Sustainable Design: From the Ground Up

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Vanderbilt University teaches all of its civil engineering students processes and practices which violate the American Society of Civil Engineers' (ASCE) code of ethics. Specifically, these practices violate Canon 1, which states: "Engineers...shall strive to comply with the principles of sustainable development in the performance of their professional duties" (ASCE 2006). Why does Vanderbilt University teach its students practices that violate ASCE's code of ethics? Unsustainable practices are taught to engineers in training because they are the methods which professional engineers use to design our world. Unless organizations such as the American Society of Civil Engineers actively push for the teaching of more sustainable design processes, not only will engineers continue practicing unethical methods, but, more urgently, the Earth's limited resources will be continually depleted.

How are today's students taught unethical design processes? Consider this example: at Vanderbilt University, every student majoring in civil engineering is required to take an introductory course in environmental engineering. A significant segment of this class is devoted to the sludge created by water treatment plants. The textbook, *Introduction to Environmental Engineering*, devotes scores of pages to a multitude of topics regarding sludge: students learn about the processes required to minimize sludge, dry it, make it smell better, thicken it, burn it, and even freeze it (Cornwell and Davis 2008, 1004). After all of these many conditioning processes, the story of sludge ends under the subheading "Ultimate Disposal" (Cornwell and Davis 2008, 521). Here, future civil engineers learn that, while some sludge can be used in a beneficial manner, the dangers from toxic pollutants severely limit sludge's applications. Having

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no other positive uses, most sludge ends up in landfills or in dedicated land disposal (DLD) areas "dedicated for all time to the disposal of wastewater sludge" (Cornwell and Davis 2008, 522).

The word "sustainable," in its simplest sense, means something relating to a method of "using a resource so that the resource is not depleted or permanently damaged" ("sustainable" 2009). Therefore, any practice which exhausts a finite resource is not sustainable and is a violation of the ASCE code of ethics. Since the relegation of sludge to permanent landfills and DLD areas depletes the Earth's supply of usable land, the creation and disposal of sludge is clearly not a sustainable process. Furthermore, the heavy metals which limit sludge's useful applications are, in more refined forms, valuable industrial inputs; by burying these materials deep underneath landfills, the sludge process wastes these potential resources and is thus doubly unsustainable.

How important is this lack of sustainability? Europe alone produced approximately 11 million metric tons of sludge in 2005 (Bailey and Barcelo 2004). Approximately 42% of this sludge went into landfills or DLD areas (Davis et al. 1997). Thus, in 2005 alone, an estimated 4.6 million metric tons of sludge found its way into landfills and DLD areas. Since populations continue to rise and farmers unions are pushing their members to forsake beneficial land applications, the amount of sludge sent to landfills and DLD areas will only increase (Bailey and Barcelo 2004). Considering that the population density of Europe is four times that of North America, the continent cannot long afford to continue wasting its precious land (Rosenberg 2005).

However, if it were not for the trace amounts of toxic compounds in the sludge, all sludge could be used for beneficial land applications instead of ending up in DLD areas (Cornwell and Davis 2008, 524). Without the toxic pollutants, then, sludge would be sustainable. How could these toxins be removed from the sludge process? Simply filtering them out of sludge does not remove the need for DLD areas; instead, the whole process must be changed so that the pollutants are never introduced into the system.

The toxins in sludge originate from chemicals washed down drains, wastewater from industrial processes, and pollutants picked up by runoff as it moves towards rivers and sewers. In order to prevent contaminants from working their way into sludge, then, a wide range of other changes must be made. For example, toxic components must be removed from the makeup of the cleaning compounds that end up getting washed down drains, manufacturing processes must be changed so that they do not give off polluted wastewater, and roads need to be made of materials that do not leach oil into river-bound runoff. Therefore, in order to create sludge that can be safely utilized in sustainable land applications, many other aspects of our world must undergo drastic change.

Even from this one example it is clear that, in order to create one truly sustainable process, thousands of other designs must be completely reengineered. There is no simple, end-of-design solution. Instead, true sustainability requires the alteration of the very design procedures that engineers use to create the millions of objects, processes, and materials that make up modern life.

The sort of new design required to create truly sustainable real-world solutions is outlined in *Cradle to Cradle* (Braungart and McDonough 2002). Authors Michael Braungart and William McDonough, a chemist and an architect respectively, explain how, by changing an engineer's goals, available materials, and criteria for analysis, the design process can be altered to consistently yield sustainable solutions.

First, the authors explain how engineers must completely overhaul the way they incorporate sustainability into their designs. Instead of designing something and then, at the end, trying to find ways to limit negative impacts, engineers should be cognizant of sustainability from the beginning so that their designs have no negative impacts that might need limiting (Braungart and McDonough 2002, 72). Consider the sludge example: the most sustainable process described in *Introduction to Environmental Engineering* seeks to reduce the amount of sludge in landfills by using some of the less toxic sludge as fertilizer. However, even the "best" current solution is greatly limited by sludge's toxicity. In comparison, a "cradle to cradle" design would focus on completely removing the toxins so that all sludge could be a beneficial fertilizer instead of most sludge being a wasteful detriment.

In order for this to happen, though, the toxins must first be removed from those cleaning products, industrial effluents, and parking lot runoff that invariably turns up in the water treatment plants. *Cradle to Cradle* provides a tool for engineers seeking to create a new generation of sustainable alternatives to these existing polluters. The authors present a system where the millions of human-manufactured compounds are all placed onto one of three lists: the "X-list" for hazardous materials, a "gray list" for materials that have mild health or environmental effects but have no better alternative, and a "P-list" containing the vast array of chemicals and materials which have no negative impact on health or the environment (Braungart and McDonough 2002, 174).

At first, engineers could improve the sustainability of current products and processes by seeking to replace ingredients on the X-list with alternatives from the P-list. Then, when designing new a cleaning product, for example, chemical engineers would focus on using only P-list (and the occasional gray list) materials in their designs. When this new product reaches the market and begins to replace older, X-list products, it also reduces the amount of toxins that end up in sludge. Repeat this process over the course of decades with thousands of other products and this cumulative reduction in toxins would prevent huge amounts of land from ending up as DLD areas.

The authors take their new approach to the materials one step further. Consider another problem with the current process of burying sludge in landfills: some of the very pollutants which limit sludge's useful applications are, in more refined forms, valuable industrial inputs. Copper, for example, is one of the main "pollutants" that the EPA uses to limit the amount of sludge that can be applied to a given plot of land (Cornwell and Davis 2008, 523); it would be an interesting thought-experiment to consider the price that all of the copper relegated to DLD areas would fetch on the commodities markets. What if, instead of being wasted, these potential resources were reused?

Recycling, *Cradle to Cradle* argues, is a poor solution to this tantalizing problem; recycled materials invariably have many more impurities than the original source materials (Braungart and McDonough 2002, 58). However, what if aluminum cans, for instance, were designed so that the aluminum could be easily reused? Instead of using paints that contaminate the recycling process, labels would be easily detachable or made of materials that would melt off of the still-solid aluminum. If such a process were perfected, the aluminum in cans could be reused endlessly.

Cradle to Cradle uses a cherry tree as a metaphor for this type of design. Instead of creating items that will only end up as useless waste, engineers should seek to design things that, like fallen fruit, can reenter the materials flow without loss (Braungart and McDonough 2002, 73). However, unlike a cherry tree, not everything in our world is biodegradable. As a result, two separate "metabolisms" must exist. The biological nutrient cycle consists of goods that are entirely made up of non-poisonous, biodegradable materials; these items can simply be returned to the soil after use. The other metabolism involves the technical nutrient cycle. These inorganic products are designed so that, after their service has been performed, the materials can be easily reclaimed in a high-quality form. If products can be easily separated into the "nutrients" of one metabolism or the other, there will be neither the loss of potential resources to landfills nor the need for DLD areas to store the poisonous byproducts of humans' lifestyles (Braungart and McDonough 2002, 104).

These endlessly repeatable "metabolic" cycles are the key to achieving the end goal of the "cradle to cradle" design process: totally eliminating the concept of waste. In order for this to happen, engineers, when trying to make their designs sustainable, must aim to create products and processes that have only positive benefits instead of just trying to limit the negative impacts of their creations. Only in this case will a design not deplete any of Earth's limited resources and thus be truly sustainable.

While this task of completely changing human society seems very daunting, the "cradle to cradle" solution is actually fairly easy to implement. *Cradle to Cradle* contains numerous examples of the authors' using truly sustainable design principles to solve their clients' real-world problems. In actuality, with this approach to sustainability, there is no need to change the whole world. Instead, by simply overhauling the goals of the design process, the "cradle to cradle" strategy utilizes the design skills of the world's millions of engineers to gradually create a better world.

In order to most effectively start this transition, engineering education requirements must be changed to emphasize this new design process. Organizations such as ASCE must use their influence in the engineering community to push for education standards that heavily emphasize teaching these new design criteria. If ABET were to include the teaching of this new type of design into its sustainability criteria, every engineering program in the country would quickly adapt. In addition, research time and money will need to be devoted to the development of the P-list and other important tools. By simply arming new engineers with a waste-is-optional mindset and the basic materials needed to create "eco-effective" designs, organizations such as ASCE can start an inexorable trend towards true sustainability.

Engineers in training are currently taught to utilize design processes that assume waste to be an unavoidable consequence of human activity. However, the results of these design processes slowly eat away at the Earth's resources. In order to live up to its own code of ethics by promoting truly sustainable designs, the American Society of Civil Engineers and other engineering organizations must promote the teaching of a new sort of design process that uses different sets of assumptions about waste and criteria for judging successful designs. Then, as engineers apply these new principles to design problems they encounter in their professional careers, they will transform our society into one that is actually able to sustainably manage the Earth's resources.

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