Sustainability in (Inter)Action provides a forum for innovative thought, design, and research in the area of interaction design and environmental sustainability. The column explores how HCI can contribute to the complex and interdisciplinary efforts to address sustainability challenges.

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Swimming Upstream in Sustainable Design

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Ballpark figures can often be quite helpful. They set the scope of a conversation so we can see its context and get a general feel for what its implications might be. For example, one could estimate that there are about 20 million designers, engineers, and architects in the world who design everything in the built environment. This is just a ballpark figure based on marketing data, but it can give us a sense of how many things need to be designed. Playing with this metaphor, consider all of the designed objects associated with an actual ballpark: the ball, bats, shoes, hats, clothes, seats, stairs, food and drinks, lights, cameras, the stadium, the cars parked outside the stadium, the electrical and mechanical structures, and the infrastructure supporting them. And this is just *one* building. Now consider how many buildings, filled with manufactured objects, exist in all of the cities on earth, and you get a sense for what has been created in the built environment.

It may seem surprising that only in the past decade or so have designers come to understand their role in this larger system [1] and in the downstream impact of their designs. But despite good intentions, there is a paradox embedded in the desire to design more sustainable products that has been challenging designers, engineers, and manufacturers alike: the need for environmental impact data early in the design process, *before* all the relevant decisions have been made.

Material choices confer direct extraction costs to the environment. In turn, the materials chosen will determine specific manufacturing processes that will have a variety of environmental implications. Recovery and recycling options will also vary greatly depending on the combination of the materials and the manufacturing processes used. Industrial designers are creative professionals trained in traditional sketching, 3-D modeling, traditional and computer-based rendering, visualization, and physical prototyping. In the past few years, specialized fields such as materials science, engineering, and manufacturing processes have begun to find their way into a designer's formal education. But despite these advances, there remains a gap between the knowledge and skills of most industrial designers and what's needed to develop sustainable products.

Could HCI help bridge this gap? One role the field could play is in supporting the decision-making process behind sustainable designs by integrating material science knowledge directly into design and engineering software. The evaluation of design alternatives, mapped against their simulation outcomes, could be an appropriate project to which HCI researchers and practitioners could contribute, integrating sustainability into the design process so it is an inherent part of a successful design instead of an afterthought that comes too late in the process to be effectively addressed.

Upstream HCI

The current sustainability movement began with growing consumer demand and is now being pushed upstream into production, manufacturing, and design. As citizen and consumer demand for sustainable products grows, so too does the political will to mandate restrictions. This puts pressure on manufacturers to address these environmental concerns. Consumers now understand that their behavior has a big impact but their actions can still be limited by unsustainable production practices.

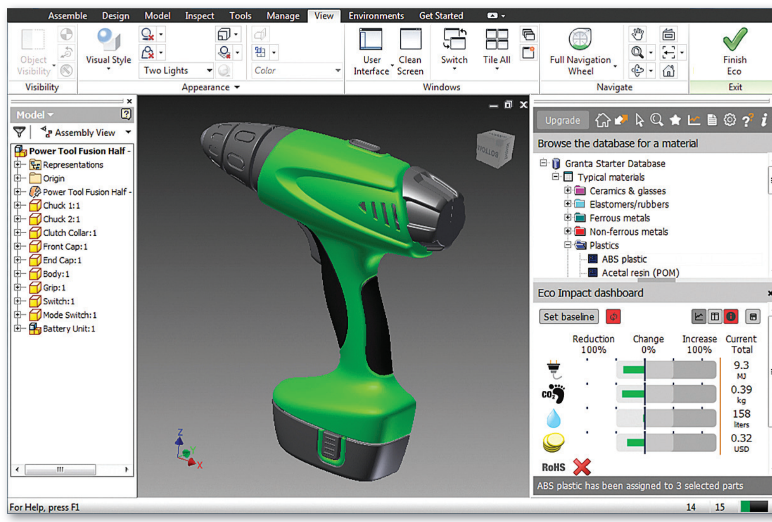
As noted by Huang [2], current downstream HCI sustainability efforts have focused primarily on consumer behavior to encourage reductions in material consumption, direct energy, and water use, and to improve consumer understanding of environmental impact. However, moving the focus of HCI efforts upstream to product design could have a multiplicative effect, as the production of goods and services is closer to the source of non-renewable consumption choices.

Environmental sustainability could be defined as the balance—or imbalance—between production and consumption. Unfortunately, a massive imbalance exists, due to the automation of manufacturing and the un-automated process of recycling and materials recovery. This lack of automation symmetry means it is very difficult for consumption to result in large quantities of recovered materials as input to the production process. Due to these difficulties, most consumption output is not reused or recycled and is essentially pollution or garbage.

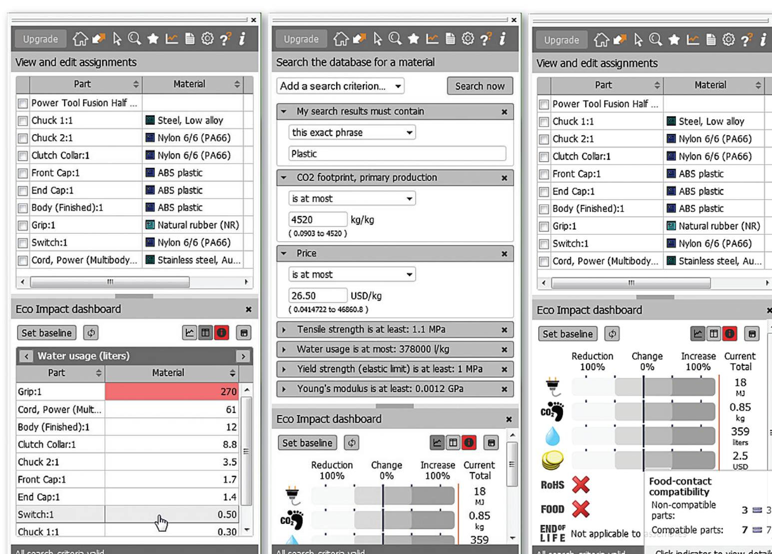
Before the industrial revolution, the large effort involved in the manual manufacturing and craftsmanship processes implicitly created a context in which goods had a high cost and, consequently, a high value. In this context of scarcity, the "consumption" of goods was just part of a larger process leading to repair or repurposing. The automation of manufacturing led to an abundance of goods, which introduced the notion of waste, in which consumption leads to the creation of garbage. The goal for sustainability could then be called a return to a mental model, or context, of scarcity in which the concept of waste is deprecated. Currently, the general feeling of abundance, together with the ongoing process of global automation, has led to both a waste problem and an emissions problem, formerly called pollution.

The task of understanding the scope and magnitude of the global pollution problem is immense. Toward this end, the Sustainable Consumption & Production Branch of the United Nations Environment Programme (UNEP) has attempted to collect data and determine key indicators for measuring environmental problems. Dimensions such as global warming potential, land-use competition, and human toxicity have been identified as key metrics in this area. These metrics can be combined into an environmentally weighted material-consumption value for understanding the primary factors that contribute to pollution. UNEP's research reports that the relative contribution to global environmental problems caused by material consumption is led by animal products (34.5%), followed by crops (18.6%), coal (14.8%), crude oil (9.4%), plastics (9.1%), iron and steel (4%), natural gas (3.7%), other metals (3.4%), biomass from forestry (1.7%), and minerals (0.8%) [3].

The use of animal products, primarily for food, is a purely behavioral problem, and so current *downstream HCI* efforts could greatly assist in encouraging consumers to reduce meat consumption. Indeed, if it could be eliminated entirely, a full



▸ Figure 1. Autodesk Inventor, with a sustainability panel (right) called Eco Materials Adviser, presents material properties from Granta Design to support the decision-making process.



▸ Figure 2. Eco Materials Adviser: (top left) Material assignments to various parts of the device being designed; (bottom left) Water usage in liters to manufacture the parts; (middle) Materials search interface to help the designer select materials that meet their sustainability, performance, and cost needs; (bottom right) Eco Impact Dashboard showing relative impact from baseline of material changes.

third of all environmental problems would be eliminated. Unfortunately, the remaining two-thirds of the pollution picture is more difficult to fix; *upstream HCI* efforts will need to be introduced to the design, engineering, and architecture communities to lower the unwanted side effects of the built environment on the natural environment.

The materials science community has undertaken the effort to break down the UNEP pollution metrics for specific materials. Granta Design [4], a U.K. research firm started by materials science professors at the University of Cambridge, has developed a highly respected data model and database of material properties that includes resource usage in manufacturing and recovery of the materials. When these databases are integrated directly into design and engineering software packages, it becomes much easier for designers to consider environmental impact early in the design process.

Case Study: Embedded Sustainability Support

As mentioned earlier, upstream HCI may be the bridge between designers and the level of sustainability in their designs. Critical design decisions *implicitly* made early in the design process should be *explicitly* presented and supported by HCI systems. Figure 1 shows the Eco Materials Adviser (EMA) tool of Autodesk Inventor [5], a design and engineering product, with the Granta Design materials database integrated, shown in the interface panel to the right. This work represents the beginning of an investigation into sustainability as an inherent design goal directly adjacent to the aesthetic and functional aspects of a design.

The EMA project was started in late 2010 to enable engineers to make more sustainable design decisions by exposing information on environmental impact, cost, and performance to inform better material selection. With 80 percent of a product's environmental footprint determined in the design phase, designers could greatly benefit from interacting with material data to better understand the material and production costs that their designs entail. The tool provides material attributes and key environmental and cost indicators, including CO_2 footprint, embedded energy and water, estimated raw cost of materials, Restriction on Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) compliance, toxicity, and end-of-life regulations.

Existing sustainable design tools are either geared toward sustainability experts or require information that is difficult for designers and engineers to obtain. Low awareness of key sustainability concepts and data sets of unknown quality create challenges for designers and engineers in a manufacturing organization. By leveraging Granta Design, a respected material database provider, designers will have confidence when presenting and justifying their material selections.

The intent of the EMA project is to make high-quality data accessible during the design process to help designers and engineers gain a sense of what their choices will require later in the production process. For users who have no previous exposure to any material data, the system provides links to more information about material properties and production processes, and it presents values in units of measure that are easy to understand by non-scientists. This combination of data sources provides designers with even more decision support for developing sustainable products.

Conclusion

As consumer demand and government regulations for more environmentally sustainable products continue to grow, design software must include support for material and manufacturing-process decision making. This emerging trend opens the door for upstream HCI, including interactive information visualization, recommender systems, and decision support, through which the interaction design community can help the industrial design community minimize unsustainable choices from the outset of the production-to-consumption *pipeline*. If successful, this pipeline will loop back on itself to become a sustainable production-consumption *cycle*. Successfully balancing consumption and production will produce a new ballpark figure for waste and environmental damage: zero.

ENDNOTES:

1. McDonough, W. and Braungart, M. *Cradle to Cradle: Remaking the Way We Make Things*. North Point Press, New York, 2002.

2. Huang, E. Building outwards from sustainable HCI. *interactions 18*, 3 (May + June, 2011), 14–17.

3. Hertwich, E., van der Voet, E., Suh, S., Tukker, A, Huijbregts M., Kazmierczyk, P., Lenzen, M., McNeely, J., and Moriguchi, Y. Assessing the environmental impacts of consumption and production: Priority products and materials. *A Report of the Working Group on the Environmental Impacts of Products and Materials to the International Panel for Sustainable Resource Management.* United Nations Environment Programme, 2010.

4. Granta Design; www.grantadesign.com.

5. Autodesk Inventor; www.autodesk.com/inventor.

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