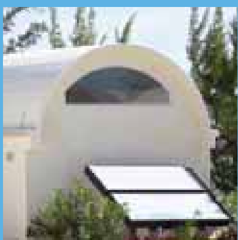
Cradle to Cradle® Criteria for the built environment



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Disclaimer

These criteria are designed as a basis for planners, architects, and other building professionals to apply Cradle to Cradle® in the built environment, especially to buildings and to materials and products that move through them. The criteria can be used as guidelines for planning and specifications, but are not intended as specifications. It is important that building professionals determine the technical characteristics and regulatory limitations associated with each site prior to applying these criteria.

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1. Introduction

The conventional approach of government and industry has been to minimize the environmental impacts of their activities by being "less bad" as products go from "Cradle to Grave". This approach is often regarded as involving extra costs for stakeholders without many quantifiable benefits.

However, the Cradle to Cradle® Design Protocol has taken a fundamentally different approach that generates benefits for stakeholders by going beyond the "grave" and beyond conventional interpretations of "environment".

Cradle to Cradle® (C2C)[1] is a paradigm-changing innovation platform developed in the 1990s by Michael Braungart, William McDonough et al., based on research at the Environmental Protection Encouragement Agency in Hamburg Germany, for designing beneficial economic, social and environmental features into products, processes and systems. Cradle to Cradle® is primarily an entrepreneurial and innovation concept that starts by determining the intended benefits of a product or service instead of focusing on minimizing negative environmental impacts.

To enhance quality and add value for stakeholders, C2C promotes innovation partnerships along the entire chain of a product, including manufacturing, distribution, use, disassembly, recovery and reuse.

By characterizing hundreds of products and thousands of materials for their human and environmental health attributes, as well as defining systems to safely and fully cycle materials into new products, C2C has already provided a practical yet inspirational scientific and business model for improving quality.

This innovation and value model makes C2C potentially attractive to planners, builders and manufacturers for integration into products, processes, buildings, materials recovery systems, and purchasing.

Extensive books, cover stories and documentary films have been published and broadcasted about C2C since the 1990s. The book *Cradle to Cradle*[2] is well known and translated into at least a dozen languages.

However, many planners are not yet familiar with how to integrate into the built environment C2C features such as beneficial materials. There is a tendency when encountering well-known phrases such as "safe materials" and "species diversity", to respond with "yes we do that already". But most buildings and area plans don't already do that. Methods are still not well established for designing sites so they contain defined materials, or are species-positive.

A rapid acceleration occurred from 2008 to 2010 in the numbers of planners, architects and engineers introducing C2C concepts into planning and construction. A priority expressed by government agencies is to translate C2C into renovation and new construction of buildings. Those requests resulted in these Cradle to Cradle® Criteria for the built environment.

To begin, it is important to describe basic C2C criteria for buildings, and how planners, architects and engineers can apply and measure those criteria.

1 Various iterations of "Cradle to Cradle" and "C2C" are registered marks of McDonough Braungart Design Chemistry.

2 Cradle to Cradle. Remaking the Way We Make Things. William McDonough & Michael Braungart, North Point Press NY, 2002.





2. Definition

What is a Cradle to Cradle® building?

Various guidelines for C2C in the built environment were established since the 1990s through published declarations such as the Hannover Principles and more recently in The Netherlands the Almere Principles and the Floriade Venlo Principles.

However, those extensive documents are only effective if they can be translated into measurable results. The first step to doing that is by studying and implementing the three defining Cradle to Cradle® Principles:

Waste = Food.
Everything is a Nutrient for Something Else.

Use Current Solar Income.
Energy that can be Renewed as it is Used.

Celebrate Diversity.
Species, Cultural, and Innovation Diversity.

Those principles define and support two types of metabolism for every product and process: *Biosphere* metabolisms for products designed to support biological processes, and *Technosphere* metabolisms for products designed to provide a technical service and whose materials are continuously recycled.

The C2C Design Protocol and Framework, developed by McDonough and Braungart, further define those principles and metabolisms. They also describe how C2C adds quality and value for stakeholders. Added quality and value often distinguish C2C from conventional interpretations of sustainability.

Because the various C2C principles and protocols were only developed near the turn of the millennium, a 100 percent Cradle to Cradle® building does not exist yet, also due to the time required for a conservative building industry to adopt new concepts and products. However, it is still possible to describe and construct a building that uses C2C innovations and C2C-defined products and materials already existing in the marketplace.

In that context, it can generally be said that a building has an excellent chance of achieving C2C if it fulfills the three basic C2C principles and the C2C defined metabolisms. Those can be roughly condensed into this general definition:

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

This definition can be applied to buildings whether they are residential, offices, factories, stadiums, or health-care facilities.

The definition also applies to materials and products such as furnishings that move through buildings, because often things that move through buildings have equal or greater impacts on their stakeholders than the structures themselves.

Criteria and tools for applying the Principles and Definition are described in the next sections.

Atria integrate C2C principles by recycling nutrients, using solar income, and celebrating innovation and biodiversity.

2.1 The Principle Criteria

The purpose of this summary is to provide planners with guiding criteria for developing a building with measurable C2C features. The focus of these criteria that distinguishes them as C2C is to *maximize beneficial impacts* instead of just minimizing negative ones. These principle criteria are in no order of priority, although "State Your Intentions" is normally done at the beginning of the process.

2.1.1 State Your Intentions

Design is the first signal of human intention. State your intentions for the building by describing your Goals and Milestones in relation to the three basic Cradle to Cradle® Principles, i.e. where you want to be by a given date.

Examples. Do you want the building to contribute air and water that are cleaner than when they were taken from the outdoor environment? Do you want the building to be deconstructable? Do you want to demonstrate that the ingredients in building materials are defined and safe?

Criteria Based on the Defining C2C Principles

C2C Principle. Everything is a Nutrient for Something Else.

2.1.2 Define Materials and Their Intended Use Pathways

A. Use materials whose quality and contents are measurably defined in technical or biological pathways from manufacturing through use and recovery.

B. Use materials whose impacts are measurably beneficial for human health and the environment.

Examples. A defined product would be a chair whose component parts come from known renewable or recycled materials and energy sources, whose composition is known to 100 parts per million, whose materials are safe for contact with human skin and lungs, and can be disassembled into materials that each can be recycled for use in other products or decomposed as beneficial nutrients for biological systems. A “beneficial” ingredient would be an ingredient added to coatings that allows them to actively clean the air.

2.1.3 Integrate Biological Nutrients

Measurably recycle biological nutrients and water by integrating biomass production into buildings, landscaping, and spatial plans to generate more biomass, soil and clean water than before development of the site.

Examples. Biological nutrients from grey water, biodigestion, and interior and exterior landscaping. Air-cleaning vegetative walls designed to metabolize pollutants. “Green roofs” that retain moisture, capture CO_2, metabolize particulates, and provide oxygen. "Topsoil manufacturing" that uses biodigestion and composting to produce humus and capture CO_2.

2.1.4 Enhance Air and Climate Quality

A. Measurably improve interior air quality for biological metabolisms so the air is cleaner than before it entered the building, and provides a comfortable climate for occupants.

B. Contribute to enhancing outdoor climate by contributing air that is healthier for biological metabolisms than before it enters a building, and using climate change gases as resources through carbon management.

Examples. Air quality can be enhanced by integrating C2C materials across products such as exposed window frames, floors, wall materials, HVAC systems, wall and floor coverings, indoor plants and green walls, furnishings, office equipment, and mold inhibitors. Active carbon management is achieved with vegetation and renewable energy. Climate change gases such as methane and CO_2 are resources that can be used to produce biomass. See later sections for details on energy and CO_2.

2.1.5 Enhance Water Quality

Measurably improve water quality so the water is healthier for biological metabolisms than before it entered the building.

Examples. Water quality improvement can be achieved by integrating water recycling systems with nutrient recycling, rainfall capture and storage, indoor plants and green walls. See also “integrate biological nutrients”.

C2C Principle. Use Current Solar Income.

2.1.6 Integrate Renewable Energy

Integrate renewable energy (current solar and gravitational income) into buildings and area plans so the building and site generate more energy than they use. Use exergy as a way to guide energy effectiveness.

Examples. Use energy efficiency to introduce renewable energy rather than reduce fossil fuel use, e.g. high-efficiency LEDs combined with direct current from photovoltaic cells. See “Energy in a C2C Building”.

C2C Principle. Celebrate Diversity.

2.1.7 Actively Support Biodiversity

Integrate measurable species diversity so the area supports more diversity than before development.

Examples. Species diversity applies to plants, animals and insects, and is quantified by counting numbers and varieties supported by a building. The concept of “natural” or “native” species has to be evaluated in each case because in many regions the natural environment has been transformed by humans, and returning it to an earlier “natural” state might be impractical.

2.1.8 Celebrate Conceptual Diversity with Innovation

Conceptual diversity can be demonstrated measurably by focusing on special beneficial features of a building and integrating innovative components that are beneficial for the well-being of occupants and the environment.

Examples. Conceptual diversity can be quantified by measuring how innovations increase: the variety and prevalence of C2C-defined materials in a building, the percentage of energy used that is renewable according to C2C definitions, and the amount of beneficial air, water, topsoil and biodiversity, contributed to the outside environment. "Buildings Like Trees" is a guiding C2C innovative approach. Some of this can be achieved through biomimicry, e.g. coatings that metabolize pollutants. Systems integration that combines such enhancements can also be considered a C2C innovation.

Stakeholder Value Criteria

These criteria are designed to make sure C2C adds value and benefits for stakeholders instead of only providing benefits for the general environment or population. Benefiting stakeholders is essential for making C2C practical for building owners, operators and occupants.

2.1.9 Add Value and Enhance Quality for Stakeholders

Describe what the C2C features of a building do practically for the users.

Examples. Cleaner indoor air enhances productivity. Recycling water reduces water fees. Building integrated photovoltaics can be less expensive than other claddings while providing energy security in regions with irregular power supply. Design for disassembly of HVAC systems supports inexpensive replacement during the life of the building. Natural lighting cuts energy costs.

2.1.10 Enhance Stakeholder Well-Being and Enjoyment

Enjoyment is part of a C2C building because an ugly unenjoyable world is not part of C2C. By implementing each of the basic criteria, a C2C building enhances enjoyment by enhancing well-being. Spatial and aesthetic features that are less quantifiable can also enhance enjoyment and support diversity by demonstrating how well a building serves diverse stakeholders.

Examples. Make areas safe for children. Make meeting areas accessible. Provide ready access to outdoors and fresh air.

Coconut for dessert? Get it from the roof. Green roof innovation at a restaurant enhances value and enjoyment.

2.2 Implementation Criteria

The tools described here are intended to enhance and accelerate implementation of the principle C2C criteria. These tools are sometimes used in other building systems and are often not unique to C2C. It is their integration rather than any individual factor that results in C2C benefits.

2.2.1 Do an Inventory

Know what you already have. Prior to a site being developed or renovated, an inventory is done preferably with stakeholders to determine what C2C features already exist and what stakeholders want to preserve, especially for renovations.

Integration.

2.2.2 Integrate Innovative Finance

To maximize C2C benefits, use financial innovations that integrate capital and operating costs.

Examples. Total Cost of Ownership financing. Power purchase and energy-to-grid agreements. Service concepts for products.

2.2.3 Integrate Innovation Partnerships

Partner with C2C-experienced organizations, especially in supply chain partnerships. To enhance innovation it is beneficial to improve on examples already in the marketplace. This avoids "reinventing the wheel".

Examples. Many companies have already developed C2C-defined products in the built environment, ranging from coatings to carpets, insulation, furniture, and structural materials.

2.2.4 Integrate Diverse C2C-Experienced Contractors

The developer makes use of contractors and suppliers who use C2C methods and materials.

Examples. Some engineering firms and architects are C2C-trained by authorized C2C training personnel. Various product companies provide C2C-defined products. C2C materials experts are available.

2.2.5 Integrate Systems and Application Tools

The level of systems integration can determine the success of C2C in a building. Each of the criteria described here can be achieved most effectively by integrating systems, components and C2C application tools.

Systems Integration Examples. To improve the quality of biodiversity, air and water, it is possible to integrate Heating Ventilation and Air Conditioning (HVAC) systems with C2C-defined coatings, furnishings, floor and wall coverings, and plants that metabolize pollutants.

Examples of C2C Application Tools.
(in alphabetical order)

Actively Beneficial Qualities e.g. coatings that clean the air.

Defined Product Recycling. Dedicated sorting, disassembly and recycling of high quality materials that are more economic to recover on their own than if they are mixed with other material streams. This also facilitates upcycling to improve materials quality and use.

Defined Use Pathways. These describe the use of materials in their pathways from sourcing to manufacturing, use, disposal and reuse, recycling or decomposition.

Defined Use Periods. Many "green" criteria require products to be "durable" to last as long as possible. However, this approach is often counter-productive because when products last longer than they are optimally useful they perpetuate obsolete technologies, resulting in reduced benefits for users and unnecessary loss of revenues for business. The "durable" approach can also make recovery of materials more difficult, for example by making them harder to disassemble. Because of this, C2C emphasizes designing materials or ingredients according to the intended use period of the product, to promote practical recovery of materials so they can be used in new products.

Design for Assembly, Disassembly and Reverse Logistics.

Materials Pooling. This occurs where diverse industries develop a pool of defined materials to achieve economy of scale, commercial flexibility, and improved quality.

Preferred Ingredients Lists (P-Lists). These are lists of positively defined ingredients that are designed to be used for materials according to their defined use in biological or technical pathways.

2.2.6 Integrate Diverse Use with Features that Apply C2C Criteria

To maximize effectiveness, the building and site perform diverse functional uses while contributing energy and biodiversity as well as beneficial climate, water, and air components.

Examples of integration. Integrate functional uses such as Recreation, Shopping, Dining, Manufacturing and Modular design with C2C features such as cleaning air and water, and producing energy.

2.2.7 Integrate Natural Light with Innovative Artificial Light

Wherever practicable for the "intended use" of the building, natural light is made available to the maximum number of occupants and integrated with artificial light to provide a consistent quality of light.

Examples. Skylights, fiber-optic transmission of daylight, locating work spaces near windows. Artificial light. Design innovative light solutions, e.g. use sensors to adjust artificial lighting for changes in natural lighting conditions. Design glare-free indirect indoor lighting. Use outdoor green-spectrum lighting on migratory routes.

2.2.8 Integrate Renewably Powered, Healthy Mobility

Support the use of current solar income for mobility in transport to, from and in the area.

Examples. Collaborate with vehicle manufacturers to use C2C criteria such as design for disassembly and materials for improving vehicle interior air quality when acquiring service vehicles for the building. Provide solar-powered charging stations for electric cars.

2.2.9 Protect Occupants from Environmental Hazards

A. The building measurably protects occupants from adverse normal elements, e.g. harmful noise, biological threats such as mold and infestations, precipitation, and outside pollution.

B. The building can adapt to natural extremes by using innovative technologies to protect occupants from extreme events such as earthquake, tornado, hurricane, sandstorm, flood, heat, cold and radiation.

2.2.10 Consider Aesthetic Opinions of Stakeholders

Provide intended occupants and viewers of a building with the opportunity to judge its beauty and enjoyability. This requires involving intended occupants and viewers in the design process.

Examples. While aesthetics are difficult to quantify, the act of involving stakeholders in the process can be quantified through consultations, creating interactive websites, and creating physical participation space where stakeholders can see plans for the building.

3. Measuring intentions, milestones & roadmaps

How can progress toward Cradle to Cradle® be measured?

3.1 Express Intentions as Measurable Goals

Because no building can yet be 100 percent Cradle to Cradle®, and in accordance with C2C criterion 2.1.1, State Your Intentions, it is important to define your intentions for what C2C aspects the building will focus on.

Intentions can be expressed as measurable Goals.

To achieve Goals it is possible to set Milestones with defined dates, then integrate those Milestones into a C2C Roadmap.

Moveable products can be improved over time to enhance quality as newer optimized products become available.

3.2 Set Goals, Milestones & Roadmaps

It is possible to quantify C2C innovation through the process of stating Goals and establishing Milestones and Roadmaps. The main components of this process can be:

3.2.1. State Intentions

State your intentions for the building by establishing Goals that address principle C2C criteria.

3.2.2. Define "Use Periods" for the Building, Products and Materials

A Roadmap is started by establishing a "Defined Use Period" for the building. The Defined Use Period is an estimated "recovery date" when the Goals will be achieved and the building will be replaced or substantially renovated. This can be 10-20 years, including the planning period prior to construction.

The 10-20 year timeframe is selected because it is in the range of most financing mechanisms and in the career timeframe of many managers who will still be active in the industry during that period, allowing them to see the results of their work. It is also selected to demonstrate there is no time to wait 40 or 50 years to implement C2C improvements. Changes are required more urgently than that.

Defined Use Periods can also be established for products that are part of a building, and that move through the building during its use period. These Use Periods will vary from years to a few months, weeks or days, depending on the product.

Purposes of Defined Use Periods or Recovery Dates in a building:

A. Provide timeframes during which continuous improvements can be made to meet measurable Goals.

B. Let manufacturers and building owners and operators know when products have to be replaced.

C. Let recyclers know when they get materials back for recycling.

Example. Defining Use Periods for products that move through a building:

Many "green" building methods focus on spatial planning and basic construction materials. However, the amount of materials that move through a building during its operation can equal or exceed materials in the structure. Those "high-velocity materials" such as furnishings can have greater impacts on the well-being of occupants than the superstructure because occupants are often more directly exposed to them.

Most products can be assigned an estimated Defined Use Period that forecasts their movement into and out of a building. For example, room dividers, furniture, office equipment, floor and wall coverings, lighting, paper, water, plants and food, move through buildings in large quantities at varying "velocities". Energy systems such as building-integrated photovoltaics and heat exchange are also renewed with improved technologies during the Defined Use Period of a building.

The quicker velocities of such products through buildings allow more rapid C2C improvements than for longer-term structural materials, because product generations turn over more quickly. It is important to plan for these diverse velocities of materials by establishing Milestones.

3.2.3 Establish Milestones and Innovation Incentives

Milestones are important to establish at every project stage, from planning through construction and operation. These allow buildings to quantifiably improve over time.

Milestones can be used as innovation incentives for builders and building managers by defining financial targets such as savings from recycling water or generating energy. These incentives promote constant innovation.

Milestones can be plotted along the vertical and horizontal axis of a C2C Roadmap. One axis describes the level of benefits for stakeholders. The other axis shows the Defined Use Period for the building. See Fig. 1.

Biodiversity, CO_2 reuse, and purifying air and water are measurable in parks and landscaping.

3.3 Examples of Milestones in Relation to Goals

No one is perfect at the start. C2C can be achieved through measured progress toward defined intentions or goals. Here are examples of quantifiable goals and their related Milestones for C2C in area and building planning. These examples are not mandatory and will vary from building to building.

1. Goal. In ten years, the building will contribute air to the outside environment that is cleaner than the outdoor air it uses.

Milestones. By the time tenders are issued, planners will have a strategy for measuring outdoor air quality in the surrounding area, beneficial indoor air quality improvements and a list of technologies and systems that can contribute clean air to outdoor air.

2. Goal. In ten years, the site and building together will be net generators of renewable energy.

Milestones. On completion of construction the building will be 50 percent self-sufficient in energy and contain outlets for charging electric vehicles. The systems will be modular so they can be switched out when renewable energy technologies improve. In ten years the building will produce all its own energy requirements and contribute energy to the grid.

3. Goal. In ten years, the building will contribute more clean water to the outside environment than it uses.

Milestones. By the time tenders are issued, planners will have a strategy for achieving this by integrating biodigestion, grey water reuse, rainwater capture, beneficial coatings, and green roofs and walls. Planners will determine cost savings to various stakeholders by substituting fresh water from municipal systems, improving sewage processing cost savings, and improving cost-savings from stormwater treatment.

4. Goal. The building will use the most advanced available level of Cradle to Cradle®-defined structural materials such as concrete and steel.

Milestones. By the time tenders for construction are issued, building planners will have identified the most advanced level that can be reliably implemented, and identify leading C2C companies in fields such as engineering, furniture and construction materials to make sure those companies are made aware of the tendering process for this building.

5. Goal. The building will be a leading example of Cradle to Cradle® Innovation Partnerships.

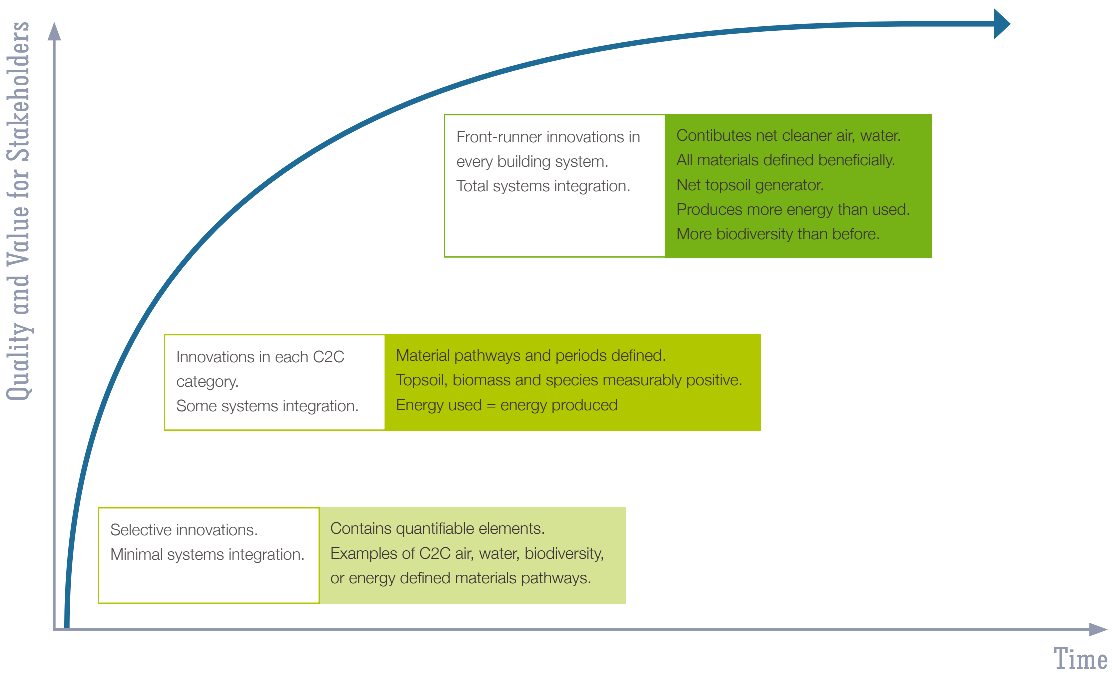
Milestones. Planners will use advanced financial tools such as Design, Build, Finance, Maintain, Operate (DBFMO) to establish materials pooling and Defined Use Periods. Service concepts will be implemented for building integrated energy generation and equipment maintenance. Building-integrated photovoltaic materials will replace other building cladding to save capital costs and improve payback time for renewable energy.

Note on definition. The term “clean” has been used here and in the following Table and Figure as an abbreviation for substances that are healthy for biological metabolisms, as described earlier in these criteria.

Table 1. Examples of different levels of Milestones for selected C2C Principle Criteria.

Air and Sound	Water	Topsoil, Bionutrients Biodiversity	Energy	Materials
Contributes net cleaner air than the building uses and protects occupants from chronic noise.	Contributes net cleaner water to the outside environment than it uses.	Generates a net positive outflow of topsoil, biomass and species diversity to the local environment.	Generates more energy than it uses based on renewable sources and recyclable materials.	Defined pathways, defined use periods, design for disassembly.
Contributes the same amount of clean air as the building uses.	Contributes the same amount of clean water as the building uses.	Maintains a rough input-output balance of topsoil, biomass and species diversity.	Generates the same amount of energy as it uses based on renewable sources.	Defined pathways and use periods.
Contains quantifiable innovative features for cleaning air and reducing chronic noise.	Recycles rainwater and greywater in quantifiable amounts.	Incorporates quantifiable topsoil and biomass generation and species diversity as features.	Uses renewable energy to generate at least a quarter of energy requirements with provisions for improvement.	Defined pathways.

Figure 1. Roadmap for achieving C2C buildings.



3.4 Examples of Milestones in the Structure of a Roadmap

Table 1 is a sample color-coded progress chart of Milestones for improvement, with bright green the highest level and light green the basic level. This is an example only and not intended as a strict definition.

When these Milestones are represented graphically in a Roadmap they can be described as in Fig. 1. White boxes indicate the level of innovation and integration. Green boxes indicate the level of individual C2C criteria applications.

Examples of methods for measuring those Milestones are shown in the following section.

C2C properties of new materials are measurable. Geopolymer concrete facade improves CO_2 profile, resists water and chemical damage.

3.5 Measurement Methods

It is possible to use well-established methods to quantify C2C principle criteria, as well as most goals, milestones and implementation criteria.

Measurement can be Financial or Technical.

Examples of financial benefit measurements.
Savings or revenues generated by producing renewable energy, recycling water, improving diversity of spatial use, improved productivity from measurable air quality improvements, and recovering high quality defined materials for reuse in other products.

Examples of technical measurements.

Outdoor and indoor air quality measurements are well established for particulates, climate change, gases and toxic gases. Off-gassing methods are well developed for analyzing substances emitted by products. Recently, various studies have quantified productivity benefits from clean indoor air by measuring improvements in absenteeism and illness rates.

Toxicity standards for products are well established and have been systematically interpreted in the C2C ABC-X system of analysis.

Water quality standards are well established for toxins, pathogens, Biochemical Oxygen Demand and Chemical Oxygen Demand.

Biodiversity quantification methods are well established for quantifying numbers and types of species of animals, insects, and plants.

Biological nutrient and toxin measurements are well established for fertilizer, humus, compost, biodigestion, and irrigation.

Renewable energy generation and use is well quantified.

Exergy as a measure of energy effectiveness is a relatively new field and requires consultation with exergy experts.

Extreme event parameters such as seismic ratings, wind and impact ratings are well established in high-risk zones.

Defined use pathways and periods have been established for hundreds of products that pass through buildings. For construction materials these are less well established, but some recyclers have made a good start.

Natural light. Many architects are well qualified to evaluate the amount of natural light available to a site at different times of year, as well as the impacts of building designs on available light at various locations in buildings. Solar power experts have exceptionally well-defined criteria for natural light.

Practical functions performed in a building are often quantifiable, such as manufacturing, recreation and residential housing.

Resilient, cool, and self-sufficient. Hurricane-proof solar powered buildings.

3.6 Energy and CO_2

Energy in a C2C Building

Buildings are leading users of energy and are becoming generators of energy. Most conventional building criteria focus on reducing the amount of energy used by a building. However, Cradle to Cradle® focuses on maximizing the amount of energy that can be produced by a building while also using efficiency to support introduction of renewables instead of just minimizing the use of non-renewables.

Most conventional building criteria for energy overlook materials. Energy is generated by using materials. Power generation and distribution, HVAC systems, and climate change gases are all made from materials, yet conventional building approaches do not consider what goes into those materials, how those materials affect occupants, and how those materials can be recycled.

Cradle to Cradle® approaches energy primarily as a materials resource issue instead of an energy issue. This introduces new perspectives such as integrating building surfaces into energy generation and use.

Example. Some buildings save energy capital costs by integrating photovoltaic tiles with building exteriors. This improves payback time because solar tiles replace normal building tiles.

C2C Energy Defined.

> *Cradle to Cradle® (C2C) energy is energy that is generated and applied effectively, using current solar or gravitational income, and material media that are defined as biological or technical nutrients. The definition is qualified and quantified by the following criteria together:*

1. Energy Sources. Use current solar or gravitational income, or other defined C2C sources. Primary examples of current solar income use, conversion and storage include natural light, solar thermal, photovoltaic, photosynthesis, photochemical, wave and wind energy, thermal mass storage, and heat exchange. Secondary solar uses include respiration, currently renewable biomass-derived energy from composting, biodigestion, thermolysis, hydrothermolysis, pyrolosis, gasification, and fuel cells. Gravitational income examples, kinetic energy from inertia or weight, e.g. descending waterways.

2. Material media. For generating, converting and using energy, use materials that contain defined biological or technical nutrients at each stage.

3. Energy Effectiveness. Generate and use energy in definably effective ways, using exergy as a way of measuring effectiveness.

Buildings and CO_2

From the C2C perspective, carbon dioxide is a resource. Surprisingly, many methods used to calculate "carbon footprint" of buildings do not include the beneficial use of carbon by, for example, vegetation.

Traditionally, emphasis is put on the large negative role of buildings adding CO_2 to the atmosphere. However, from the C2C perspective CO_2 is a chemical resource that is part of biological and biochemical processes. If buildings integrate those processes as well as becoming net producers of renewable energy and users of renewable materials, they will be beneficial participants in the CO_2 cycle, in a similar way that trees are.

Examples. Biodigestion, production of topsoil for landscaping, green roofs and walls, and algae tanks that use CO_2 as food, and solar thermal conversion more effective than many water heating technologies. Those elements can be integrated to develop a beneficial CO_2 footprint.

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Extensive green roofs use CO_2 as a resource while enhancing enjoyment, biodiversity, air quality, insulation and water purification.

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Cradle to Cradle® (C2C) is a paradigm-changing innovation platform developed in the 1990s by Michael Braungart and William McDonough et al. Extensive books, cover stories and documentary films have been published and broadcasted about C2C since the 1990s. The book ***Cradle to Cradle. Remaking the Way We Make Things*** is well known and translated into at least a dozen languages.

However, many planners are not yet familiar with how to integrate into the built environment C2C features such as beneficial materials. A rapid acceleration occurred from 2008 to 2010 in the numbers of planners, architects and engineers introducing C2C concepts into planning and construction. A priority expressed by government agencies is to translate C2C into renovation and new construction of buildings. Those requests resulted in these Cradle to Cradle® Criteria for the built environment.

The purpose of this book is to provide planners with guiding criteria for developing a building with measurable C2C features. The focus of these criteria, that distinguishes them as C2C, is to maximize beneficial impacts instead of just minimizing negative ones.

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