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Mending Broken Promises in Sustainable Design

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Mending broken promises in sustainable design

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Abstract

Sustainable Product Design is effectively combining solutions that address environmental issues while elevating user experience and achieving success in the marketplace. A closer look at the effectiveness of sustainability strategies in the design process reveals that some of the best efforts in this area do not yield the benefits promised. Examples of these shortcomings include product operation with unnecessary features that push performance beyond environmentally friendly levels, products made out of recyclable materials that still end up in landfills and consumers that do not connect sustainable lifestyles to the products they use.

An effective model for consistent benefits in sustainable product design begins with making the right choices for materials, processes and manufacturing so that products have an innately low environmental footprint. Then an understanding of the product lifecycle within a circular economy context ensures that steps such as recyclability and reuse are not ignored as products go through iterative cycles of fabrication, use and repurposing. Lastly, promoting positive user behavior so that products are enjoyable and meaningful enablers of short and long-term sustainable benefits. By having these strategies working together as a multi-layered approach, all stakeholders in a given product's lifecycle will consistently make choices that result in sustainable advantages.

Keywords: Sustainability, product design, circular economy, user behavior, systems thinking

Introduction

Sustainability is now established as an essential tool in any designer's tool kit (Robert et al., 2002). Its demand comes from a variety of stakeholders; everyone from businesses to organizations and particularly consumers are all looking for products that reduce environmental impact and promote sustainable lifestyles (Black and Cherrier, 2010; Axsen et al., 2012). Despite skepticism around climate change from some organizations and even from United States Congress (Nuccitelli, 2015), it is widely understood that traditional manufacturing practices need to change dramatically in order to stop exploitation of finite resources. Designers have a key role

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in defining pathways towards sustainable practices and positive wellbeing while delivering design solutions that perform successfully in the marketplace.

To date, most of the work around sustainable product design has focused on the early stages of the lifecycle. There are plenty of guidelines for sustainable design process, which normally fall into three factors: product specifications around unmet user needs; market considerations around cost, materials, appearance, etc.; and knowledge from designers as they define their final intent (Waage, 2007). These factors define, in large degree, the overall environmental impact of mass-produced objects, which in some products such as laptops, have up 80% of their total energy demand during their fabrication (Williams, 2004). An area frequently looked at for environmental impact is end of life. Recyclability is a key component for measuring how 'green' a product as it reduces landfill waste and provides a method for processing materials for reuse. The reality is, however, that recyclability is not as successful as people commonly assume. Recycling rates in the US, for example, show that about 55% of aluminum cans were recycled in 2013 (Environmental Protection Agency, 2015) and electronic waste, which is one of the largest sources of toxic waste, showed a ratio of only 25% in 2009 (Environmental Protection Agency, 2011). Recyclability has a large weakness in that its benefits are based on the potential of the recycling act being fully performed and so there is no guarantee that these predicted benefits will occur. This is a big problem when industries increase product complexity in order to accommodate features around disassembly and recyclability, assuming that the metals, plastics and other materials that they use will be disposed of appropriately. If products like these are not recycled they waste materials as well as features planned for end of life.

In order to obtain sustainability strategies that exist in reality and not only in potential, this chapter discusses a set of tools and case studies that promote a more effective product lifespan that integrates sustainability throughout product pre-use, use and post-use. As a starting point is the attention to material and processes that follows ecological, social and economical needs as organized in the Triple Bottom Line (TBL) model (Elkington, 1999; Norman and MacDonald, 2004). The TBL perspective provides products with a more comprehensive view of their sustainable potential that goes beyond environmental benefits. TBL resonates with various manufacturers and it is no longer foreign to designers and engineers. Second is an attention to the entire product lifecycle based on circular economies as an excellent vehicle for rethinking products in a way that guarantees sustainable lifecycles, given that steps in it depend on – and in

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many cases cannot occur without – the correct completion of the previous step. Third is a strong focus on user behavior towards sustainability, health and wellbeing. Products that promote these types of positive behavior are most times used and maintained in the most effective and sustainable way as they provide satisfaction and benefits to their users both in short and long terms (Chapman, 2009). Users not only benefit from the product performance but also enjoy having an active role in making their products truly sustainable. As overarching goal is the simultaneous implementation of these steps along with other strategies already familiar in sustainable product design. This combination eliminates the assumption that any single sustainability action will happen as it provides as many chances a possible for products to be manufactured, used, and disposed of in the most responsible way.

Broken promises in sustainability

While interest in sustainability grows among manufacturers, suppliers, consumers and other stakeholders it also shows a significant limitation. Its implementation in many cases, particularly during use and end of life, relies heavily on someone making conscious and active decisions. This means that sustainability features in consumer products planned during their development phase are not guaranteed to generate positive results, down the line. Breaking down the term 'sustainability' gives insight to this core limitation. On one hand we have the notion of 'sustaining' as a way of using natural resources without compromising them for future generations (World Commission on Environment and Development, 1987). The need for having the vision of an uninterrupted continuous cycle is the result of shortsighted methods that have provided society with vast amounts of goods and services that result in many of the ecological problems we face today. Whether it is wrong selection of materials, abuse of resources or excessive production, most typical manufacturing processes cannot be maintained forever as they use more resources than what exist or can be replenished. The second part of the term 'sustainability' is its ability to make things right. Ability implies potential and not reality. This means that while there are solutions for issues related to ecological problems, there is no guarantee that these solutions will be implemented. Most manufacturing cycles are so complex that it is very easy to break the cycles that are needed for a successful sustained model to happen. From manufacturers who design their products adequately and with the best materials, to users who know how to dispose of their products correctly to recyclers that process them correctly so that recycled materials make it back to the production cycle, there are just too many variables that can be misunderstood, go wrong, or even worse, just be ignored.

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The issue of *potential* versus *reality* can be applied to more specific strategies within sustainability practices. Several key terms around this topic show the same issue: recyclable (as in able to be recycled); compostable (as in able to be composted); or, biodegradable (as in able to be degraded by natural decomposition). While these strategies have the potential to be good solutions, they rely on someone consciously taking the appropriate steps to fulfill them. ~~self-induced~~. In the case of a sustainable product, however, achieving environmental benefits can be significantly more challenging than simply pressing a button, or twisting a dial. Biodegradable products are a good example of this failed potential. Disposable tableware made out of starches such as potato and corn has become fairly popular in the marketplace and consumers purchase them because of their ability to decompose in a natural way instead of ending up in landfills. The 'potential' of these products reduces consumer's involvement in their end of life, giving out a false impression that the products will decompose in any setting when in reality they need to sit in special bioactive environments that promote the breakdown of their particles (Gross and Kalra, 2002). It can be argued that plastic ware has the advantage that most consumers know how to recycle it and there is a growing infrastructure that provides recycling bins and collection stations so that this happens. In contrast, consumers don't know what to do with biodegradable tableware and end up throwing it in the trash.

Shifting from potential to reality

As designers began to adopt sustainability practices into their process they were oftentimes puzzled on how to effectively implement them as well as to how to communicate their benefits to other stakeholders in the process (Waage, 2007). Designers had good intentions but lacked technical knowledge to understand the impact of some of their decisions while engineers had a good handle on processes and tradeoffs but showed little understanding of how these choices affect user experience and consumer preference in the marketplace (Lobos and Babbitt, 2013). Luckily this scenario is becoming uncommon as interdisciplinary collaborations become more prevalent in both academic and professional environments. From the consumer's perspective, the introduction of sustainable products initially implied tradeoffs such as reduced durability, flawed appearance and higher cost. Even today, consumers continue to struggle with purchase decisions around 'green' products because of factors such as time needed for researching product options, price, lack of information on environmental performance, knowledge needed for understanding eco-benefits and balancing all of these with other general product criteria not related to environmental performance (Young et al., 2010). In the case of automobiles, while most manufacturers offer models with alternative energy technologies such as electric and hybrid technologies, consumers face a price premium and limited availability in comparison to internal combustion equivalent models (Orbach and Fruchter, 2011). Balancing sustainability trade offs can be difficult, even with products that are apparently simple. Toy manufacturer LEGO has spent years trying to find a sustainable alternative to Acrylonitrile Butadiene Styrene (ABS), the plastic it uses to produce its iconic bricks. ABS allows for high tolerances that provide the tight fit and durability that LEGO bricks are famous for but it is also harder to recycle than other plastics such as polyethylene. So far the alternatives found for environmentally friendly plastic do not achieve the high tolerances and fit the company needs but a strong push on materials research has prompted LEGO to announce its transition to an environmentally sound plastic by 2030, which includes an investment of 1 billion Danish Krones (USD150 million) and the creation of a research center for sustainable materials (Trangbaek, 2015).

The best way of moving towards sustainability as a reality that doesn't leave consumers and the planet with unfulfilled promises, begins by understanding how to maximize entire life cycles and turn them into iterative systems. By doing this, you transform sustainable advantage from a variable, into a constant. The model proposed herein for achieving sustainability with certainty combines strategies across the product's lifecycle and involves several actions. These actions are taken by designers and engineers as they design the product, by the product itself during its operation, and perhaps most importantly, by users. The model is composed of three main levels: innate product sustainability as defined by materials and processes during manufacturing; circular lifecycle that guarantees that all steps in a sustainable product lifespan will occur as planned; and, positive user behavior that leads to achieving short and long term sustainability goals (See Figure 1).

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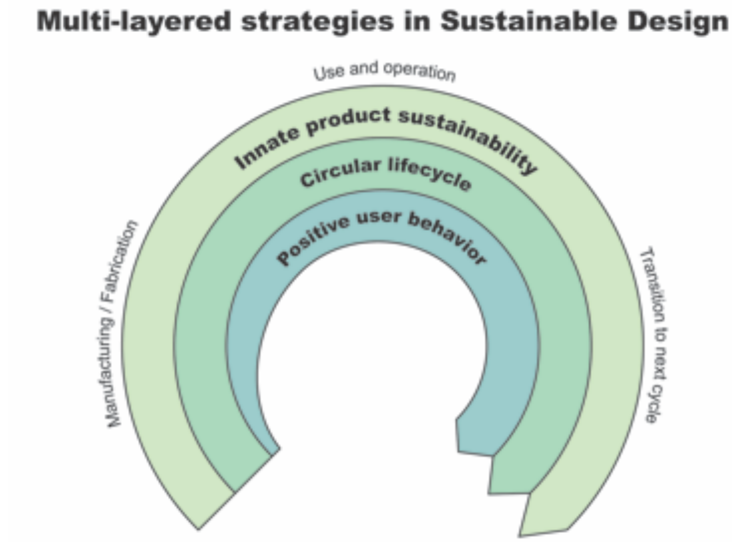

Figure 1: A model for effective sustainability in product design is based on three parts laid simultaneously across a product's lifecycle

Innate product sustainability

This strategy relies mostly on the decisions made during a product's creation, from design to manufacturing which can account for as much as 70% of the overall costs for development, manufacturing and use (National Research Council, 1991). It provides insight to the core sustainability of a product by analyzing the materials and processes involved in its creation, which fortunately is an area where most manufacturers are fairly knowledgeable. When sustainability began to be implemented in product design there was a strong focus on lifecycle and maximization of resources. This focus reflects the control that manufacturers have in the front end of the lifecycle as well as corporate responsibilities they have on business practices. In terms of overall benefits for reducing environmental impact, optimizing components in the front end of the lifecycle (such as research, development, fabrication, and transportation) is a very effective way of seeing significant results in a product's environmental footprint. Depending on the product category, the stage of the life cycle that will have the most impact is the manufacturing stage. Most products will have the majority of their resource needs allocated to materials extraction and processing, production (via energy and water) and transportation costs although products with long lifespans such as home appliances actually have most of their environmental impact happening during their use phase. Because of these reasons it is critical to optimize methods for material extraction and selection and fabrication methods with reduced

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energy and water usage. Making better decisions during this makes also allows for designers and engineers to have full control over how and to what degree these changes happen.

While skeptics see these guidelines for materials selection and processes as limiting for their product development, there are various manufacturers who cleverly turn these limitations into intrinsic features that give their products a competitive edge. Furniture manufacturer Emeco released in 2012 a line of chairs and stools named *Broom* (see Figure 2), in collaboration with prominent designer Philippe Starck. These chairs are made from 75% recycled propylene and 15% wood waste (Emeco n.d.) which gives them a rugged finish, interesting texture and deep character. These products are as durable as other chairs in their category and go as far as including a recycling symbol No. 5 for polypropylene underneath the seat (see Figure 3), meaning that it can be put out on the curb for recycling as is. *Broom* is a good example of sustainability strategies innately embedded in the design of a product.

Figure 2: Broom chair. Photograph by Alex Lobos.

Figure 3: Detail of chair's recycling symbol. Photograph by Alex Lobos.

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Circular lifecycle

Traditional industrial systems are linear, meaning there is little consideration on how the end of life of a certain product can lead to the creation of a new one, or on how sustainable their cycle is. It's basically a linear system based on a constant sequence of production and consumption. As issues around depletion of finite resources became obvious more attention was put on how to bend the linear cycle into a circular one, where waste could be used as source for other cycles, mimicking the behaviour of natural ecosystems. This approach, known today as circular economy, has been adopted since the 1970's but it has not gained significant attention by consumers and key stakeholders in various industries until recent years (Preston, 2012). The model works on a set of principles that do not necessarily depend on large infrastructures but can be adapted to both small and large-scale environments. The principles include: a systems-based approach with components that are modular, resilient and flexible; use of energy from renewable sources at all parts of the lifecycle; and, elimination of any components that won't have use after the product's useful life, thus becoming waste (Ellen MacArthur Foundation, 2013). A basic example of circular economy can be vegetable gardens, which generate a highly involved participation from the user, generating a continued relationship with the garden, consumption of the produce grown and composting of organic waste that goes back to the soil for new vegetables to grow. This is a radical departure from the consumer-based linear cycle, where people will go to a super market, consume produce, throw away the waste along with the packaging in which the food came, just to make another trip to the store and begin a new cycle all over again, all with minimal interaction with food in its natural state.

While it is relatively easy to imagine how circular economies can be implemented around farming and food, there are ingenious ways of adapting the model to more complex systems such as consumer goods.

An area that requires special attention for improvement of sustainable design practices is that of Information Communication Technologies (ICT's) and electronic waste (e-waste). ICT's include smartphones, tablets, computers and other similar devices, which at their end of life create a wide array of environmental issues due to various factors, all of them complex within themselves. Product complexity puts demands on a large number of materials, many of them from scarce resources that are hard to extract. There are several known issues with the generation of toxic substances either as result of the processing of the materials or as by-products during use and end

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of life of ICT's (Widmer, 2005). The issue is aggravated by the large rate of product replacement, generated, in large proportion, by planned obsolescence (Tang and Bahmra, 2008). In the US the typical lifespan of a mobile phone is just 21 months, which puts enormous demand on fabrication of ICT's but also creates a flow of hazardous e-waste that cannot be handled properly. While short lifespan in ICT's is largely due to consumer preferences and aggressive advertisement, technology advances at an accelerated rate, which can make electronic devices technically obsolete and incompatible, limiting their productivity.

Within ICT's, mobile phones are extremely popular and show continued market growth as result of their improved performance, portability and convenience. Circular economy can be used for improving ICT's, based on software with extended longevity, better options for reuse, component modularity, cloud-based memory and processing, parts remanufacturing and consumer-based repairs (Benton et al., 2015). When it comes down to designing mobile phones that are environmentally sound, modular architectures are a common approach. The idea is logical and straightforward: most components of the phone such as case, buttons, microphone, speakers etc., remain relatively unchanged from model to model and only a few components become outdated often, such as memory, processors, screens and batteries. The idea of upgrading components instead of replacing an entire device seems to be a natural direction but it is hard to find an example out in the market that executes this principle successfully. While the general concept of a modular phone with interchangeable components is attractive, challenges with technological compatibility, energy output, standardized parts between manufacturers etc. make it a challenging task. A phone concept that is gaining significant traction and shows a promising direction for actual implementation is Google's Project ARA (see Figure 4).

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Figure 4: Project Ara Spiral 2 Prototype. By Maurizio Pesce and licensed under CC BY 2.0. Available from: <https://flic.kr/p/qzjYEY>

The ARA phone, which is similar to other concepts such as PhoneBlocks, is a device with a basic exoskeleton frame and slots that can be populated according to the user's interests and needs, potentially sourced by different manufacturers, making it disruptive enough to revolutionize the mobile phone industry (McCracken, 2014). The business model would require the user to send unwanted modules to the manufacturer to be replaced with new ones, achieving the concept of a circular economy cycle. In theory this model would reduce significantly the amount of e-waste created given that instead of replacing entire products consumers would only replace specific components and keep using the rest of the phone. The concept is raising doubts about its feasibility, business model, and even if the modular aspect of the phone would encourage consumers to upgrade components at a higher rate because they feel that they are doing a 'responsible' replacement. Nevertheless, concepts such as Project ARA are interesting examples of how circular economy can be achieved in highly complex product categories.

Another area in hi-tech products that is gaining important momentum is personal fabrication. The rapid growth of 3D printing is empowering people to fabricate their own designs without need for complex infrastructures. Benefits of this technology include the ability to fabricate goods within a distributed system, innumerable options for mass customization, and a reduced environmental impact as a direct result of simple fabrication methods on site that eliminate transportation, distribution, storage and other factors needed in large scale commercial models (Wittbrodt, et al., 2013; Garrett, 2014). With the increase of circular economy systems it is important to watch out

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for a surplus of artifacts being produced simply because they are easy to print as well as for limited attention to recyclability since users are not required to have plans for end of life as large manufacturers do. Following on the circular economy's principle of using waste as input for future products, solutions for easily recycled unused 3D printed parts is necessary. 3D printers allow consumers to print objects out of materials such as plastic, paper, metal and even food. In terms of plastics, two of the most popular options for 3D printers are Polylactic Acid (PLA) and ABS. PLA is a good option in terms of environmental impact given that it can be recycled in most facilities. But, as previously discussed, the potential for something to be recycled does not guarantee an environmental benefit.

Dennon Oosterman, Alex Kay and David Joyce, students at the University of British Columbia developed a desktop plastic recycler for common plastics in 3D printing such as PLA and ABS so that they can be reused to print new objects (Streeter, 2015). The ability to recycle materials at home offers significant benefits for achieving closed-loop sustainability in consumer products. The most direct one is savings in terms of materials since users can reuse plastic instead of purchasing new spools. At a larger scale, the notion of recycling and printing products at home eliminates the need for packaging and transportation, which in the case of many product categories are responsible for most of their environmental impact. There is also a utopian advantage to the model where in order to create a new product users have to get rid of something they don't want anymore. In a consumer-driven society that is pushed by consumption beyond actual needs, there is certain magic in obtaining new products without increasing the manufactured landscape and maintaining the same material footprint.

Positive user behavior

Product efficiency provides abundant mechanisms for reducing negative impact in the environment but in order to generate a permanent change in business and society it is critical to look beyond environmental benefits and to enable user sustainable behaviors that transcend what products can contribute by themselves (Spangenberg et al., 2010). As discussed earlier, once consumers start using products, the environmental impact is no longer in control of products themselves. A television set with low energy consumption might offer the promise of being an environmentally friendly choice but if it sits in the home turned on all day long with no one watching it (because the user forgot to turn it off or consciously decided to leave it on as background noise) then the accumulated energy usage will still have a negative impact on the

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environment. When consumers acquire products that are environmentally friendly but end up being less proactive about having a responsible use assuming that the products won't have negative effects regardless of how they are used, they create what is known as a 'rebound effect' (Hertwich 2005). Examples of this behavior include people who replace incandescent bulbs with more efficient technologies such as compact fluorescent or LED ones but then leave lights on around the house; or people overusing paper and thinking that putting it in the recycling bin will make everything right. While these behaviors show good intentions, such as selecting light bulbs with better performance or disposing of paper appropriately, they also show how easy it is to take sustainable benefits for granted, resulting in unplanned environmental issues. While some consumers might not feel naturally attracted towards environmentally friendly behaviors, they might be more inclined to minimize the operation of unused devices if they see a higher energy bill due to increased running time. In this way, the balance between sustainable and economic factors in consumer behaviors fluctuates significantly among different groups of consumers (Young, 2010). Designers should try to take full advantage of both components when they design products, so that they provide consumer rewards in both sustainable and economical terms. The combination of environmental benefits with other consumer benefits is crucial for the effective and long lasting implementation of sustainable practices.

When consumers purchase products they do it mostly because of needs and wants. While sustainability is important to many people it will not be a core *motivator* for initiating a purchase but rather a *differentiator* when deciding which product to buy, bringing it back to a basic situation of needs and wants. Products that address those basic needs and wants and include sustainability benefits alongside have better chances of success than products that presume to be acquired just because they are greener. Consumers cannot be forced to choose between a product that works well and one that is sustainable; both components need to be merged together and be dependent on each other. A way of achieving this is making sure that products first fulfill common user needs by being useful, enjoyable, durable etc. This creates a connection that results in a more sustainable product with a longer lifespan, offsetting the energy that went into creating it (Lobos, 2014). If users enjoy a product they will be more likely to follow its cues for positive behavior and meaningful activities that are built into it, increasing sustainable benefits further. Products can serve not only to meet needs and wants but also as resources that promote and engage meaningful activities (Desmet and Pohlmeyer, 2013). The idea of promoting positive behavior has been classified in different categories depending on the level of imposition that it

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has on the user and how direct or indirect its reaction is, ranging in influence from weak to strong and in presence from hidden to apparent (Tromp et al., 2011). Finding the right balance can be challenging as in many cases a stronger persuasion for positive behavior can be perceived as intrusive and undesirable, while a more subtle strategy can be easily ignored. For example, an automobile with a sound system that varies its volume or music selection based on how good (or bad) the driver's habits are might send a clear message to reduce acceleration and frequent braking … but it will also make for an unhappy driver.

When defining sustainability goals, it is important to focus both on short and long term ones that provide larger benefits down the road. For example, household products that use less energy might not yield significant benefits immediately as monetary savings could be measured in fractions of a cent at best. Yet, when added together over longer periods of time and with other products, these benefits can be substantial enough to maintain better user behaviors. This mindset of working towards long-term goals is an excellent way of addressing some of the most challenging sustainability issues that are too big and complex to be solved by individuals. If we want to make a difference in climate change or pollution of a certain eco-system, it will take thousands of people over various decades to obtain a noticeable change.

In contrast to ICT's which have most of their environmental impact during their production phase, other products such as home appliances have up to 90% of their total impact happen during their operation (Otto et al., 2006). In the case of a washing machine, this is due to their long lifespan and heavy use of energy and water during washing and drying cycles. This product lifecycle provides a different set of needs for implementing the strategies that have been discussed. At a recent collaboration between General Electric and Rochester Institute of Technology's Industrial Design program, students designed major home appliance concepts that promoted sustainable behavior in order to address the high environmental impact that occurs when products are in use. Graduate students Patricio Corvalán and Aisha Iskanderani teamed up to develop a laundry system named *Acute*, which offers a combination of reduced water and energy use as well offering the user multiple options for making sustainable decisions when using the machines.

Their design is a full-size washing machine with a cylindrical form factor that makes it easier to fit and move around the home. These reduced proportions are possible due to the use of an

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inverted direct drive to spin the drum, which only needs a dynamic frame to absorb vibration, leaving the unit to perform as free floating; eliminating the need for a boxed shape and a heavy base that keeps the unit in place (see Figure 5). One of their key insights during user research identified that while front loading machines use less water and take better care of garments, consumers find top loading machines easier to load and unload. The team's response to the challenge of integrating performance with convenience was solved with a pivoting frame allowing the drum to be swivelled, setting the machine as a top loader for improved accessibility during loading/unloading, and then rotating it forward so that it runs as front loader, using less water (see Figure 6). The drum uses a weight sensor to compress the drum to the ideal volume, eliminating unused space that leads to wasted water when running cycles. A closed-loop system allows for water to be filtered and reused throughout a wash cycle, eliminating the need for purging and refilling. This feature also makes the washer extremely portable with no need to be permanently anchored to water inlets and outlets. The washer features a repositionable handle that emphasizes how lightweight and portable the machine is, while also allowing for garments to be hung from the handle to air dry. This feature encourages users to dry clothes without using a dryer but its actual acceptance would need to be tested if the concept is developed further[1].

Figure 5: *Acute* washer concept with floating frame allows for reduced proportions without worrying about excessive vibration. Image by Patricio Corvalán.

[1] A video of the *Acute* washer can be watched at: http://youtu.be/T229vm8n_NY.

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Figure 6: Washer can be accessed as a top loader (increasing convenience) and run as a front loader (reducing water consumption). Image by Patricio Corvalán.

The importance of multi-layered strategies

Achieving true sustainability is no small feat and it cannot be the result of a single effort. This is because most issues around sustainability have scales that transcend individuals, and in many cases, communities. Large issues such as economical development, climate change and limited healthcare are causes of distress to humans and other living beings regardless of political and geographical boundaries.

Even if we scale down some of these issues at levels that are applicable to consumer goods, many challenges still stack up very high and need different types of approaches and solutions. This is why in order to guarantee that sustained practices will occur it is also critical to offer multiple solutions that can work well by themselves, but also work even better together. This multi-layered approach is common in sustainable development, where solutions commonly work as interrelated systems that address different sections on one big problem (Robert, 2000). From short- to long-term solutions, features that reduce impact across the lifecycle, and business plans that promote steady growth it is key for any product to contain as many of these strategies as possible. The biggest challenge for sustainable products is to make sure that consumers make the right choices. If a product offers only one opportunity for its user to behave sustainably the chances of this actually happening are very slim. The more options that products offer their users, the larger the chances of products achieving their sustained potential and fulfilling their promises of reduced environmental impact. Additionally, given the complexity of many products during their lifespan, what might be a good strategy early in the lifecycle might not be the best one as the product approaches its end of life.

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The goal for products that follow this approach is to offer a solid base of component parts that provide a guaranteed benefit in terms of sustainable needs. Materials selection and reduced manufacturing and transportation impact are essential considerations for this base. From there, products can start combining short term and immediate benefits that address both everyday needs with sustainable advantages (for example improved portability in a product by using a lighter material). This should also make the product easier to manufacture and to ship, leading to longer terms benefits that can be combined at larger scales and for longer term solutions (such as disassembly options that eliminate the uncertainty whether a product will be recycled or disposed of properly). This multi-layered approach should not be seen as a complicated system to implement, but rather, as a way of dividing a large challenge into manageable parts that can be addressed effectively and individually, through design.

Conclusions

Sustainable product design has shown a dramatic growth since its beginnings, mostly due to the increased use of strategies that balance perceived notions of 'green design' with features that deliver tangible enhancements across a product's lifecycle. Being able to communicate and to prove positive environmental impact is a key skill in new product development that designers are mastering and sharing with other stakeholders in the process. While using a systems-thinking approach is a widely used for defining solutions while minimizing trade offs, most solutions still focus only on manufacturing, and end of life stages. Manufacturing decisions that have to do with material selection and low-energy processes are great ways of reducing a product's environmental impact, given that most of them have their largest impact during manufacture. End of life strategies are effective ways of engaging consumers into sustainable practices and also address issues related to waste management and depletion of non-renewable resources. Unfortunately, many efforts for the recycling and reuse of components are not effective because consumers and other stakeholders rarely follow guidelines for recycling. This limitation results in a broken cycle that makes little progress to reduce waste. Additionally, many consumers are not invested enough to change the way that they use products and don't place enough importance on environmental actions such as recycling, reusing and extending product lifetimes.

Emerging models such as circular economy look at breaking down product cycles into closed loops that are easier to control and to follow successfully by industries or communities without

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need for larger infrastructure common in current economical models. Circular economy enables more participation from consumers and fabricators while making every single component of the cycle essential for its success. The result is a manageable, iterative workflow that minimizes use of new resources and environmental impact while giving consumers a more central role in the process.

Whether products are designed for a small circular economy or for a larger lifecycle, encouraging positive user behavior around sustainability, health and wellbeing, enhances the enjoyment and success of any product. Users who receive immediate benefits and rewards from using their products in a responsible way tend to maintain that behavior, which overtime adds to the improvement of communities, society and the planet as a whole. As designers integrate strategies like the ones previously mentioned, they don't need to choose from one or two of them but rather should try to integrate as many of them as they find appropriate. This integration of sustainable features that can be used simultaneously, results in the highest performance possible and also minimizes the likelihood that a product with good sustainable potential will fail to perform in that way and won't be part of a continuously deteriorating cycle. Just as with natural habitats filled with multiple components, each performing predictable roles, small changes in product design and user behavior can cause significant chain reactions that work together to achieve a sustained, perpetual and harmonious macro-system.

References

Axsen, J., Tyree-Hageman, J., and Lentz, A. (2012) 'Lifestyle practices and pro-environmental technology', *Ecological Economics,* vol 82, pp64-74

Benton, D., Coats, E., and Hazell, J. (2015) A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, London

Black, I.R. and Cherrier, H. (2010) 'Anti-consumption as part of living a sustainable lifestyle: Daily practices, contextual motivations and subjective values', *Consumer Behavior,* vol 9, pp437-453

Chapman, J. (2009) 'Design for (emotional) durability', *Design Issues,* vol 25, No 4, pp29-35

Desmet, P., and Pohlmeyer, A.E. (2013) 'Positive design: An introduction to design for subjective wellbeing', *International Journal of Design,* vol 7, No 3, pp5-19

Elkington, J. (1999) Cannibals with forks: Triple bottom line of 21st century business, Capstone, Oxford

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Ellen MacArthur Foundation (2013) Towards the Circular Economy. Available from: <http://www.mvonederland.nl/system/files/media/towards-the-circular-economy.pdf>. [24 May 2015]

Emeco (n.d.) Broom stacking chair. Available from: <http://www.emeco.net/products/emeco-brm-natural-broom-chair-natural-philippe-starck>. [12 June 2015]

Environmental Protection Agency (2015) Aluminum Common Wastes and Materials. Available from: <http://www.epa.gov/osw/conserve/materials/alum.htm>. [12 June 2015]

Environmental Protection Agency (2011) Electronics Waste Management In the United States Through 2009. Available from: <http://www.epa.gov/epawaste/conserve/materials/ecycling/docs/fullbaselinereport2011.pdf>. [10 June 2015]

Garrett, B. (2014) '3D Printing: New Economic Paradigms and Strategic Shifts', *Global Policy,* vol 5, pp70–75

Gross, R.A. and Kalra, B. (2002) 'Biodegradable polymers for the environment', *Science Magazine,* vol 297, pp803-807

Hertwich, E. (2005) 'Consumption and the rebound effect: An industrial ecology perspective', *Industrial Ecology,* vol 9, No 1-2, pp85-98

Lobos, A. (2014) 'Timelessness in Sustainable Product Design', in Salamanca, J., et al. (Ed) *The Colors of Care : proceedings of the 9th International Conference on Design & Emotion*, Universidad de Los Andes, Bogotá, pp169-176

Lobos, A., and Babbitt, C. (2013) 'Integrating emotional attachment and sustainability in electronic product design', *Challenges,* vol 4, pp19-33

McCkracken, H. (2014) 'Project Ara: Inside Google's bold gambit to make smartphones modular', Time magazine, February 26. Available from: <http://time.com/10115/google-project-ara-modular-smartphone/>. [18 April 2015]

National Research Council (1991) *Improving engineering design: designing for competitive advantage*. Washington, DC: National Academy

Norman, W. and MacDonald C. (2004) 'Getting to the bottom of the triple bottom line', *Business Ethics Quarterly,* vol 14, No 2, pp243-262

Nuccitelli, D. (2015) 'Congress manufactures doubt and denial in climate change hearing', The Guardian, 21 May. Available from: <http://www.theguardian.com/environment/climate-consensus-97-per-cent/2015/may/21/congress-manufactures-doubt-and-denial-in-climate-change-hearing>. [30 June 2015]

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Orbach, Y. and Fruchter, G.E. (2011) 'Forecasting sales and product evolution: The case of the hybrid/electric car', *Technological Forecasting & Social Change,* vol78, pp1210–1226

Otto, R., Ruminy, A. and Mrotzek, H. (2006) Assessment of the Environmental Impact of Household Appliances. Appliance Magazine, April

Pearce, J.M. (2013) 'Life-cycle economic analysis of distributed manufacturing with open-source 3-D printers', *Mechatronics,* vol 23, No 6, pp713-726

Preston, F. (2012) 'A global redesign? Shaping the circular economy. Chatham House website. Available from: <http://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/bp0312_preston.pdf>. [3 May 2015]

Robert, K.H. (2000) 'Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development and to each other', *Cleaner Production,* vol 8, pp243-254

Robert, K.H., Schmidt-Bleek, B., Aloisi de Larderel, J., Basile, G., Jansen, J.L., Kuehr, R., et al. (2002) 'Strategic sustainable development - selection, design and synergies of applied tools', *Cleaner Production,* vol 10, No 3, pp197-214

Spangenberg, J.H., Fuad-Luke, A. and Blincoe, K. (2010) 'Design for sustainability (DfS): The interface of sustainable production and consumption, *Cleaner Production,* vol 18, pp1485-1493

Streeter, A.K. (2015) '3-D printing gets a way to instantly recycle plastic waste into new 3-D 'ink'. Treehugger magazine, March 26. Available from: <http://www.treehugger.com/sustainable-product-design/3-D-printing-plus-way-instantly-recycle-plastic-waste-3-d-ink.html>. [28 May 2015]

Tang, T. and Bhamra, T. (2008) 'Understanding consumer behavior to reduce environmental impacts through sustainable product design', in *Unidisciplined! Design Research Society Conference*, Sheffield Hallman University, pp183/1-15

Trangbaek, R.R. (2015) 'Lego group to invest 1 billion DKK boosting search for sustainable materials'. Lego, June 16. Available from: <http://www.lego.com/en-us/aboutus/news-room/2015/june/sustainable-materials-centre>. [24 June 2015]

Tromp, N., Hekkert, P., and Verbeek, P.P. (2011) 'Design for socially responsible behavior: A classification on influence based on intended user experience', *Design Issues,* vol 27, No 3, pp3-19

Waage, S.A. (2007) 'Re-considering product design: a practical "road-map" for integration of sustainability issues', *Cleaner Production,* vol 15, pp638-649

***NOTE**: This is a preprint of an article whose final and definitive form is published in the book: Routledge Handbook of Sustainable Product Design. Editor: Jonathan Chapman. Taylor & Francis, 2017. ISBN: 978-1138910171*

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., and Bonni, H. (2005) 'Global perspectives on e-waste', *Environmental Impact Assessment Review,* vol 25, pp436–458

Williams, E. (2004) 'Energy intensity of computer manufacturing: hybrid analysis combining process and economic input-output methods', *Environmental Science and Technology,* vol 38, No 22, pp6166-6174

Wittbrodt, B.T., Glover, A.G., Laureto, J., Anzalone, G.C., Oppliger, D., Irwin,

World Commission on Environment and Development (1987) Our Common Future, Oxford University Press, UK

Young, W., Hwang, K., McDonald, S. and Oates, C.J. (2010) 'Sustainable consumption: green consumer behaviour when purchasing products', *Sustainable Development,* vol 18, No 1, pp20-31

NOTE: *This is a preprint of an article whose final and definitive form is published in the book: Routledge Handbook of Sustainable Product Design. Editor: Jonathan Chapman. Taylor & Francis, 2017. ISBN: 978-1138910171*