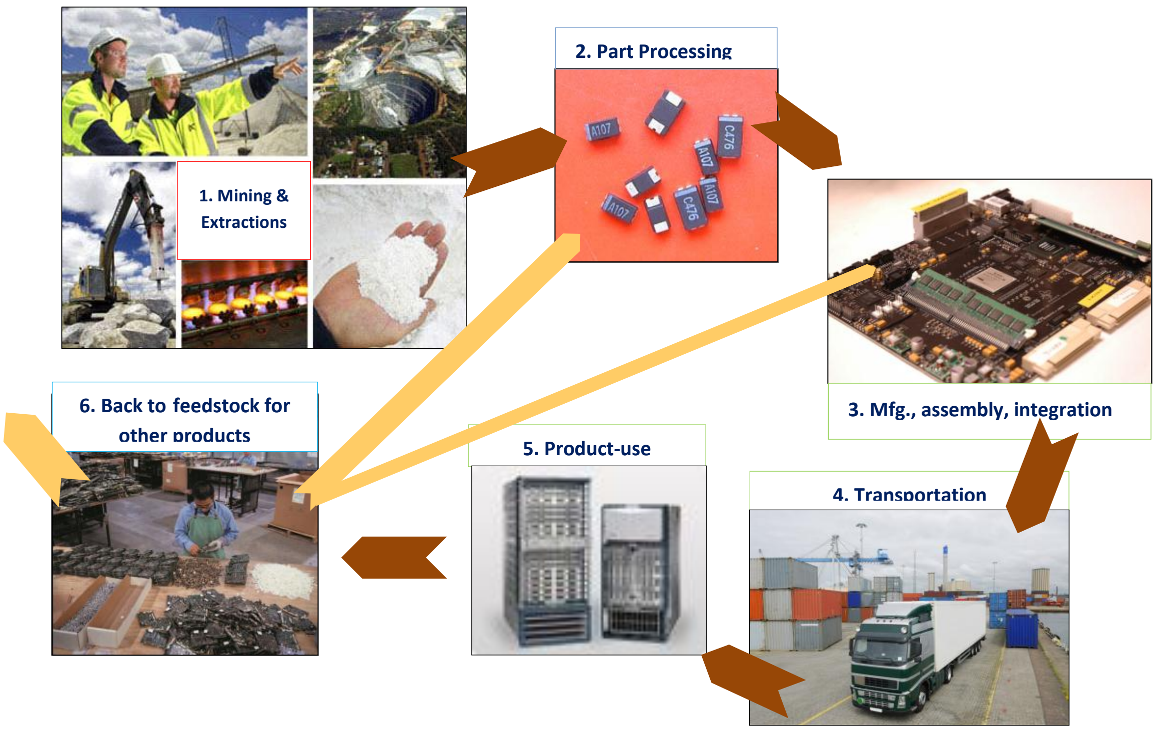
Design for Environment (DfE):

Steps to Sustainable Product Development



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TFI ENVIRONMENT

Table of Contents

	page
The Intersection Between DfE and Reliability	3
Roadmap to Navigate the Next 5 years of Environmental Design Requirements	7
Stepping up Sustainability of Entire Product Lines	11
Putting Life Cycle Analyses to Work	17
DfE Considerations for Plastics	23

The Intersection Between DfE and Reliability

Design-for-Environment (DfE) principles — which include minimizing numbers and types of parts, reducing heat generation and power consumption, and deploying replaceable/upgradable modules — also tend to increase products' reliability and lifespan. The DfE link with reliability helps answer the question, "What does DfE have to do with our products and competitiveness, and why is it important to learn it?"

Another dimension of DfE benefits is competitive advantage. DfE promotes lower cost of materials and greater value at end of life; more efficient assembly; lighter weight and smaller dimensions as a benefit to users and to more efficient storage and shipping; competitive advantages owing to less power consumption; and reduced risk of supply-chain interruptions stemming from restricted substances.

Examples of the DfE/Reliability Link

One of the tenets of DfE is to use as few different types of materials as possible in a product to foster the recycling of higher percentages of the product's mass (like materials can be recycled together) and in some cases to make refurbishment/upgrade more efficient – thus extending the life of the product before recycling. The link with reliability is that reducing the number of different materials also reduces the risk of material failure. On top of the environmental and reliability benefits is a business benefit: like materials can be purchased in bulk at quantity discounts, shipped from one or two reliable suppliers.

Another example of the DfE/reliability link is that of minimizing power consumption of the product while in use. The reliability benefit of lower operating temperatures is extended product life. The business benefit is compelling: deliver a product to customers that will cost them less to operate (less electricity, less cooling) and in some cases operate longer when not plugged in.

Table 1 lists a dozen more examples of the reliability benefits of DfE principles.

Table 1 Sample items from DfE checklist correlated with reliability factors

Excerpts from Design-for-Environment Checklist	Reasons Why these Steps Improve Reliability
Has the number of different materials been limited where practical?	Less chance for material failure
Is the product designed for minimum power consumption in use?	Reduces operating temperature , which extends life
Are there minimum waste consumables in use (e.g., batteries)?	Waste consumables have a short life and when they fail, usually the entire product fails until they are replaced.
Is the product designed to prevent accidents during the use phase (when customers are using the product)?	Fewer accidents mean fewer failures
Can assemblies and components be removed with a standard tool? Are high-value parts grouped together or otherwise accessible?	Easy disassembly make it more likely for parts to be re-used instead of discarded
Have nuts, bolts, and rivets been avoided? (in favor of, for example, snap fits)	Easy repair lengthens life as users are more likely to repair than replace
Has the product been designed to have as few parts as possible?	Fewer joints, seams, and fasteners to break
Does the design leverage multifunctional parts (e.g., a single fastener that serves multiple purposes)?	Fewer parts to fail
Are you using common parts across different designs?	Fewer parts to fail
Do you design multifunctional products -- "parallel" (several purposes for the same product) and "sequential" (product retired to secondary use?	Using a product known to be reliable for other uses and second uses, vs. getting a new one that might be a "lemon"
Are the products designed to be modular and upgradeable	Upgrading a product known to be reliable, vs. getting a new one that might be a "lemon"
Is durability achieved without compromising disassembly and recovery?	Durability is closely tied with reliability
Can batteries be avoided? Is there another technology to achieve the same end?	When batteries die, which is often times within the life of the product, usually the whole product fails
If batteries are used, does the design maximize battery life based on the battery technology chosen?	This decreases amount of times battery will die in the life of the product
Are batteries removable and replaceable by the user?	Easy repair lengthens life as users are more likely to repair than replace
Are products manufactured close to customers when possible, optimizing supply and logistics?	Optimizing supply and logistics leads to less handling and shipping, which reduces damage and the possibility of inducing latent failure mechanisms

Source: Technology Forecasters Inc., with insights from TFI's DfE Intern Ben Marshall

Do **try this at home**

Most DfE principles are easily learned by design engineers, but training is highly recommended. DfE principals can be learned during a one-day, hands-on workshop offered by TFI. So that DfE becomes a cohesive strategy at the company, we recommend including in the training design engineers (electrical, mechanical), reliability / test engineers, compliance managers, R&D, new product introduction (NPI), product management (for future product platforms), supply-chain management, marketing, EHS (environment, health, and safety), legal, and executives in operations, R&D, and marketing.

The workshop covers, especially for the executives present, business imperatives for DfE. These include meeting regulations to avoid being blocked from markets, achieving industry-respected standards that yield competitive advantage, delivering lower cost of ownership for customers, increasing revenues through product refurbishment and reuse, and generating revenue at the end of the product's life. In addition to summarizing applicable environmental regulations and standards from around the world, the workshop coaches attendees through the DfE principles – why they reduce environmental harm and increase reliability and other technical benefits – and gives participants several hands-on exercises for putting DfE to work immediately.

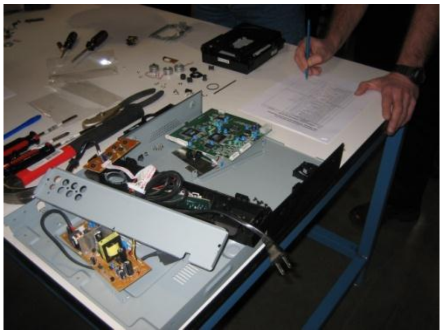


Figure 1 Hands-on disassembly exercise at DfE Workshop

Figure 1 illustrates a disassembly exercise, conducted in teams, to demonstrate the advantages of using a good DfE checklist when designing and auditing the design of a product. By the end of the day, participants also learn how to choose and manage suppliers that are also committed to DfE – a point more important now than ever in this age of increasing outsourcing of design and manufacturing.

An even stronger recommendation is to hone individual company processes to build in competitive levels of DfE, with an audit trail. My colleagues at Design Chain Associates (DCA) and I call this the DfE Process Integration Roadmap (DPIR).

Regulations that may contradict reliability

Regulations formed without adequate investigation of environmental science, such as the lead-in-solder portion of the European Union's RoHS Directive, can have adverse effects on reliability. Tom Valliere of DCA makes this point: "If we were to take a really objective and high level look at toxicity versus benefits, removing lead from solder might be proven to be an unwise action. Certainly the higher process temperatures cause more energy expenditure and reliability degradation, and tin whiskers and reliability of SAC joints are still unresolved issues as far as I am aware."

Today, well-thought-out checklists are used that present design principles whose net effect on the environment is positive, and that take into account business factors such as material availability, ease of assembly and disassembly, advantageous shipping, and longer revenue streams. For a complimentary copy of TFI's DfE checklist, contact me at PGordon@TechForecasters.com.

The "gift" of a DfE checklist

Last week a client (a VP in Operations) told me that engineers love to have design rules, but not to create the rules themselves. To the extent that this may be true, the DfE principles are a great gift for engineers, because they (finally) explain how one design choice over another can reduce the product's environmental impact and in most cases also increase reliability and business benefit.

A story from my book "Lean and Green: Profit for Your Workplace and the Environment" illustrates the "gift" of providing engineers with DfE principles:

Texas Instruments' VP of Worldwide Facilities, Shaunna Sowell, eloquently describes numerous examples of the Lean and Green promise; the ease with which old processes can be replaced with cleaner ones surprised even her: "We showed our designers a list of 50 chemicals—from 10,000 chemicals that TI uses for everything from washroom soap to glue in desk drawers—we wanted to remove from our process. The 50 comprised known carcinogens or otherwise needed to be reported in compliance with the Clean Air Act. We thought it would take 6 to 12 months to design out as many of the 50 chemicals that were possible to avoid.

The design team came back to us in two months saying, 'We found substitutions for 49 of the chemicals, but it'll take a year for the 50th.' We were stunned and asked, 'How did you do it?' They replied, 'Look, this early in the design we've got lots of choices; we know what is good for processes, but we didn't know what worked for the environment and health. We care too, but just didn't know which chemicals were on the list.'" Shaunna had wondered, "Where have we been? We could have done this earlier. In two months of work that cost TI next to nothing, we designed out significant costs for the next ten years."

— Gordon, Pamela J., Lean and Green: Profit for Your Workplace and the Environment, Berrett-Koehler Publishers, 2001

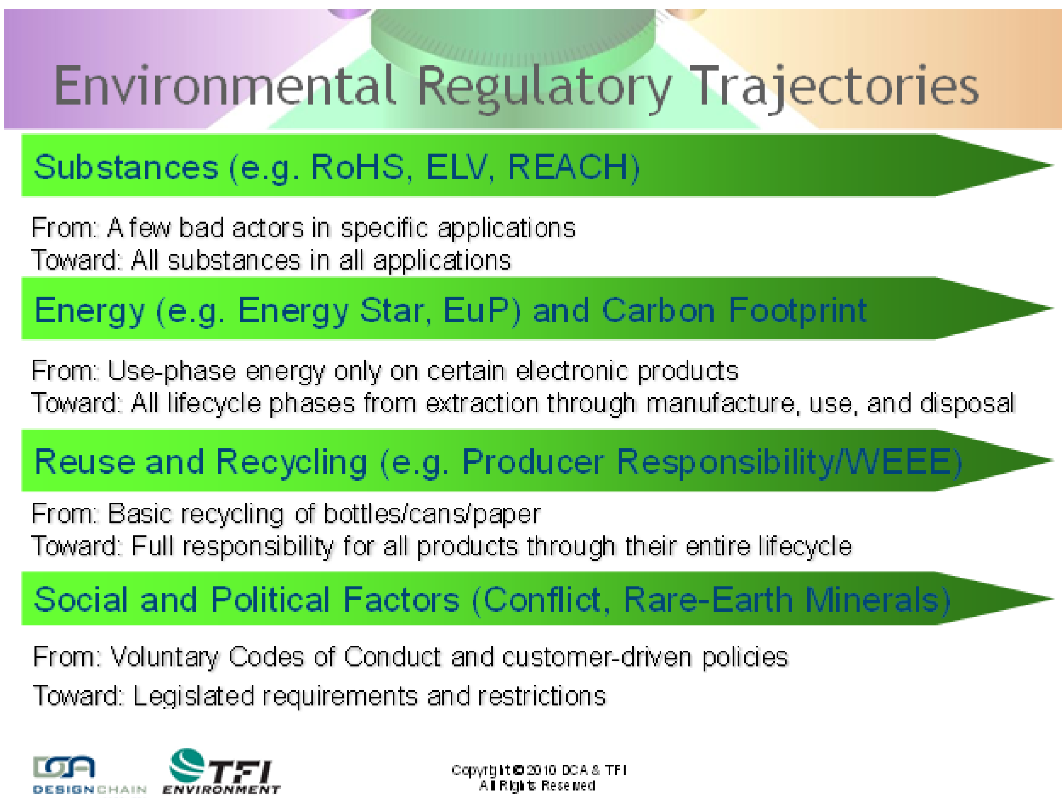
I trust, with full reliability, that *your* organization can obtain surprising "gifts" from DfE.

Roadmap to Navigate Next 5 years of Environmental Design Requirements

With the rapid pace at which global regulators, standards, and customers are increasing their demands for environmentally-responsible products, the thought of developing a five year roadmap may seem daunting. Just think—five years ago the European Union RoHS Directive (restricting 6 hazardous substances in electronics) was not yet law, few companies had a clue about the carbon-emissions of their products, and today's efficient power supplies were not yet available.

Could we have foreseen then the explosion of environmental requirements around the world that exist today? Well, the answer is a qualified yes, based on a trajectory of probable requirements for products' substances, energy and carbon footprint, reuse/recycling, and social/political factors (Figure 1).

Figure 1, DfE Regulatory Trajectories



It is because of the uncertainty of future design-for-environment (DfE) requirements that creating and following a five-year roadmap is critical. My colleagues at Design Chain Associates (www.DesignChainAssociates.com) and I have developed a methodology for projecting and planning for those environment requirements that will surely pertain to our clients' products in 2011 through 2016.

The methodology is called DPIR, the Design-for-Environment Process Integration Roadmap (http://www.techforecasters.com/resources/downloads/DPIR_description.pdf). The following four steps illustrate how developing a confident forward view and implementing the five-year roadmap is possible and desirable.

#1: Assess Current Readiness for Environmental Requirements and Identify Gaps

Our clients always have some information on environmental requirements, though not necessarily matched specifically to their own product roadmaps into the future. Given that, it's good to start the roadmap-creation process by assessing what the company already has in place and what knowledge and processes are needed to accomplish a five-year plan. Listed in Table 1 are examples of current readiness and gaps typical for companies, especially at today's mid-sized and smaller technology companies.

Table 1, Examples of Current Readiness and Gaps for Future Environmental Requirements

Knowledge and Processes Needed for DfE Roadmap	Typically in Place at Companies	Gaps to Fill for 5-year Roadmap
Information about current and future regulations	General information about more widely-known, existing regulations	Determine which types of regulations will affect the company's products and global markets and what is planned and foreseeable in the next 3-5 years.
Understanding beyond-compliance requirements from customers, standards, NGOs	Knowledge of questions asked in customers' RFQs and very common standards such as Energy Star	See how leading corporate customers are requiring beyond-compliance steps from suppliers, and how standards committees are formulating new standards.
Processes to ensure that environmental requirements are met in all applicable products	Owing to lack of executive support for strategic approach, repeated "scrambles" to meet impending requirements	Establish systemic processes throughout the company for addressing requirements and verifying success, reducing "emergency mode."
Training in DfE principles	Basic understanding about replacing commonly-known hazardous substances with other materials	Train not only hardware and software designers, but also R&D, supply chain, logistics, marketing, and all mid-management in LCA and DfE principles that reduce costs.
Executive support of DfE	Executives leave "compliance" up to managers whose responsibility is EHS, and do not strategically elevate DfE	Educate executives about the wide-reaching strategic imperative of systemic DfE processes and ensure necessary intervention & funds.

Abbreviations: DfE = Design for environment; NGO = Non-governmental organizations (e.g. World Wildlife Fund, Greenpeace) that educate customers about environmental issues in electronic products; RFQ = Request for quotation; EHS = Environment, Health, and Safety; LCA = Lifecycle analysis; R&D = Research and development; COGS = Cost of goods sold

Our colleagues at DCA deploy their rapid-review methodology for assessing the company's readiness. Then, through benchmarking with best-practice companies, the gap is analyzed.

#2: Create the Five-Year Roadmap

Based on step #1 above, the company now has a sense of which specific environmental requirements will affect their products and global markets. Now, for each product line, map current and anticipated environmental requirements along the left column and on the top row list each quarter for the next five years. Populate the roadmap, as shown in Figure 2, according to the specific steps for anticipating and meeting all necessary requirements plus those DfE principles that will save the company money and garner competitive advantage.

Leverage best industry practices for systemically addressing the requirements, and assign champions for each task. The DfE roadmap parallels the company's own product roadmap -- five years into the future.

Figure 2, Sample Roadmap Format

Fiscal Quarter	Responsible organization and individual	Regulations & Standards	Business Benefits	4Q10	1Q11
DfE Principle					
1. Improve Reuse and Recyclability		Regs: EU WEEE, Calif. SB50. Stds: EPEAT	Take-back for inexpensive warranty replacement, mine valuable parts, additional "touch point" for Sales.		
1a. Tasks	R&D: Sarah Smith			Identify recyclable materials	A) Determine current percentage in example product B) Determine potential for improvement and set target (with marketing) C) Define design criteria
1b. Tasks	Reduce number of screws; use snap fasteners				
2. Reduce use of toxic substances		Compliance: EU RoHS & REACH, USA TSCA. Stds: XYZ	Can sell products to any region. Avoid interrupted supply chain bcs of restricted materials.		
2a. Tasks: Substances ID	Commodity purchasing: Roger Jones			Identify short and long-term lists: JIG, SIN, Prop 65	
2b. Tasks: Infrastructure				ID data management capabilities; define needs	Review tools/systems/service providers; propose solution to management
2c. Tasks: Design Process					

#3: Learn DfE Principles and Implement the Roadmap's Tasks

It is now necessary to train employees in R&D, product designers, and marketing in business-beneficial DfE principles from product concept through the end of the product's useful life. We use a full-day DfE Workshop in which executives and mid-level managers are exposed to the strategic reasons for proactively designing products and processes for environmental efficiency and designers practice using a DfE checklist in two hands-on exercises. Designers even have a real-time opportunity to design a DfE-exemplary product with their colleagues during the workshop; the results have surprised even the designers themselves.

The DfE Workshop fosters a confident and enthusiastic start to roadmap execution. Then, as clients progress along the roadmap over the quarters and years, they appreciate coaching in carrying out roadmap's tasks as the quarters and years progress.

#4: Update the Roadmap Annually

Create a "rolling roadmap" by updating it every year – honing the requirements, strategies, and tasks for the four remaining years of the roadmap and adding a new fifth year. Sources for the updates will be results from regulators' and standards bodies' committees' decisions, and eliciting key customers' new environmental requirements, bringing forth new best practices for DfE, as well as considering the company's own changing business objectives and product roadmaps. Study classes of requirements in order to predict trends.

Now, you have a sustainable process for integrating DfE in the company's processes to the benefit of cost savings, competitive advantage, and far less stress owing to reacting to "surprise" environmental requirements.

Stepping up the Sustainability of Entire Product Lines: Start with One Exemplary Product

Business rewards from designing "sustainable" electronic products—(otherwise known as products with "design-for-environment" (DfE) principles) abound. Manufacturers purchase fewer components/materials, assemble products in shorter time, and ship smaller/lighter products. Sales and marketing get to promote a more efficient, competitive product. Retailers economize on shelf space. Customers save operating costs and reduce packaging waste. And the products are worth more after they have been used. However, even though DfE principles themselves are not complicated, some electronics companies need a kick-start to deploying DfE throughout their product lines. One way to start is to design one "DfE-exemplary" product.

Designing DfE-exemplary products can be a positive initial move toward stepping up the sustainability of entire product lines and entire industries. In this column I describe the characteristics of DfE-exemplary products, offer examples, discuss the pros and cons, and offer suggestions for overcoming any objections to the idea.

Characteristics of DfE-Exemplary Products

A DfE-exemplary product benefits from sustainable thinking during product concept (including developing the business model); product design, manufacturing, and distribution; and planning for reuse and end of life. Table 1 lists the main categories of a DfE checklist along with sample questions within each category. A DfE-exemplary product should result in a "yes" answer to most of these questions.

Table 1. Main Categories of a DfE Checklist, with Examples

Design-for-Environment Categories	Sample questions on the DfE Checklist
Executives' commitment to DfE	• Have you established company-wide DfE metrics and targets with phase gates and internal audits? • Have you chosen a business model conducive to sustainability, such as leasing, service models, and more modular products? • Do Marketing and Sales executives leverage environmental-performance strengths in a similar manner to cost and quality?
Design for dematerialization	• Could the functionality that this product provides be achieved through The Cloud -- selling a service instead of hardware? • Does your company have another hardware product whose functionality could include the function of this product -- to have one hardware product instead of two?
Design for simplicity	• Have you reduced the complexity of enclosures and assemblies? • Are fewer parts used? Have you leveraged multifunctional parts (such as a single fastener)?
Design of multifunctional products	• Can the product be used for several purposes at one time (in parallel)? • Are there secondary uses after the product retirement? • Is the design modular—common across products and easy to replace/repair?
Design for source reduction	• Has the product's dimensions and weight been reduced? • Has the mass of key components been reduced?
Design for longevity	• Is durability achieved without compromising disassembly and recovery? • Is the product upgradeable—particularly without having to ship or install new hardware?
Labeling	• Have material coding symbols been molded into plastic parts in accordance with ISO 11469 and ISO 1043?
Batteries	• Can batteries be avoided? • If batteries are necessary, are they easily removed and replaced by the user?
Packaging	• Has packaging been minimized in mass while still passing drop tests? • Are recycling-incompatible packaging materials not glued together or otherwise attached?
Material choice and sourcing	• Has the number of different materials been limited where practical? • Have paints, surface coats, and adhesives been avoided? • Have scarce and hazardous materials minimized / avoided? • Are materials from environmentally responsible raw material conversion, manufacturing processes, and suppliers?
Manufacturing and distribution	• Is the component/assembly designed for energy conservation, minimized waste and air/water pollution, and scant use of water during manufacturing? • Is the product shipped in reusable containers? • Are the distribution logistics optimized for minimum carbon emissions and energy use?
Use phase	• Is the product designed for minimum power consumption, waste-consumables, serviceability, and accident prevention in use? • Do you educate customers on how to use the product such that energy and material efficiency is maximized?
End of life: Design for re-use, disassembly and recycling	• Is there a secondary market for the product, components, and materials? • Are instructions for how to dismantle, which components and materials are recyclable, and how to process them easily accessible? • Can assemblies and components be removed with a standard tool?

For the full Design-for-Environment Checklist, contact Technology Forecasters Inc.

Debate about Carbon Off-sets

Some companies' DfE-exemplary products include carbon offsets to arrive at or close to "carbon neutral." Motorola's "MOTOCUBO" is touted as the world's first BFR/PVC-free, CarbonFree® certified phone. The phone is certified carbon neutral by Carbonfund.org. According to the press release, "through this partnership Motorola will offset all the carbon emitted in the manufacture, distribution and use of the cellular phone with investments in preservation, reforestation and renewable energy project."

Most DfE-exemplary products, however, minimize the product's own environmental footprint – during all phases of the product's life—and do not leverage carbon offsets. My recommendation is to go as far as possible reducing environmental impact before considering offsets. If market research indicates that your product's market share will be significantly enhanced by certifying as carbon neutral, do strongly consider making these investments.

Emphasize Overall Cost of Ownership

Many of the design strategies represented in the DfE checklist reduce the cost of materials, manufacturing, and shipping. Now and then, however, a smart DfE design will leverage a component or subsystem whose purchase price is higher, but whose performance and/or synergy with other parts reduces the total cost of ownership. One example is choosing solid state drives instead of hard drives, which yields approximately five times the reliability and energy efficiency of a hard drive. It can be lighter and generate less heat as well. However, the solid state drive's purchase price is currently quite a bit higher than standard hard drives; we are confident that in time, costs and prices will come down. In the meantime, several tech companies' DfE-exemplary products do use solid state drives . Their Marketing and Sales groups position these products to customers as providing long-term lower cost of ownership due to lower energy consumption, higher reliability, and other factors.

Sometimes a more expensive component can eliminate the need for purchasing several other components. For example, a component that generates less heat can alleviate the need for fans and heat sinks; this can reduce the size, weight, and reliability of the product as well.

So, do consider choosing for your DfE-exemplary product elements that may increase purchase price but reduce operating costs. Choose your market for the product based on value given to sustainability features.

Pros and cons of starting with a DfE-exemplary product

Let's explore the pros and cons of packing numerous DfE attributes into one or two products, while incorporating minimal DfE features in the rest of the product line. (These pros and cons are summarized in Table 2.)

Table 2. Summary of Pros and Cons to Releasing a Single DfE-Exemplary Product

Pros	Cons
Exposes executives, designers, and other employees to DfE principles	Draws attention to other products *not* being as environmentally responsible
Marketing/Sales learn to emphasize total cost of ownership	Raise corporate risk if a health or environ-mental issue develops with another product
Positive publicity can carry over to full product line	Could be viewed as a red herring.
Stakeholders (employees, investors, etc.) increase loyalty to the company	This singular product could lack strategic support and momentum to propagate DfE
Designers will be drawn to creating sleeker, efficient products	If executives are convinced of the business benefits of wide-spread DfE, dive in to all products

The main "pros" are to expose executives, designers, and customers to DfE principles such that over time business-savvy DfE features will spread into entire product lines. Marketing and Sales learn to position environmentally-advantageous products to the most receptive markets and emphasize the lower cost of ownership and environmental benefits. The company likely will experience positive publicity about the one product, which carries over into customers' desire to do more business with the company overall—spurring sales of the products not yet packed with DfE attributes.

Stakeholder loyalty will increase: Employees feel pride in their company, investors view this as a plus, and environmental organizations may publicly praise the accomplishment. A precedent will be established for a sustainability-minded business model, as well, which can be applied to other products. My favorite advantage of this strategy is that once a design engineer achieves technology, performance, and market wins based on DfE principles, he or she will likely be drawn to incorporate more and more sleek DfE elements into every product designed thereafter.

The main "con" is the possibility of drawing attention to customers and other stakeholders the fact that your company's other products are not as environmentally responsible. A TFI client in the insurance industry points to a potential issue with "eco" products that stand alone in a company's product line, because this practice could make them vulnerable to a claim about a standard product's health or environmental hazard when the company has demonstrated sufficient knowledge to design and manufacture an environmentally responsible one.

Another disadvantage is that the market (or a non-government organization) could view the singular product as a move to capture positive attention, without doing the work to transform the entire product line to DfE (the expression “red herring” comes to mind). Finally, executives may permit this one DfE-exemplary product to be designed and sold without developing broad-based strategies for requiring DfE principles in all designs – with phase gates and internal audits; in other words, the singular DfE product could lack the momentum to bring about others. It’s much more efficient, of course, to convince executives of the business benefits of wide-spread DfE requirements and not to take it too slowly by focusing on only one product to start.

Resistance to DfE: How to overcome it

We’ve not run into much resistance at client companies regarding DfE training; once the executives understand the business and competitive benefits they are usually amenable to funding DfE workshops. And following the training DfE elements start popping up in product designs everywhere. But we have run into resistance about packing a singular product with as many DfE features as possible. “It could cost more,” some say. “We’ll have to market it differently,” say others. Change is not always welcome.

Here are some ways to overcome these reservations:

- Find out if a competitor has released such a product, and make this fact known.
- Analyze key customers’ latest Request for Quotes (RFQs), and point out the numerous DfE requirements
- See if there are influential designers who will lobby strongly for approval of an innovative, efficient design.
- Finally, give your designers an experience of designing a DfE-exemplary product.

How can your designers experience designing a DfE-exemplary product? Several years ago we added another hands-on exercise to our DfE workshops. We form teams comprising the client’s designers (best if at least one electrical, mechanical, and manufacturing/test engineer is in each team) and challenge each one to design a practical yet visionary product within their company’s mission. The team incorporating the most DfE principles in a feasible and marketable design wins. We’ve found that it’s a competitive - and fun – way to build your team and give them a direct experience of designing DfE products. Attendees have reported back to us that it’s an “eye-opening” practice and forever changes how they approach product design.

Designing a DfE exemplary product can clearly bring significant benefits to your company, including positive publicity, shifting awareness and emphasis to total cost of ownership, increased customer and stakeholder loyalty, and increasing your designers' knowledge and motivation to design DfE products.

At the same time, it's not for everyone. We recommend carefully considering your product design strategies – knowing that whether you focus on a DfE exemplary product or disseminate DfE throughout your product designs (or both!), your company and customers will only benefit.

Putting Life Cycle Analysis to Work

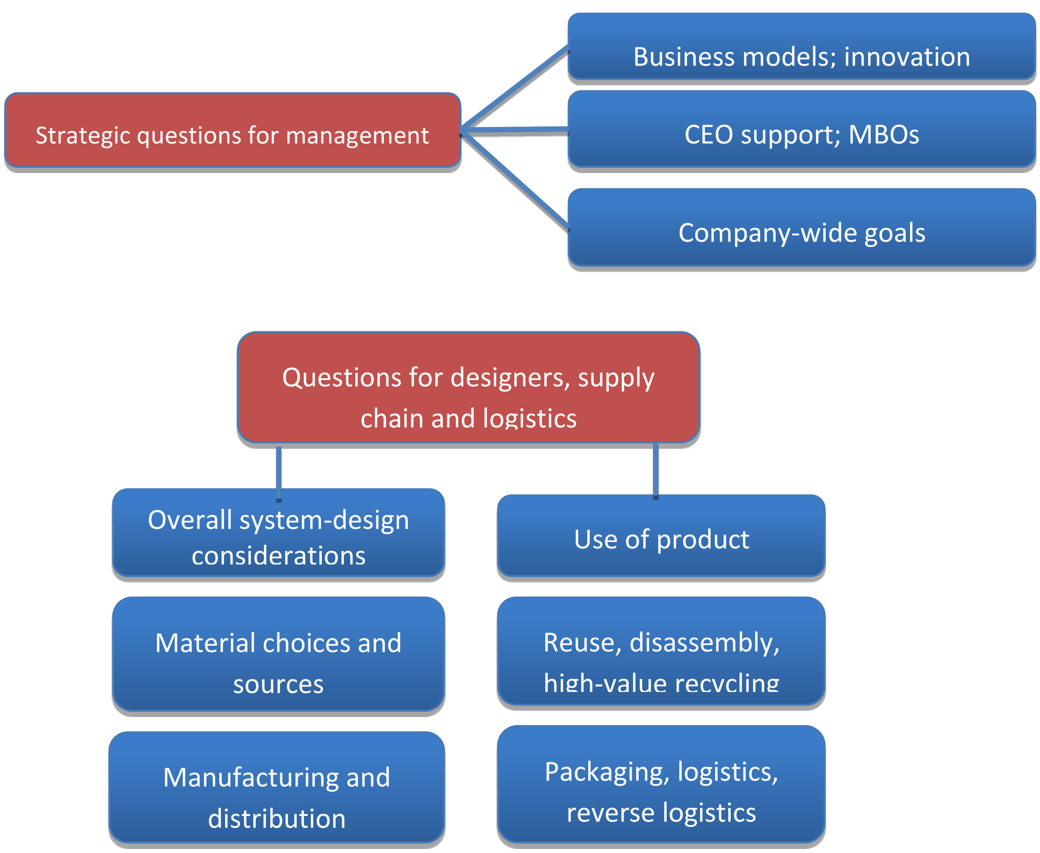
By Pamela J. Gordon, Technology Forecasters

There is little argument these days that enhancing electronic products' functionality while reducing product size and power consumption is a win both for users and the environment. Smaller, lighter products that need less electricity and can be upgraded using software are easier to use, and by reducing the number of components and weight of the product the supplier saves money in supply-chain, manufacturing, shipping, and storage.

But how does one *quantify* the degree of a product's efficiency? How can designers choose between options to continuously reduce power draw, mass, toxicity, and other environmental impacts?

One answer is to use a Design-for-Environment Checklist, as I wrote about in a previous column. (see "Stepping up the Sustainability of Entire Product Lines: Start with One Exemplary Product") By using a DfE checklist, designers can implement and "check off" as many DfE principles as possible for customer advantage and cost savings.

Figure 1: Overview of the Design for Environment (DfE) Checklist



A complementary approach is to conduct a Life Cycle Analyses (LCA) of a product. An LCA provides quantitative, comparative environmental footprint data for different environmental impacts such as CO2 equivalent emissions, hazardous waste and use of material resources throughout a product's life cycle from material extraction to end-of-life. This can be used to highlight areas for improvement in product design. Product-development organizations can use LCAs at the early-stages of planning and concept design to anticipate environmental impact well before detail design is started.

In this chapter, I address the pros and cons of LCA. Readers may want to know how feasible these tools have become (they were once very arduous!) and whether they can start using LCA right away.

Stages of Product "Life" Quantified by an LCA

Taken together, the mining, fabrication, assembly, shipping, usage, and reuse/recycling are six stages in a product's "life cycle," as shown in Figure 2 (note that after stage 6 material is used as feedstock for the same or other products – as indicated by the yellow arrows -- therefore closing the loop).

Figure 2. Six Stages of the Life Cycle of an Electronic Product

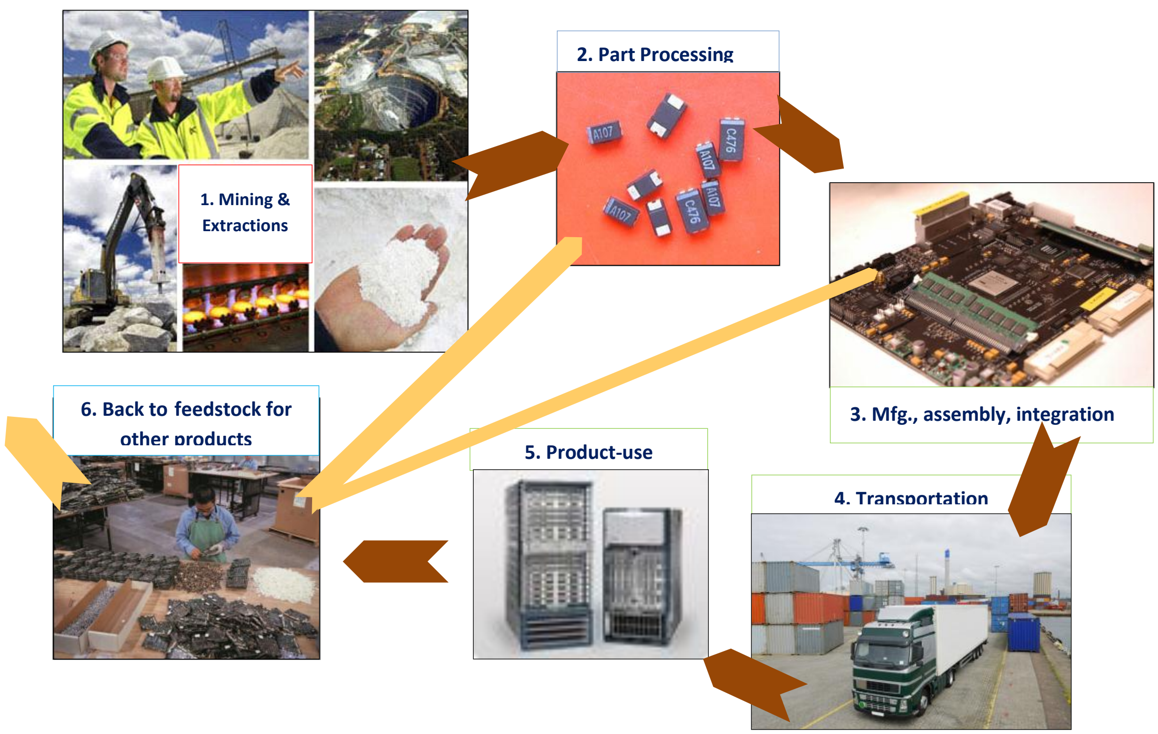


Photo credits: 1. Australian mine (not a conflict mine). 2. Proan Electronic Co. Ltd. 3. Digicom Electronics' website (www.digicom.org), 5. www.Cisco.com, 6. Photo courtesy of Sims Recycling Solutions.

By having environmental footprint information about each of the six stages of life, management can choose different business models and engineers can choose different designs and materials to significantly and measurably reduce impact. For example, engineers and supply-chain professionals can choose materials with less toxicity and eliminate sales barriers raised by proliferating global regulations restricting hazardous substances (addressing life cycle stage 1).

Management may decide to offer a leasing model with easy upgrades and refurbishment to keep products in service longer and at iterative customers, generate more revenue over time, and reduce end-of-life processing (life cycle stage 6). Designers can improve power efficiency to reduce life cycle stage 5 impacts, and combine two types of functionality into one hardware system to reduce impacts in all 6 stages.

The question often asked is why consider the life cycle as a whole and not just take the checklist approach alone, which is much simpler. LCA-type tools bring to light actual comparative values, which are important especially because improvements in one area of the life cycle can make it worse over the complete life cycle. For instance a plastic housing often produces less CO2 emissions than a metal housing, but the total could be greater if a fan is required as a result for cooling because of the increased power consumption in the use phase. Also LCAs enable analysis of a range of important environmental impacts together, to ensure that improvements in one area are not at the expense of other detrimental environmental impacts. Finally, an LCA generates values that can be used to drive improvements. Why is this important? Well, just as management wouldn't drive down costs and improve quality solely with check lists and devoid of quantitative measure of improvement, so should environmental-footprint improvements be quantified as well.

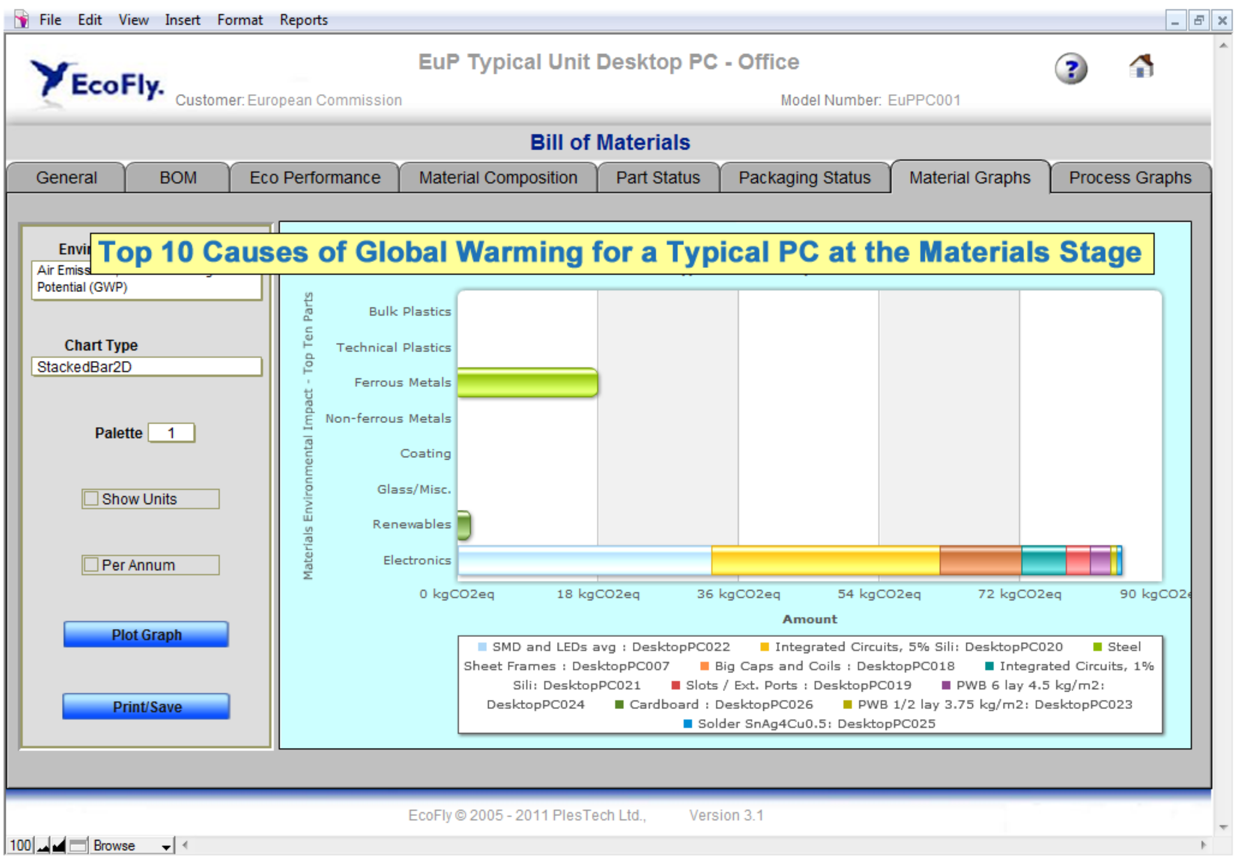
From Arduous to Practical

Conducting LCAs used to be year-long, arduous processes that few people undertook (other than at universities and in giant electronics companies). Early in the development of LCAs, scant data was available on the environmental impact of components and materials. Today, thankfully, using new, friendly LCA software approaches that incorporate environmental-impact databases, an LCA for a moderately-complex electronic product can be completed in one week.

I had a recent experience of conducting an LCA for a Silicon Valley client – a maker of networking products. My client and I spent a half day disassembling the product and noting on the bill of materials the size, weight, and type of components and materials. We also photographed key parts and subassemblies. We then shared the information with my colleague Graham Adams, who developed the LCA tool EcoFly. He spent four days analyzing and quantifying the environmental impacts (using EcoFly software). In one week, we delivered data on each of the six phases of product life. Shortly afterward, the same client ordered LCAs for 2 pairs of products: legacy and new products in the same classes of functionality; now they can compare functionality and environmental impact between product generations, and gear up for even greater efficiency in future generations.

In Figure 3 there is a sample chart from a generic LCA—showing environmental impact from the materials phase. LCA data is available **for all** stages of the product life cycle.

Figure 3. Sample chart resulting from an LCA on the materials stage of the product's life cycle



Another relatively easy LCA tool is Sustainable Minds. Sustainable Minds' CEO, Terry Swack, told me, "My mission to bring LCA to mainstream product design. It's software that teaches, so people learn as they do."

Business Advantages of Using LCAs

Environmental benefits of improving products through LCAs are numerous: learning where to reduce hazardous substances, seeing tradeoffs between different types of housing and packaging, comparing efficiencies of various components and subassemblies, removing mass (weight) from the product and therefore transportation impact, and more.

Business benefits abound, as well, as listed in Table 1. Executives who might be reluctant to commit employees' time to conducting LCAs for environmental benefits alone are usually persuaded when presented with the business advantages.

Table 1. Business Advantages of LCAs

Category	Advantage
Marketing	Customers – consumers, corporations, and governments – increasingly want to know if their suppliers are doing all they can to mitigate the environmental impact of their products. Companies conducting LCAs on iterative product generations can point to the environmental improvements, as well as savings for customers in operating costs.
Investor relations	Companies knowing the carbon footprint of their products of their products' life cycles can report estimates and targeted improvements to the Carbon Disclosure Project, which is viewed by investors in trillions of dollars of corporate funds.
Employee satisfaction	For 15 the last years TFI has been interviewing electronics design engineers about "design for environment" – well before most had heard of DfE. Our research indicates that most engineers care about environmental health and want the tools/insights for efficient product designs. LCAs give designers clear guidance as to the relative environmental impacts of myriad design choices.
More reliable products	As explained in chapter 1, there is tremendous overlap between DfE and enhanced product reliability. LCAs can lead to more reliable products through design choices that also reduce environmental impact.
Cost reductions	LCAs guidance in designing smaller, lighter products and packaging fosters lower shipping and inventory costs. Design for disassembly reduces costs of assembly, eases refurbishment, and increases end-of-life value. Through smarter, more efficient design decisions, companies can reduce products' cost of goods sold by 1%-5+%.

Caveats about LCAs

I'd also like caution people about using LCAs ineffectively. We do not recommend that companies make public comparisons between competitors, use LCA data for marketing purposes only, or select an LCA that is too light or overly rigorous.

LCA Don'ts:

- Don't make public comparisons between the results of the LCAs of your and your competitors' products. Competitors can fight back by hair-splitting methodologies or arguing that one LCA tool is more accurate than another. It is best to use the LCA results to improve one's own product designs.

- Don’t use the LCA data for marketing only and not continuously involve product designers. The design-feedback-loop is essential for informed, substantive improvement.

- Finally, don’t select an LCA tool that is either too light or overly rigorous for your products and needs. The former will leave designers with more questions than insights, and the latter may not reach conclusions in time for today’s short product-design cycles.

Why Not Try an LCA Today?

We recommend that all interested parties receive a demo from one or several LCA companies, and socialize the business benefits of LCAs to their management. Starting today can foster smarter, more efficient designs that are good for the company, customers, and the environment.

DfE Considerations for Plastics

In her new book *Plastic: A Toxic Love Story*, author Susan Freinkel confirms the suspicions we've had about the multifold damage of production, use, and waste of plastic materials on human health and the environment. She spells out case after case of discovered ill-effects of producing, using, and disposing of plastic materials—from credit cards made of PVC to chemical leaching from plastic blood bags to blister packs for electronic devices. The book prompted us to address Design-for-Environment (DfE) principles that can (1) mitigate harmful aspects of plastics in products and packaging, and (2) make good economic sense.

Choice of Petroleum Plastic vs. Other Materials

In a recent lecture, Freinkel described how she planned to spend one full day without touching any plastic – as an exercise to see how prevalent plastic is today. In the first hour, she had to morph the experiment to recording the number of times she touched plastic instead of avoiding touching plastic, just to be able to maneuver necessary objects for household living. She writes, "By 1979, production of plastics exceeded that of steel." Though Henry Ford's dream was to make the first automobiles from grown materials (primarily soybeans), he – and just about every other industry -- had to succumb to using petroleum plastics.

Recycling plastics is critical. Ultimately, however, using renewable, compostable, reusable, and recyclable materials is better than recycling one-use plastics.

Today's designers have several alternatives for material selection, from the most harmful petroleum plastics (such as PVC), to slightly more benign plastics (such as HDPE or PET), to metals (e.g., aluminum or steel), to bio-plastics (made of soybeans, corn, and other plants), to recycled metals and plastics.

Using life cycle analysis (LCA) is a great way to measure and compare the environmental impact of one material over another in your product or packaging. Sometimes decisions are straight forward: material A is chosen over material B because it better meets product requirements and has lower environment impact at the production, use, and waste stages. One example that our colleague Graham Adams explains is Apple Computer's decision a few years ago to use a metal (vs. plastic) enclosure that doubled as a heat sink. Other times, there are so many environmental and technical trade-offs that the choice of materials is more complicated.

In general, though, use these DfE principles when selecting material:

Use recyclable materials that are not: (a) hazardous, (b) coated, painted, or pigmented, (c) scarce, (d) flame-retardant plastics, or (e) glued to other materials. Using hazardous materials or flame-retardant plastics, which have been linked to health issues in humans and animals, means putting dangerous chemicals into a customer's hands, and later into landfill or bodies of water. Material selection as it pertains to Design for Environment is also about recyclability. Using coatings, paint, or pigment means that it is difficult to isolate the raw materials for recycling. Avoid coated, pigmented, and painted plastics unless the application necessitates the treatment for cosmetic reasons. (Your marketing department may be aware of the growing popularity of unpainted, unfinished materials.)

Limit the number of different materials. Using fewer unique materials makes products easier to recycle and more likely to be recycled at end of life. With different collection schemes around the country, customers may be less likely to recycle, for instance, a product with three types of plastic and aluminum than a product with just one type of plastic. Some schemes require customers to separate plastics from metals. Because of the added step of dismantling a product with mixed materials before they can recycle it, many customers will simply choose the easier option and trash the product. Making a product easier to recycle makes it more likely to be recycled. Using fewer materials allows a product's parts to be more easily sorted at or on the way to a collection facility.

Reducing Plastics Waste

Freinkel writes, “We bury in landfills the same kinds of energy-rich molecules that we’ve scoured the far reaches of the earth to find and excavate…these materials are too valuable to waste.” Following are DfE principles that we use to reduce waste of plastic.

A “Plastic Beach” of waste. Maximize reuse and recycling of plastics through DfE principles and a sound business model.

Plastics are wasted instead of recycled if they cannot be separated and properly identified. To make plastics easily separable, design connections so that they are easily accessible and can be disassembled with a standard tool.

Connections are a main factor in the recyclability of a product. DfE principles rank connections from best to worst as follows: (1) snap-fits, (2) push-in plugs, (3) easily accessible screws, (4) hidden screws, (5) rivets, (6) glue, (7) solder. Ease of disassembly is a major component of Design for Environment. Separating attached parts must be easy to facilitate recycling and proper disposal of each material which makes up the product. Snap-fits and push-in plugs can be removed with no tools, easily accessible screws require no special tools or skills, hidden screws require disassembly to access, rivets can be difficult to remove, and glue and solder cannot often be removed.

Label plastic pieces weighing more than 25 grams with material codes according to the SPI Resin Identification Codes (these are the 1-7 numbers indicating type of plastic enabling proper sorting at collection facilities). Many collection facilities choose which plastics they will accept (and sort plastics at their facility) according to this 1-7 labeling system. If we are to use plastics, we should properly label them to make use of the recycling technology available to extend the life of the materials. There are opportunities in the design stage of a product to make that possible.

Using Dematerialization to Reduce Plastics – and All Materials

One of the essential DfE principles – regardless of type of materials used – is dematerialization. While selecting the right type of materials and extending their life through reuse and recycling is a step in the right direction, limiting their use is the goal. This can be done in two main ways. One is to physically reduce the amount of material in a product. The other is to extend the life of the product so fewer materials need to be purchased over a span of time.

A plastics recycling plant. Leverage DfE principles in product design and utilize a business model that maximizes the likelihood of the product's materials to be reused and recycled.

The first method (physically reducing material) can happen in a few ways. One is to minimize empty space in a design. This has been the main component driving the shrinking of PC towers in the last ten years. Another is to utilize cloud computing. By centralizing more functionality, use-premises products can be smaller and/or disappear. This direct material reduction combines with reduced packaging because the cloud's servers can be housed at a central facility instead of shipping units to each customer.

The second is giving the materials themselves a longer life. One product does not save any material this way, but because products last longer, less material will have to be bought (and later wasted) long term. Designing a product to be more reliable (often a DfE endeavor in itself extends the life of a product, including of course its materials. Alternatively, designing easily upgradeable products (through modular design and/or software updates) can allow customers to keep the plastics and other materials that are still perfectly good while upgrading hardware components for longer life.

Final Word About Plastics in Product Design

Plastics are inexpensive, they can be used in nearly limitless applications, have a relatively low carbon footprint, and – when designed and applied with DfE principles and a smart business model -- can be reused and recycled. However, using plastic materials without analysis of health effects and the waste stream can be detrimental not only environmentally but also to the ability to attract and retain customers who are increasingly selecting renewable materials.

Use DfE principles to make our society's love story with plastic a little less toxic (with thanks to Susan Freinkel for the insights and inspiration).

About the Authors:

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Note on Connect Press:

Please note that the DfE chapters in this Technology Forecasters Inc. white paper were originally published in a slightly modified version on the ConnectPress websites www.catiacommunity.com, www.inventorconnections.com, www.creocommunity.com, www.siemensplmcommunity.com, and www.solidworkscommunity.com. To sign up for ConnectPress free newsletters visit www.connectpress.com.