VIBE (Flemish Institute for Bio-Ecological Building and Living) label, can be found on the VIBE website at www.vibe.be.

7.6. Passive building

A passive home aims to create a thermally comfortable, high-quality indoor climate with a high level of energy reduction by using the building mass within an extra insulated shell. Use is made of solar energy and residual heat to keep the use of energy for heating and cooling to a minimum. To achieve this, passive building has a number of rules:

- Optimum insulation;
- Use the building mass within the insulated shell;
- Fresh air is introduced and stale air exhausted by a ventilation system;
- Orientation to the south;
- Carefully planned internal zoning;
- Integrated design.

Optimum use of solar energy starts with the orientation of the building in the urban setting, after which the design and building process starts on a careful and highly integrated basis. In the most optimum case the energy requirements can be reduced by 80%. The energy consumption of a current newly built home and a passive home are 120 and 15 kWh per square meter, respectively. In a renovated home, these figures are 130 and 25 kWh per square meter, respectively. Passive building provides comfort with minimal energy consumption. A high level of draught elimination is an important factor in achieving a high insulation value. Ventilation is by a mechanical system (Kaan, 2007).

7.7. Cradle to Cradle®

The Cradle to Cradle® principles are now being applied on a limited scale in the built environment. The Cradle to Cradle® approach aims not only to minimize negative ecological effects, but also to take the first step towards the transition from a linear to a closed-cycle system without harmful effects for the environment. A number of building projects using the Cradle to Cradle® principles have already been realized as examples.
One of those examples is the old, contaminated River Rouge factory site of the car manufacturer Ford in Dearborn, Michigan (USA). The site was transformed by Braungart and McDonough, making it completely clean and 'friendly' for its surroundings. A second example is the Nike European Headquarters in Hilversum (Netherlands). This office complex was designed by William McDonough based on the 'imagine a tree' C2C concept. The Oberlin College in Ohio (USA) was designed by McDonough & Partners on the basis of ecological and social health. The educational institute for environmental studies is an ongoing 'green' experiment, with a building that produces more energy than it uses and that also purifies its own waste water.

Despite these example projects, the application of the Cradle to Cradle® closed-cycle principles in the built environment is taking off very slowly.

8. Closing remarks

The preceding sections have outlined the development of increasing attention for the environment from both the practical and scientific perspectives.

The past decades have seen repeated scientifically-based warnings about the deterioration of the environment (Carson, 1962; Meadows, 1972; IPCC, 1990; Gore, 2006). 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 (see e.g. Metz *et al.*, 2007). 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. This section considers the necessary initiatives to achieve the desired sustainable built environment, on the basis of the potential solution directions referred to earlier.

8.1. Energy

The use of fossil fuels accounts for a large proportion of greenhouse gas emissions, and thereby contributes to global warming. The use of fully renewable energy allows greenhouse gas emissions to be reduced. Renewable energy is obtained from clean, inexhaustible sources such as solar, wind and geothermal energy, bioenergy or energy from water or human power.
The Alternative Policy Scenario (APS) places great importance on the share of renewable energy. The aim of the APS is for the share of renewable energy in the OECD countries to increase in 2030 to at least 38% of the total energy demand at that time (IEA, 2007).

In 2004, 13.1% of total world energy demand was met by renewable energy, with a share of 49% in Africa, 5.7% in the OECD countries, 15.4% in China and 31.8% in Asia. The renewable energy share in Africa is high particularly because of the importance of energy from biomass. This share may change drastically in the future as a result of increasing energy demand and a transition to non-renewable energy sources.
In Europe the Netherlands is lagging far behind with a renewable energy share of only 2.0% (Roubanis, 2010). For other countries the comparable figures are 3.2% in Japan, 4.2% in the USA and 2.9% in Russia (IEA, 2007).
Dutch policy, using instruments including the EPC and the energy label, has up to now focused primarily on reducing energy consumption and increasing efficiency, and much less on achieving the desired transition. This contrasts with developments in other countries, where many of the developed countries are focusing on a transition to renewable energy applications.

If the present developments continue, the use of renewable energy can be expected to increase strongly in the coming decades. However the economic growth in countries such as China, India and Brazil means a tremendous increase in total energy consumption can also be expected. This not only makes further efficiency increases in the use of (renewable) energy necessary, but also demands a reassessment of the way in which increasingly scarce resources can be used sustainably in the economic process.

8.2. Raw materials

Estimates by the European Commission (2010) show that demand for raw materials may more than triple in the coming 20 years. On top of that, most raw materials are found only in a limited number of countries, such as graphite in China, cobalt in Congo and lithium in Chile. These raw materials are particularly important for the high-tech industries to enable the transition to sustainable development to be made with today's technologies.
If we also want future generations to be able to use these scarce raw materials, it will be necessary not only for focused research to be started into finding ways to drastically reduce the use of these materials, but more particularly to carry out research into ways to fully re-use raw materials after their initial use. In addition, it is also desirable to investigate the use of alternative, much less scarce materials.

The Cradle to Cradle® and Industrial Ecology principles, as described in the earlier sections of this report, aim at closed biological and technological cycles. Fully closing these cycles by means of recycling and upcycling allows the concept of waste to be eliminated, so that residual materials serve as raw materials for following cycles. Complete separation of the materials used in products and objects is a prerequisite for returning residual materials to closed biological and technological cycles.
In relation to the built environment, it will be necessary for buildings and elements to be dismantled in such a way that they can be re-used in the intended cycles, so that building transformations can be realized without waste.

There is an increasing awareness in society of the importance of the closed cycle, and not only scientific studies but also concrete experiments and applications of the closed-cycle principle are currently in progress worldwide.
It is clear that applying the closed-cycle principle at the earliest possible stage in the design of new products, processes and objects should be regarded as a 'must'.

8.3. Design process

Applying the closed-cycle principle in the design process means that within the focus of the defined project objectives of a product, process or object, an appropriate solution will also have to be found for the re-use of the materials. For the design process, this means that the design should enable a transformation and/or dismantling of the product, process or object with full re-use of the materials.

Significant progress has been made in recent years in the application of this closed-cycle principle. The Steelcase office interior design process is structured in a way that allows products to be dismantled simply when they are taken back after first use. The ability for dismantling and material re-use means the product is up to 99% re-usable (Steelcase, 2010). The materials of the Herman Miller Mirra office chair can be separated right down to molecular level, and are 96% re-usable. Carpet manufacturer Desso regards its products as a raw material with which new products can be made, or as materials that can be re-used in the technological cycle (Desso, 2010). The T-shirts made by Trigema are fully biodegradable (Trigema, 2010).
Government legislation has ensured that industry has also started to use the closed-cycle principle for its own economic benefit. The Dutch government promotes and integrates the closed-cycle principles in its existing waste and innovation policy, and in its Sustainable Procurement program. Sustainability aspects are taken into consideration in this program in purchasing and tendering decisions (NL Agency, 2010).
Industry is offering leasing facilities in which products are taken back after use by the manufacturers, depending on the consumer needs defined in advance. Desso is introducing an international product-return system in which used carpets are taken back and recycled. This applies to all grades of carpet, regardless of brand or type, with the exception of those containing PVC (Desso, 2010).

8.4. Conclusion

The application of the Cradle to Cradle® continuous-cycle principles 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 closed 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 closed-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 means a building that can later be changed or dismantled with full re-use of the materials of which it is made, and in which the energy supply is based on renewable energy.

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).

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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. This review aims to provide a literature study of sustainable development in the built environment, and to identify the most important underlying principles.

The literature study contains information from articles published in scientific and professional journals searched using ScienceDirect, Google Scholar and the 3TU catalog. The review focuses on the period from 1962 to 2010. 1962 was the year in which, in an important scientific contribution, Rachel Carson first published her concerns about the increasing environmental pollution.
This review provides a literature study of the sustainable development in the built environment, including the associated reference framework and basic principles of the different lines of thinking. Attention will be given specifically to the most recent Cradle to Cradle approach, which forms an important step towards the transition from a linear to a closed-cycle system, without harmful effects on the environment.

In the book *Cradle to Cradle: Remaking the Way We Make Things*, William McDonough and Michael Braungart present a ‘cradle to cradle’ approach in which biological and technical cycles are closed without damaging effects on the environment. in this approach, waste materials are turned into ‘nutrients’ for a following cycle. To achieve this, the Cradle to Cradle approach uses the following principles:

1. Waste is food, everything is a nutrient for something else;
2. Use the sun, use fully renewable energy;
3. Enjoy diversity in kind, culture and innovation.

This approach introduces the concept of eco-effectiveness to address the shortcomings of eco-efficiency. Eco-efficiency aims as far as possible to reduce and compensate the harmful effects on the environment. Eco-effectiveness aims for development without harmful effects on the environment. The aim of the Cradle to Cradle approach is: ‘A delightfully diverse, safe, healthy and just world, with clean air, water, soil and power – economically, equitably, ecologically and elegantly enjoyed’.

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