Design for the Environment

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Primary goal: **SUSTAINABILITY**
(responsibility toward future generations)

Basic approach: **INDUSTRIAL ECOLOGY**
(imitation of nature)

Imitation of ecosystem:
**ECO-INDUSTRIAL PARKS**
(closing material loops, energy efficiency)

In addition:
**GREEN TECHNOLOGIES**
(pollution avoidance rather than pollution treatment)

**POLLUTION PREVENTION**
(green processes)

**DESIGN FOR ENVIRONMENT**
(green design)

**DESIGN FOR RECYCLING**
(to promote material loops)

**DEMATERIALIZATION**
(doing with less)

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*Our efforts to develop environmental technologies will change over time as we place greater emphasis on pollution prevention approaches with high efficiencies in resource use and on the restoration of critical ecosystems. At some point in the future, we will have moved from an environmental paradigm built on control and cleanup to one also based on assessment, anticipation, and avoidance.*

*(Bridge to a Sustainable Future, Clinton White House, April 1995)*
“Design, if it is to be ecologically responsible and socially responsive, must be revolutionary and radical in the truest sense.

It must dedicate itself to nature’s principle of least effort. […]

That means consuming less, using things longer, recycling materials, and probably not wasting paper printing books.”

Victor Papanek, *Design for the Real World*, 1971

The IMPORTANCE of the DESIGN STAGE:

70% of costs of product development, manufacture and use are decided in early design stages


*Examples:*

GM truck transmissions: 70% of costs decided at design stage

Rolls Royce: 80% of costs decided at design stage, as determined from an average among 2000 parts

Likewise, it is clear that most decisions that affect future environmental impacts are made at the design stage.
Major design considerations:

Industrial designers need to mind:

- Functionality and performance (product must do the job)
- Manufacturability, logistics (one should be able to make the product)
- Reliability, safety (there must be some quality standard)
- Cost, market penetration (product needs to be competitively priced)
The various levels of **DESIGN**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DfM</td>
<td>Design for Manufacturability</td>
<td>So that the product can be made easily and at reasonable cost</td>
</tr>
<tr>
<td>DfL</td>
<td>Design for Logistics</td>
<td>So that all production activities can be well orchestrated</td>
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<tr>
<td>DfT</td>
<td>Design for Testability</td>
<td>So that the quality of the product may be conveniently checked</td>
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<tr>
<td>DfP</td>
<td>Design for Pricing</td>
<td>So that the product will sell</td>
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<tr>
<td>DfR</td>
<td>Design for Reliability</td>
<td>So that the product works well</td>
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<tr>
<td>DfSL</td>
<td>Design for Safety &amp; Liability</td>
<td>So that the product is safe to use and the company is not held liable</td>
</tr>
<tr>
<td>DfS</td>
<td>Design for Serviceability</td>
<td>So that service after sale can be offered at a reasonable cost to the company</td>
</tr>
<tr>
<td>etc. etc.</td>
<td>– to be added:</td>
<td></td>
</tr>
<tr>
<td>DfE</td>
<td>Design for Environment</td>
<td>To reduce or eliminate environmental impacts from cradle to grave</td>
</tr>
</tbody>
</table>

**Basic idea:** Include environmental considerations at the very beginning of the design process, together with performance, manufacturability, cost, safety, etc.

The various levels of **DESIGN for ENVIRONMENT:** DfX

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<thead>
<tr>
<th>Acronym</th>
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<th>Purpose</th>
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</thead>
<tbody>
<tr>
<td>DfM</td>
<td>Design for Manufacturability</td>
<td>To enable pollution prevention during manufacturing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For less material</td>
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<tr>
<td></td>
<td></td>
<td>For fewer different materials</td>
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<td></td>
<td></td>
<td>For safer materials and processes</td>
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<tr>
<td>DfEE</td>
<td>Design for Energy Efficiency</td>
<td>For reduced energy demand during use</td>
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<tr>
<td></td>
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<td>For flexible energy use</td>
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<td></td>
<td></td>
<td>Design for use with renewable energy</td>
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<td></td>
<td></td>
<td>Design for Zero Emission</td>
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<td></td>
<td></td>
<td>Design for Carbon Neutrality</td>
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<tr>
<td>DfZT</td>
<td>Design for Zero Toxics</td>
<td></td>
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<tr>
<td>DfD</td>
<td>Design for Dematerialization</td>
<td></td>
</tr>
<tr>
<td>DfP</td>
<td>Design for Packaging</td>
<td>Minimize packaging – Rethink selling method</td>
</tr>
<tr>
<td>DfL</td>
<td>Design for Logistics</td>
<td>Use of local materials – Less Transportation</td>
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<tr>
<td></td>
<td></td>
<td>Arrange outsourcing to minimize transportation</td>
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<tr>
<td>DfL</td>
<td>Design for Longevity</td>
<td>Design for Modularity</td>
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<tr>
<td></td>
<td></td>
<td>Design for Serviceability</td>
</tr>
<tr>
<td>DfMo</td>
<td>Design for Modularity</td>
<td>To ease upgrading → Delay replacement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>To ease serviceability and, later, disassembly</td>
</tr>
<tr>
<td>DfS</td>
<td>Design for Serviceability</td>
<td>For ease of repairs → longer life</td>
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<tr>
<td></td>
<td></td>
<td>For recapture of used/broken parts</td>
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</tbody>
</table>
The various levels of DESIGN for ENVIRONMENT
(continuation)

DfRM  Design for use of recycled materials
DfRMV Design for reduced material variety
DID  Design for Disassembly
      To promote re-use of components
      For quicker and cheaper disassembly
      For more complete disassembly
      For dismantling by simple tools
DfR  Design for Recycling
      For greater materials recovery
      Use of materials that can be locally recycled
      For easier materials identification
      For safer disposal of non-recyclables
DfER Design for Economic Recycling
      To enable and promote recycling
DIC  Design for Compostability
DfER Design for Energy Recovery
      For safe incineration of residues
      For composting of residues
DIC  Design for Compliance
      To meet regulations more easily
      To prepare for future regulations

Major questions arising in
DESIGN FOR ENVIRONMENT

1. Product or process?
   Make essentially the same product, but with different materials
   Make the same product in a different way
      ex: as to minimize energy consumption or generation of by-products
   Make a different product that fulfills the same function

   Automotive examples:
   Steel → aluminum chassis
   Gas car → hybrid car
   Personal cars → public transportation

2. At which level?
   Microscale: Part of a product
               A unit of production
   Mesoscale: The entire product
              The entire factory
   Macroscale: Meeting the function (service) in a new way
               Rethinking the industry-environment relation (social concerns)
Redesign of PROCESSES versus redesign of PRODUCTS

Option 1: REDESIGN of PROCESSES

- Many times the only way to approach the redesign (ex. paper, steel)
- Rethink what enters the manufacturing (ex. pulping and bleaching chemicals)
- Rethink technology of specific processes (ex. water consumption, energy, solvents)
- Consider what goes out besides the product itself (ex. smokestack emissions)

Barriers: - Technological (alternative is not technically feasible)
- Cost of research and development
- Risk associated with the unknowns
- Corporate inertia (“Don’t mess with success!”)

Example of Design for Environment applied to a manufacturing process

Advantages: - Less air to be dust-free and less chance of dust intrusion
- In the absence of personnel inside the controlled volume, freedom to have an oxygen-free atmosphere (pure nitrogen) to reduce oxidation or other undesirable side effects
Option 2: REDESIGN of PRODUCTS

- Consider function rather than the object:
  Can this function be met with a smaller product, with a more benign product?
  Or, at the limit, could it be met as a service without any material product?

- Don’t forget: Package is part of product
  → Rethink the packaging of the product, too

Barriers:
- Technological (alternative is not technically feasible)
- Ergonomic, Safety (alternative may be a misfit or unsafe)
- Societal (people may not be prepared for the alternative)
Examples of radical redesigns
(unfortunately having little to do with environmental considerations…)

Note how in each instance, the function is met by a radically different product, which happens to use less material.
A major historical disruption

New York City Easter Parade in 1900

New York City Easter Parade in 1913
Pollution Prevention:

**Basic idea:** Avoid waste pollution in the first place, as much as possible

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**Waste Reduction by Electrode Redesign**

A 3P project team from 3M’s Valley, Nebraska facility reduced the inherent waste (waste inherent to the product design and process) from adhesive electrodes used in electrocardiogram (EKG) applications, by redesigning the electrode. The team changed the configuration of the electrodes on the card which reduced silver coating weight, adhesive coating weight, and the overall size of the electrode. The project prevented nearly 11 tons of waste and saved nearly $1,000,000 in its first year of implementation.

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**Reduction in Solvent Emissions from Tape Production**

In 2005, a 3P team from 3M Brazil's Itapetininga facility replaced the solvent-based paper treatment process the plant used to manufacture packaging, medical and masking tapes with a new, water-based process.

As a result of this change, the facility reduced solvent emissions by over 45 tons per year. By preventing solvent emissions at the source, the plant also eliminated the need for pollution control equipment, reducing the plant's energy use and eliminating over 125 metric tons of CO₂ emissions annually.

The project saved the facility over $850,000 in its first year of implementation.
Example from 3M: The manufacture of Scotch® tape

4 layers, each using a solvent for its application!

One of 3M’s primary strategies for continuing to reduce air emissions has been the development of solventless technologies, for a variety of products including tapes.

Some new processes are hot-melt technology, ultraviolet curing, and caustic wash materials.

Smart use of material and modularity

Glass-filled Durethan polyamide-6 resin from Miles Polymers Division, injected on and around a perforated piece of metal, solidifies to cribbed a ribbed, securely bounded, interlocked composite structure.

The Eiffel Tower in Paris, an excellent example of parsimonious use of material.
“Herman Miller’s award winning ergonomic Celle chair is the output from Herman Miller’s unique Design for Environment cradle-to-cradle protocol. Environmentally friendly manufacturing techniques means the Celle chair is 99% recyclable, and fits into Herman Miller’s vision of sustainable design.”

Considerations:
- Less material
- Less material variety
- Recycled materials
- Recyclable materials
- Ease of disassembly
- Less energy consumption
- Longevity
- Modularity

etc.

The Equator EZ 3612CEE is a washer/dryer combination that meets the strict energy efficiency requirements of Energy Star's Tier 4B.

This great little machine is not only two machines in one and compact; it also requires no venting. The 3612CEE offers the perfect solution for apartment dwellers who are unable to vent a standard-type dryer.

The downside of this option is that this type of drying, called condensing, is much slower than a vented dryer. Many users find the best way to do laundry with this machine is to put it in before they go out for the day. It is then completed by the time they return home.

An added benefit is that this machine operates on standard electrical power and does not require 220-volt electrical service like a regular dryer. It does, however, require a water source and a drain.
LEVELS OF DESIGN FOR ENVIRONMENT

From tinkering at the margin to the social revolution!

Example: Automobile

1. Re-design of parts: Aluminum or plastic radiator cap
   Longer-lasting tires and batteries
   Aluminum or steel engines

2. Re-design of assembly: Eco-friendly painting
   Facilitating disassembly
   Recycling of plastics

3. Re-design of automobile itself: Alternative fuels (e.g., ethanol, methanol)
   Alternative powertrains (hybrids, fuel cells)

4. Re-design of transportation systems: Smart highways
   Public transportation

5. Re-thinking the need for mobility: Virtual office (telecommuting)
   Community layout

XEROX:
Parts Reuse and Equipment Remanufacturing

Reuse/Recycle Process

Goal: optimize financial and environmental benefits...
The story of Ray Anderson and Interface, Inc.

Company founded in 1973
From selling carpets to providing a carpeting service
Goal to become a sustainable corporation by 2020

Measuring the environmental impacts of your designs:
A basic life-cycle approach
Charts of Okala millipoints

<table>
<thead>
<tr>
<th>Material or Process</th>
<th>Unit</th>
<th>Okala</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POLYMERS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABS</td>
<td>lb</td>
<td>47</td>
<td>acrylonitrile butadiene styrene</td>
</tr>
<tr>
<td>EPP</td>
<td>lb</td>
<td>33</td>
<td>ethylene propylene rubber</td>
</tr>
<tr>
<td>PP</td>
<td>lb</td>
<td>50</td>
<td>polypropylene</td>
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<tr>
<td>HDPE</td>
<td>lb</td>
<td>70</td>
<td>high-density polyethylene</td>
</tr>
<tr>
<td>PVC</td>
<td>lb</td>
<td>60</td>
<td>polyvinyl chloride</td>
</tr>
<tr>
<td>PS</td>
<td>lb</td>
<td>40</td>
<td>polystyrene</td>
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<tr>
<td>PA</td>
<td>lb</td>
<td>30</td>
<td>polyamide</td>
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<td><strong>POLYMER PROCESSING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>injection molding</td>
<td>lb</td>
<td>60</td>
<td>injection molding</td>
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<tr>
<td>extrusion molding</td>
<td>lb</td>
<td>90</td>
<td>extrusion molding</td>
</tr>
<tr>
<td><strong>OTHER MATERIALS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wood</td>
<td>lb</td>
<td>50</td>
<td>hardwood</td>
</tr>
<tr>
<td>metal</td>
<td>lb</td>
<td>70</td>
<td>stainless steel</td>
</tr>
</tbody>
</table>

An application example of the Okala method:

Button vs. Zipper?
So, which one is better for the environment?