Cradle to Cradle Design℠

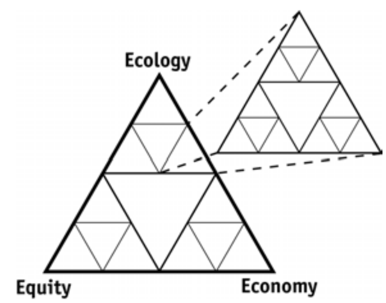
Cradle to Cradle Design is a holistic view of the role of human design and the pursuit of economic, social, and environmental value. It is a new design paradigm that is always evolving but originated in the work and thought of William McDonough and Dr. Michael Braungart.

Fundamental Principles

Cradle to Cradle Design proposes that design is a signal of human intention, and that all decisions humans make can be considered design activities. The Paradigm is also based on the conviction that design should pursue a more complete interpretation of value – not just functional and aesthetic excellence or economic prosperity.

One of the first clear and extensive expressions of the Paradigm was *The Hannover Principles: Design for Sustainability*. In 1991 the City of Hannover, Germany, commissioned William McDonough to write design principles for EXPO 2000, The World's Fair. Mr. McDonough wrote *The Hannover Principles* in collaboration with Dr. Braungart, and since its publication in 1992, the set of nine principles has been widely acknowledged as a guide for sustainable design.

Understanding Value – The Fractal Triangle



The Paradigm sees value as infinitely interconnected, and sees an abundance of opportunity to create value throughout the 'spectrum' of Economy, Equity, and Ecology.

MBDC represents this idea with a conceptual tool we call the fractal triangle. The fractal triangle represents economy, ecology, and equity as anchors in a spectrum of value, intimately interrelated and analyzable at increasing levels of depth and detail.

The spaces between the corners (economy, ecology, equity) represent the infinite shades of value between one of the three categories and another. At any level of detail, each design decision is threefold in its implications—thus the self-similar fractal structure.

We use the fractal triangle to ask ourselves questions that help identify opportunities to generate greater value and recognize the abundance of opportunities to create value each design problem presents.

Design Modeled on Nature

Cradle to Cradle Design proposes that human design can approach the effectiveness and elegance of natural systems by learning from nature and incorporating its patterns into our own systems.

Consider the cherry tree: each spring it makes and sheds thousands of blossoms. Those blossoms fall to the ground and decompose into food for other living things. The cherry tree's abundance (its "waste") is useful and safe.

The tree is part of an interdependent system: it engages with other plants, organisms, and animals in its ecosystem to contribute to a thriving, healthy whole. And the tree spreads multiple positive effects: it makes oxygen, transpires water, builds soil, and provides habitat, among other things. The tree is also beautiful.

Human designs should create systems and things that are interdependent with other living systems and spread multiple positive effects, like the cherry tree. Our designs can enrich and replenish ecological, economic, and social systems instead of depleting them.

Nature's Design Principles

The Paradigm is grounded in fundamental assumptions of intelligent design, based on patterns found in nature. Looking to the natural world for inspiration, we aspire to learn from the intelligence of its design, elegance, and effectiveness.

The three basic design principles MBDC seeks to follow, based on natural models, are:
- Waste Equals Food
- Use Current Solar Income
- Respect Diversity

Waste Equals Food. Nature knows no waste -- the waste of one living thing eventually becomes "food" for another. As designers, we can move beyond the idea of simply minimizing waste, and eliminate the concept of waste altogether. Cradle to Cradle Design considers every element of a product "food" for either biological or industrial processes. Materials that are harmful to biological systems or are not perpetually useful to industry do not fit this first design principle and should be redesigned.

Use Current Solar Income. Natural systems satisfy their energy requirements with energy from the sun. Likewise, human design should move toward the use of abundant, renewable energy and materials, neither mining the past nor mortgaging the future. Cradle to Cradle Design promotes energy efficiency strategies in the short term and the active production of renewable energy and materials over the long run.

Respect Diversity. Nature engenders almost infinite variety in its design solutions, with the constant creation of niches. Similarly, sustainable design must embrace the diversity of solutions to design challenges. All sustainability is ultimately local, though it must be considered in terms of both global and local impact. The celebration, preservation, respect and enhancement of diversity of all kinds – biological, geophysical, cultural, climatic, material, gender, etc. – lead to an enriched rather than degraded environment.

The Cradle-to-Cradle Product Typology

The Cradle-to-Cradle Product Typology is a method for the conception, development, manufacture, and distribution of goods and services so that product and system waste can be safely cycled back into the production process.

The Cradle-to-Cradle Product Typology is adapted from Dr. Braungart's original work on process engineering published in Germany as *IPS –The " 'Intelligent Product System' To Replace 'Waste Management'*, *"* Fresenius Environmental Bulletin #1, 1992, p.613-619.

Biological Nutrients and Metabolisms

The natural world continually cycles all of its materials. Each organism cycles nutrients according to its own metabolism, through the interdependent system of the biosphere. In what we refer to as a *biological metabolism*, the waste of one organism feeds the growth and development of another. Materials that safely circulate within the biological metabolism are called *biological nutrients*.

A biological nutrient is a biodegradable (or otherwise naturally degradable) material posing no immediate or eventual hazard to living systems that can be used for human purposes and can safely return to the environment to feed ecological processes.

Technical Nutrients and Industrial Metabolisms

Human industry makes use of many substances that are not suited for the biological metabolism. These synthetics and minerals, which are valuable for the services they perform in industry, are what we call *technical nutrients*. In the Cradle-to-Cradle Product Typology, technical nutrients cycle perpetually within a contained *technical metabolism*, analogous to biological systems. Cradle to Cradle Design strives to maintain the value of industrial materials through unlimited product life cycles, ensuring that they never are unintentionally released into the biosphere and that their material value is retained.

Certainly the complete separation of biological and industrial metabolisms is an ideal. The small scale and accidental release of these materials into the environment is unavoidable. As a result, the industrial metabolism is not a true closed loop – it inherently exists within the context of the natural world's biological metabolism. Therefore, industrial products and materials should be designed so that incidental releases are within nature's capacity to safely manage them.

Products of Consumption

A *product of consumption* is a product designed for safe and complete return to the environment at the end of its use, becoming nutrients for healthy, living systems. A product of consumption is made of

biological nutrients. Products designed to be products of consumption are consumed or used up by the customer. This includes single use, ephemeral items, and products that wear out readily, abrading into the environment.
EXAMPLE: A wool fabric made with ecologically benign dyes and additives is a biological nutrient, compostable and safe for return to the environment.

Products of Service

Products of service are made from technical nutrients and are designed to remain within a technical metabolism. In general, the materials in a product of service aren't as valuable to customers as are the services they perform. They are, however, of continued value when reclaimed by the manufacturer. For instance, a car battery is valuable to customers for the service of powering cars, but not for the several pounds of hazardous materials it contains.

Products of service are typically leased to the customer rather than sold. Customers receive the service of the product, but the manufacturers reclaim it at the end of its term of use to retain its material value. For example, when a car battery is replaced, the customer gets credit towards a new battery in exchange for the old battery, which is returned to the manufacturing system and recycled into new products.

Closing material loops through the return of products to producers provides incentives to maximize product disassembly and recycling capacity, and to design costly and toxic waste out of existence.

EXAMPLE: The aluminum in a soft drink can is a technical nutrient, that can be recycled again and again into beverage containers.

Hybrid Products

Some products of service are *hybrid products*, made of both biological and technical nutrients. Certain components are designed to return to the environment, while others remain in technical production. As with other products of service, hybrid product design must facilitate the economical disassembly of components so that all materials can return to their proper metabolism.

EXAMPLE: An office chair with an aluminum frame and wool upholstery, designed for disassembly into discrete recyclable parts, is a hybrid product made of both biological and technical nutrients.

Cradle to Cradle Design℠ Protocol

To assist companies in (re)designing cradle to cradle products, MBDC uses the Cradle to Cradle Design℠ Protocol , a scientifically-based, peer-reviewed process, to assess materials used in products and production processes.

The Protocol is a useful tool for a variety of environmental management approaches including design for environment and life cycle thinking. The objective of both of these approaches is to design products with the environment in mind, considering all phases of the product life cycle. The Protocol facilitates this design process through the selection of materials that are safe for human and environmental health in their specified use and application.

In applying the Protocol, materials in products are first inventoried and then evaluated according to their characteristics within the desired application, and placed into one of four categories (Green, Yellow, Orange, or Red) based on human health and environmental relevance criteria. After all chemicals are assessed, the materials in a product application are optimized by positively selecting replacements for chemicals characterized as Red and using Green chemicals as they are available.

Material Inventory

The first step of the Protocol is to conduct a material inventory with the objective of collecting 100% of the content information and information for every material used in the manufacture of the product. Each material is then inventoried for its chemical constituents. The inventory process results in a complete listing of components by CAS number[1], name, function, and % weight. All components with a % weight of .01% or more must be included.

The inventory process requires open communication with suppliers. Manufacturers should clearly communicate their goals and objectives and the information they need from their suppliers. Suppliers are encouraged to share their constraints and concerns. Closer communication with suppliers fosters a better understanding of the manufacturers needs and requirements resulting in improved levels of supplier performance.

Assessment

Each chemical will be evaluated using the human health and the environmental relevance criteria shown below:

Human Health Criteria
- Carcinogenicity
- Teratogenicity
- Reproductive Toxicity
- Mutagenicity
- Endocrine Disruption
- Acute Toxicity
- Chronic Toxicity
- Irritation of Skin/Mucous Membranes
- Sensitization
- Other Relevant Data (e.g., skin penetration potential, flammability, etc.)

Environmental Relevance Criteria
- Algae Toxicity
- Bioaccumulation (log Kow)
- Climatic Relevance/Ozone Depletion Potential
- Content of Halogenated Organic Compounds (AOX)
- Daphnia Toxicity
- Fish Toxicity
- Heavy Metal Content
- Persistence/Biodegradation
- Toxicity to Soil Organisms (Bacteria and Worms)

[1] Chemical Abstract Service Number. This number uniquely identifies each pure chemical compound.

Assessment of Individual Criteria

A color designation will be established for each criterion as shown below:

GREEN	No problems identified or expected, or extremely low risk
YELLOW	Low to moderate risk
ORANGE	Lacking sufficient data to make a determination
RED	Severe problems or high risks identified or expected

Preliminary Assessment of Chemicals

Research on individual chemicals begins using the priority criteria (X-filter). The priority criteria include the first five Human Health criteria: Carcinogencity, Disruption of Endocrine System, Mutagenicity, Reproductive Toxicity, and Teratogenicity. If any of these criteria is assessed as Red, research stops and the chemical is assessed as Red. If the chemical meets the priority criteria, all of the remaining criteria are assessed.

Chemicals will be given an overall color rating using a “weakest link" methodology. This means that the preliminary assessment is equal to the lowest rated criterion. Thus, if mutagenicity data for a chemical is given a red flag, the overall chemical assessment can rate no better than red.

In many cases, a lack of data results in criteria being assessed as Orange. With in-depth knowledge of chemistry, assessments can sometimes be done by analogy. A judgment is made that the human health and environmental relevance of given substance will be much like another substance with similar chemical attributes changing the assessment from Orange to Yellow or Green. These assumptions will be documented in the Chemical Assessment Report so that these issues can be easily revisited when additional information becomes available. This also helps ensure that another assessor trying to verify this assessment will be able to arrive to a similar conclusion.

Material Assessment

Preliminary chemical assessments may change based on how the specific chemicals are used in the material. A classic example of this is the use of carbon black as a pigment in polymeric materials. As an ingredient, carbon black is assessed as red because it is a suspected carcinogen. However, when one assesses the potential routes of exposure for carbon black as it exists in a polymeric material, it becomes clear that carbon black does not pose a risk to the user or recycler of the material. Therefore, the preliminary red flag for carbon black merits a yellow assessment when used in the material. Additionally, the assessor needs to determine if there are any known chemical interactions that might alter a yellow assessment result to red. These changes are documented in the notes section. Using the “weakest link" method, the material is assigned a color value rating similar to the colors used for individual chemical assessments listed in the second column. This means that the material evaluation will be the same as the lowest color designation for any component present in that material.

GREEN	This is considered a preferred material. It is a positively identified, healthy, safe, non-problematic material.
YELLOW	This material presents low to moderate risks and cannot be classified as green, but it also does not have any characteristics that classify it as red. For this reason, yellow chemicals are recommended for continued use.

ORANGE

For this material, insufficient information is available to adequately assess its human health and environmental relevance characteristics.

Two potential options are available (selection is based on the necessity of using the material and the time and budget available to conclusively assess the material):

- Phase out the use of this material.
- Perform tests to fill in data gaps with respect to human health and environmental relevance characteristics.

RED

Phase out the use of this material. Known health and environmental hazards exist, or the risk is too great to continue using it. Look for alternatives for replacement, redesign the material formulation, or at minimum, establish and implement a strategy for minimizing the risks (a technical solution).

Closing the Loop on Materials – Value Recovery

To recover value and maintain materials in closed loops, materials must either return safely to soil or be recyclable as a technical nutrient. The following is a sample list of questions to ask when evaluating the value recovery potential of a material:

- Is it technically feasible to compost or recycle the material?
- Does a recycling or composting infrastructure exist for the material?
- What is the resulting quality of the recycled material?

In addition, products must have a defined end -of -use strategy and be designed for disassembly so that recovery of materials is possible. The following is a sample list of questions to ask when evaluating the recoverability of materials in a product:

- What is the take-back strategy for the product and its materials?
- Can dissimilar materials be easily separated?
- Can common or readily available disassembly tools be used?
- Can one person disassemble the product quickly?
- Can the material type be identified through marking, magnets, etc.?