

## Applying Cradle-to-Cradle Principles to the Product Development Process

### Product Development Stages

Cradle-to-cradle principles can be applied at each stage of a product development process. The following pages list questions and tasks that a product design team should address when trying to integrate cradle-to-cradle thinking into its product design efforts. These design guidelines are subdivided into the following eight product development stages that we have identified (grouped into four phases):

Phase	Product Development Stage
Ideation & Concept Development	Expansive Ideation
	Focused Ideation
	Defining the Concept
From Concept to Design	Translating the Concept into Design
	Actualizing the Design
Production & Value Recovery	Producing the Product & Helping Prepare the Value Recovery System
	Activating the Value Recovery System
Evaluation	Learning from the Experience & Guiding Future Enhancements

### Cradle-to-Cradle Principle Categories

The questions and tasks are further subdivided into the three cradle-to-cradle principle categories, plus an additional “all of the above” category for the design guidelines that apply to all three categories, as below:

Safe Materials

Renewable & Efficient Energy

Products & Systems Designed for Value Recovery

Across All Design Principles

These guidelines should provide a map of the issues to address in designing electronic products, although the actual responses to these questions and tasks are not fixed and will vary among different product development teams.

**Questions &  
Tasks to  
Address**

## I. Ideation & Concept Development

### A. Expansive Ideation

#### *Safe Materials –*

What does the concept of "safe materials" mean?

How are safe materials potentially valuable for our product system?

#### *Renewable & Efficient Energy –*

How can we use renewable energy for product life cycle stages (e.g., raw material collection; manufacturing; distribution; use; recovery; reuse/recycling)?

How can we efficiently utilize power in product operation and our manufacturing processes?

#### *Products & Systems Designed for Value Recovery –*

What are the potential benefits of designing products and their materials to be recycled perpetually?

What is the difference between cradle-to-grave and cradle-to-cradle thinking?

How does design relate to biological and technical metabolisms?

What does the concept of "materials as assets" mean for a product and value recovery system?

How could we establish our own product recovery system or help establish a collective one for various manufacturers?

#### *Across All Design Principles –*

What could changing the design of our product and related processes mean for worker safety, public health and environmental health?

### B. Focused Ideation

#### *Safe Materials –*

Will we select materials for characteristics beyond performance, price and aesthetics?

What criteria do others use to select "safe materials" or to ensure that problematic materials flow safely?

What is our company's process for selecting safe materials (i.e., do we emphasize an approach that is "preventive" or one that responds to emerging problems)?

What, in general, are the human and environmental health issues of the materials that the industry uses in products and processes?

How will impending or future regulations affect our approach? What are the benefits of designing "beyond regulations"? How do our competitors view the material selection process? Will innovation within these areas provide our company with new business opportunities or enhance our competitiveness? If so, how do we begin?

***Renewable & Efficient Energy –***

What sustainability criteria do others use with regard to types of energy used in manufacturing and energy efficiency of the product in use?

How might we alter the energy mix (renewable vs. non-renewable) of our manufacturing processes? Any opportunities to implement at the product-use level?

How can we maximize energy conservation within product operation, manufacturing, distribution and recycling?

***Products & Systems Designed for Value Recovery –***

What criteria do others use with regard to product recyclability? For the recovery and recycling infrastructure?

What is the current state of recyclability for electronic components and materials? What is on the horizon and beyond? Are there opportunities for our company to differentiate our products by enhancing these attributes?

How can we recover, reuse and recycle materials at their highest level of value? Are there opportunities to collaborate with other companies and/or industries?

Is there value in pursuing a Product of Service (PoS) strategy? Does the "servicing/leasing" concept increase the profitability of design for recyclability attributes?

**C. Defining the Concept**

***Safe Materials –***

Select material success metrics (e.g., aesthetics; safety; recyclability; modularity; remanufacturability; performance; cost).

***Renewable & Efficient Energy –***

Select renewable energy and energy efficiency success metrics.

***Products & Systems Designed for Value Recovery –***

What is our ideal role in product recovery and recycling?

How can we facilitate the recovery of our products/components and help our industry manage its materials as assets?

Select post-use recoverability success metrics (e.g., modularity; ease of disassembly; reusability; recyclability).

Select recovery system success metrics (e.g., magnitude of material flows; amount of cost savings/avoidance; degree of customer participation; ability to cycle materials safely).

***Across All Design Principles –***

Select processes and individuals to manage necessary changes.

What would the proposed change mean from the perspectives of cost effectiveness, customer preferences, and marketing?

## II. From Concept to Design

### A. Translating the Concept into Design

#### ***Safe Materials –***

What is our current materials palette for products? What materials are used in our manufacturing processes? Will these materials meet our newly established criteria?

Are materials available that come from recycled feedstock, are safe for use and can be reused or truly recycled to provide a range of applications following their first useful life?

How can we safely cycle materials that do not pass material safety metrics and for which viable alternatives are not currently available?

#### ***Renewable & Efficient Energy –***

What is the mix of energy (renewable vs. non-renewable) currently used by our suppliers, recyclers and us?

How can we help lead our industry's efficient use of clean energy?

#### ***Products & Systems Designed for Value Recovery –***

How are our products and materials currently reused and/or recycled (e.g., recovered; resold in secondary markets; donated)?

How can we involve other partners in the value recovery system (e.g., customers; distributors; dismantlers)?

Is there value in standardizing materials, components, assembly design and techniques and/or recycling processes, while allowing for future technological changes?

What is the possible market value of selling modular equipment, to promote post-sale upgrading and post-use disassembly?

What type of financial or ownership mechanisms would allow us to recapture our materials and use them as assets for future products?

What is the current status of recycling technologies (e.g., what is prevalent)? How can we design products to be recycled within this framework while also anticipating more sophisticated technologies in the future?

#### ***Across All Design Principles –***

Communicate new success criteria to procurement colleagues, suppliers and recyclers; work with those partners to select the most appropriate materials, product designs and life cycle processes.

Assess current and alternative materials, components and processes using success metrics for safe materials, energy, post-use recoverability, and value recovery system.

How can we market these advantages to potential customers? Will these changes provide competitive advantage?

## B. Actualizing the Design

### ***Safe Materials –***

Can we partner with other manufacturers to purchase materials together and reduce costs (e.g., via a "materials pooling" strategy)?

Select the type of system to be created/used to safely cycle materials that do not pass the material safety metrics.

Identify materials R&D priorities for the future based on current gaps in achieving success metrics.

### ***Renewable & Efficient Energy –***

If we are not currently using any renewable energy, what specific steps are required to begin doing so? Can we help build a market for renewable energy by implementing an offset purchasing program (i.e., purchasing an amount of "green energy" equivalent to the amount needed to manufacture our products but is transferred to other uses such as facility operations)?

What opportunities exist to implement renewable energy or a more efficient use of energy in transporting materials and distributing final products? Could empty delivery trucks be transporting nutrients to recyclers or remanufacturing facilities on their return route?

### ***Products & Systems Designed for Value Recovery –***

Implement Design for Modularity, Design for Disassembly, and Design for Recycling activities; adjust materials palette and product design attributes to maximize these design strategies.

Test prototype for ease of upgrading, disassembly and reuse/recycling.

Create post-industrial and post-consumer recycling plans.

## III. Production & Value Recovery

### A. Producing the Product & Helping Prepare the Value Recovery System

#### ***Safe Materials –***

Select material suppliers.

Procure materials.

Manufacture product.

Communicate new product attributes and company initiatives to the marketplace.

#### ***Renewable & Efficient Energy –***

Select equipment suppliers and/or manufacturing contractors. Create or participate in an industry cooperative to collectively purchase renewable energy.

Procure manufacturing equipment and activate contract manufacturers.

Manufacture product.

Market product to potential customers.

Request all partners to provide an annual statement of their continued efforts to improve the energy efficiencies and energy mixes of their operations.

***Products & Systems Designed for Value Recovery –***

Select partners for post-use recovery and recycling system (e.g., customers; distributors; dismantlers; recyclers) and discuss format, roles and logistics (e.g., reverse distribution; financing; ownership model; relationship among parties).

Educate recovery and recycling partners about their roles and the larger system (e.g., provide dismantling instructions). Implement feedback loops with partners (e.g., have partners educate you about feedstock or material quality constraints for recyclers).

Label materials to facilitate recovery, disassembly and recycling.

Communicate product and value recovery system attributes to the marketplace.

What are the economics of your recovery plan? Will you attempt to build a recovery and recycling network for your nutrients only or will you collaborate with other manufacturers?

**B. Activating the Value Recovery System**

***Safe Materials –***

Are any leakages of materials from the value recovery system that are also a threat to public health?

***Renewable & Efficient Energy –***

Utilize recovery, refurbishment and recycling processes that operate on renewable energy and are energy efficient.

Optimize supply and delivery routes to maximize energy used in transport of materials and final products.

***Products & Systems Designed for Value Recovery –***

Implement the post-industrial recycling plan and related activities.

Activate the post-consumer recovery, reuse, refurbishment and recycling system and associated industry partnerships.

Gather and review data on the flows of materials and finances within the recovery and recycling system.

Promote value recovery system to customers and emphasize their role within it.

## IV. Evaluation

### A. Learning from the Experience & Guiding Future Enhancements

#### ***Safe Materials –***

Collaborate with suppliers to develop next generation materials.

#### ***Renewable & Efficient Energy –***

Collaborate with suppliers and contract manufacturers to develop next generation manufacturing equipment and processes.

#### ***Products & Systems Designed for Value Recovery –***

Revise the materials flow model for the recovery and recycling system as needed.

Are materials leaking from the value recovery system? How can we prevent leakage of our valuable materials in the future?

How can we work with other parties to improve the recovery of valuable materials through needed product or recovery system design changes?

Establish feedback loops to use recycling data to improve the design of the product and value recovery system during the next iteration of the product development process.

#### ***Across All Design Principles –***

Collect data for the future redesign of the product, processes and value recovery system.

Measure actual outcomes against stated goals and anticipated outcomes.

Identify opportunities for improved goal achievement in the future.

## Appendix: Definitions for Principle Categories & Product Development Stages

**Cradle-to-Cradle Principle Categories**

- I. Safe Materials**
  - II. Renewable & Efficient Energy**
  - III. Products & Systems Designed for Value Recovery**
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**Product Development Stages**

### **I. Ideation & Concept Development**

#### **A. Expansive Ideation**

***Definition***

"Blue sky" or "clean slate" stage; initial, solution-focused brainstorming of future possibilities; envisioning a new way of doing things unencumbered by current concepts or constraints.

***Sample Activities***

Educating self about the need for change and possible new design goals; envisioning a product system in which materials are safely cycled; generating ideas.

***End Goal***

An idea of how a product and value recovery system might safely cycle materials and valuable nutrients.

#### **B. Focused Ideation**

***Definition***

Moving from "blackboard" to "sketch pad"; first filtering of brainstormed ideas; researching other novel approaches, especially those that have been implemented.

***Sample Activities***

Researching industry initiatives, perspectives and design criteria; finding others inside your organization interested in similar questions; looking outside for innovative ideas; considering how these ideas translate into design criteria.

***End Goal***

Penciled idea to present to supervisor or project team for feedback.

## C. Defining the Concept

### ***Definition***

Refining the concept and gaining consensus within division or project team; developing content; begin "reality-check" process.

### ***Sample Activities***

Deciding what you want/expect to do; selecting goals and success metrics; charting design and implementation process and activities.

### ***End Goal***

A tangible concept approved by project team, benchmark against success metrics throughout the product development process.

## II. From Concept to Design

### A. Translating the Concept into Design

#### ***Definition***

Translating concepts into design; comparing alternative designs; deciding how the idealized concept of safely cycling materials can be realized through the design of the product and the value recovery system.

#### ***Sample Activities***

Researching what is currently practical for your product and value recovery system based on your success metrics; communicating objectives to suppliers; defining the breadth of gap between the practical design and ideal concept in order to strategically plan for possible future enhancements.

#### ***End Goal***

Tentative design specifications, subject to additional research and project team feedback.

### B. Actualizing the Design

#### ***Definition***

Revising and finalizing design based on gathered data and current constraints.

#### ***Sample Activities***

Selecting conforming materials; optimizing assembly and disassembly attributes; aligning manufacturing processes; identifying and prioritizing needed changes to recovery and recycling system based on constraints and opportunities; developing an actionable plan for changes.

#### ***End Goal***

Formal design of product and value recovery system that will be enacted as fully as possible in current product development process.

### III. Production & Value Recovery

#### A. Producing the Product & Helping Prepare the Value Recovery System

**Definition**

Starting to manufacture product; collaborating with identified partners to prepare the value recovery system.

**Sample Activities**

Selecting suppliers; manufacturing product; adjusting logistics of value recovery system; communicating goals, benefits to end-users and asking for their participation to help you meet your goals faster.

**End Goal**

Product is available for sale and value recovery system is ready to operate.

#### B. Activating the Value Recovery System

**Definition**

Making value recovery system operational.

**Sample Activities**

Starting value recovery activities in collaboration with other companies or actors if that is the model chosen.

**End Goal**

Fully functioning value recovery system, returning products and materials to become manufacturing feedstock.

### IV. Evaluation

#### A. Learning from the Experience & Guiding Future Enhancements

**Definition**

Checking progress by comparing idealized concept with success metrics; identifying gaps for future improvements or innovation.

**Sample Activities**

Evaluating actual design performance versus ideal to improve future efforts; collaborating within industry or across other industries to identify possible solutions to obstacles or for needed improvements.

**End Goal**

Measure product and system shortcomings; documentation of possible future enhancements.