Sustainable Engineering: From Myth to Mechanism

Can "sustainable" products and technologies be more than an ideal?

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The concept of "sustainable engineering" is a powerful one. For some, it raises the possibility that good engineering and appropriately designed technology systems will play an important—perhaps a determining—role in achieving sustainability. For others, it implies an engineering that takes the environmental and social dimensions of products, processes, and technologies much more seriously.

For the earth systems engineer, it raises the possibility that we can understand, and rationally and ethically manage, the complex integrated human/natural/built systems that characterize what scientists increasingly refer to as the Anthropocene—roughly speaking, the Age of Humans (Allenby, 2005a).[1]

For many environmentalists and sustainability activists, however, the idea of "sustainable engineering" is an oxymoron, little more than an attempt to make an environmentally problematic activity—creating new products, infrastructures, and buildings—appear to be environmentally acceptable.

This attitude reflects the influence of earlier writers such as Renee Dubos (1968), Charles Reich (1970), and Theodore Roszak (1972), who were highly skeptical of technology. In the modern version of this school of thought, "sustainable engineering" is seen as a duplicitous attempt to undermine the concept of "sustainability" by making it an instrumental value—as if it could be designed into a product like electrical safety, or testability.

Indeed, for some the idea of sustainability itself is not enough. These critics view sustainability as a mechanism through which existing political and economic elites can protect their privilege by reducing the risk of social revolution and environmental collapse while safeguarding the status quo (Hardt & Negri, 2000).

These debates are interesting, but of marginal benefit to the working technologist or engineer. While often sympathetic to the goals of environmental and social activists, these professionals ultimately are tasked with designing, building, or maintaining particular structures or systems intended to perform certain functions and solve certain problems.

The challenge for technology and engineering professionals—and, indeed, the challenge to the environmental and sustainability discourses—is how in practice to enable creation of better engineering and better technology. This is a complex

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challenge, but we conclude that it is by no means an impossible one.

About This Article

We begin by discussing the salient features of the sustainability discourse, and those of engineering as a profession. We then suggest a path forward, with one important caveat and caution that must always be borne in mind by policymakers, activists, and technologists: We will do no one any favors by allowing the best to become the enemy of the good. Even where there is uncertainty and disagreement regarding specifics, there are usually better and worse designs, and we all benefit by striving for the former even if they are not everything we would desire in an ideal world.

In less than 20 years, the idea of sustainability evolved from being an explicit construction derived from a particular political philosophy, to adoption as an integral part of modern environmentalism, to emergence as a major policy discourse in itself.

What Is "Sustainability"?

This question is not unambiguous, for it points to two separate questions that are both important for our inquiry. First, what is the current operational definition of sustainability? Second, and more fundamental, what cultural role does the concept of "sustainability" play?

Only the first of these questions is usually discussed. However, addressing the latter as well may make understanding the specifics of "sustainability" (and how they may be applied in the context of technology and engineered systems) more tractable.

To begin with, sustainability is a classic example of a cultural construct—that is, a symbol, idea, or phrase by which societies create and transmit meaning (Allenby, 2006a). The sustainability concept was initially popularized in the book *Our Common Future* (World Commission on Environment and Development, 1987). It was in large part created to try to reduce conflict between two important discourses: the economic development discourse that sought to encourage economic growth, especially in developing countries, and the environmental discourse that sought to preserve as much biodiversity and unspoiled land as possible.

Progress of a Construct

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Especially at the beginning, sustainability (or "sustainable development"—the two tend to be interchangeable in use) embodied two major themes: egalitarianism within and among generations (including redistribution of wealth) and environmental preservation and protection (World Commission on Environment and Development, 1987).

The term has, however, become more widely applied as different discourses and institutions have adopted different definitions to suit their requirements. In the process, it has lost much of whatever substantive rigor it originally had (Allenby, 2005a).

But "sustainability" has not suffered from this ambiguity. If anything, it is expanding in common use, as the increasing popularity of "sustainable engineering" itself suggests. This development reflects a number of factors that relate to the second question raised above regarding the cultural role of sustainability.

Most important, "sustainability" is solidly grounded in traditional Western culture. It represents an interesting evolution of the Christian-Marxist utopian discourse, which has its roots in

Christian doctrine,[2] as is particularly evident in the emphasis on egalitarianism and wealth redistribution (More, 1516/1965).

Meeting the Need for Metaphor

These obvious cultural similarities have led some to identify sustainability as a modern mythology—not in the pejorative sense, but in the sense of a foundational narrative that helps individuals make sense of a complex and unpredictable world. As Walker (2007, pp. 1, 8) comments:

> There have always been, and will always be myths because it is through the metaphorical language of myth that a culture articulates its deepest concerns. Sustainable development can be seen as our modern myth, emerging from a culture of science, technology and reason. . . .
>
> On the one hand, [sustainable development] represents much more than simply an analytical approach to environmental auditing or improving business accountability. It also encompasses and represents a way of acknowledging our values and beliefs, and ascribing meaning to our activities. In this sense, sustainable development offers a contemporary way of, at least partially, filling the void left by the demise of religion in public discourse. On the other hand, it must also be acknowledged that sustainable development is both ideological and immature. As such, it has neither the breadth nor the profundity of the traditions that, to an extent, it supersedes.

Once sustainability is understood as an evolving myth that enables modern humans to deal with an increasingly complex world, the language and culture surrounding it become more intelligible. Comments such as McKibben's (1989, p. 180) that "the planet" is "suffering" make no sense to a scientist, for planets cannot suffer. But in a mythic structure, the suffering of nature, the individual, and society are frequently coupled.

In another example, consider the apocalyptic tone of Gordon and Suzuki in a book on energy savings, where they state, "The simple truth is that we are the last generation on Earth that can save the planet." In fact, this is neither simple truth nor even defensible in any factual context. But the idea that the end is near, and that only immediate, dramatic action can avoid it, is typical of mythic structures (quoted in Walker, 2007, p. 2).

In one important and relevant way, the mythos of sustainability differs from its roots. Unlike Christian theology (but like much of Marxism), the language of sustainability is based on the scientific and technological discourses, which are the recognized sources of secular truth in developed societies. In this way, "sustainability" arguments reflect contemporary understanding and values, and can be coupled to the authoritative language of science.

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Misunderstanding Mythology

The power of science is needed, of course, for sustainability to be an effective modern myth. But the construct of sustainability is an objective façade over a normative structure. Unless understood as such, it can significantly mislead those who attempt to apply what they conceive of as an objective set of criteria to technological or engineering situations.[3]

In fact, it is the misunderstanding of "sustainability" as an objective function, rather than as a guiding myth, that perhaps causes the major conceptual problems regarding sustainable engineering. To understand why, we must first briefly outline the relevant aspects of engineering and, more broadly, technology management.

Engineering and Technology Management

Engineers are basically problem solvers. Whether working for a private firm, a government agency, or as an independent consultant, an engineer's primary responsibility is to produce a solution that works in the real world, with all the constraints that entails. Such constraints may be competitive, ergonomic, regulatory, economic, and temporal (such as time to market), and are often complicated by implicit and explicit customer preferences.

The constraints are often different for different customer groups. In addition, most engineering activities involve other stakeholders as well, especially where workers (and thus occupational health and safety issues) may be important.

Good engineering is highly creative, but it is also constrained, and explicit in the problem and in the material artifact created to respond to the problem.

Because the public relies on many engineered products, processes, and structures, virtually all engineering occurs in highly regulated environments. Globalization, with its mix of differing cultures, technological infrastructures, and regulatory regimes, adds to the complexity.

To enable solutions in such complicated spaces, engineers are highly quantitative both by inclination and by methodological choice. Design solutions arise out of algorithmic treatment of design objectives and constraints.

The luxury of constructive ambiguity does not exist for engineers. At the end of the day, the product—be it bridge or toaster or chemical production facility—must be physically instantiated, it must work, and it must meet all the different requirements of a very complicated design space. Good engineering is highly creative, but it is also constrained, and explicit in the problem and in the material artifact created to respond to the problem.

Engineering and Ethics

It is also worth noting how engineering is changing as the society around it changes. It is not only the obvious interest in sustainable engineering that creates new challenges. It is also a change in how engineering is conceptualized.

Traditionally, engineers have been relatively instrumental, in that they were presented with problems arising from design, manufacture, construction, operation, and management of technological artifacts of all types and scales. Both professional ethics and legal systems held them responsible for failure to carry out their tasks professionally and competently.

Increasingly, however, engineers and technologists are being tasked with understanding the broader social, economic, and environmental impacts of their work, with an implication that they have some responsibility for those dimensions.

Thus, for example, an engineering firm building a road might find itself responding to questions about how the road could change future settlement patterns in nearby sensitive locations. Similarly, engineers and scientists working on biotechnology or nanomaterial projects may be quizzed on the ethics of the underlying technology systems. This is a subtle change, but it has potentially huge implications for the engineering profession, which has been slow to recognize it (Allenby, 2005b).

In this regard, it is useful to quickly review the structure of engineering ethics, which become implicated in any discussion of environmentally and socially responsible engineering (Allenby, 2006b).

To begin with, engineering disciplines have long had explicit professional codes of ethics. In general, these have been directed at the behavior of individual engineers (National Academy of Engineering, 2004). And, of course, all engineers carry with them a variety of explicit and implicit ethical networks, which in turn reflect the various communities of which they are a part.

Increasingly, the importance of institutional ethics is being recognized as well, since many major engineering failures derive not from a lapse in individual ethics, but from pressures and constraints created by the institutions within which the activity was performed or the decision taken.

Sustainability and Unpredictability

Although sustainability is recognized in the codes of ethics of various organizations, it is frequently involved at a level that transcends the scale of the organization. For example, earth systems engineering and management operate at a global scale, as do foundational and rapidly evolving technologies—particularly the complex of technology systems collectively referred to as "NBIC" (nanotechnology, biotechnology, information and communication technology, and applied cognitive sciences) (Allenby, 2005a; Garreau, 2005).

At this level, current ethical approaches arguably break down (Allenby, 2006b). It is one thing to require that engineers not be negligent in their professional actions, and that they duly consider all relevant dimensions of their activities. It is quite another to link engineering responsibility with the response of the unpredictable, and unknowable, systems within which they function.

Consider, for example, the Internet, a complex adaptive system that is clearly entirely human in origin, yet functions as a self-organizing system that continually redesigns itself. If a design team creates a new Internet router that routinely catches fire, most people would hold the design engineers ethically responsible. Indeed, it is quite likely that this moral judgment would be confirmed by legal liability.

On the other hand, suppose the router functions as designed, and in doing so contributes to the continued growth of the Internet, with all the environmental and social implications that entails. Such implications might include changes in cognitive function and networking among the young of Internet-literate society, or massive migration to virtual spaces, such as Second Life or World of Warcraft, with attendant social and psychological effects.

Most people would consider it inappropriate to charge the design team with responsibility for the effects of the Internet as a system, because these effects are far beyond the capability of any engineer or design team to foresee. There are simply too many unpredictable intervening decisions and stochastic events that contribute to the ultimate effect.

Although sustainability is recognized in the codes of ethics of various organizations, it is frequently involved at a level that transcends the scale of the organization.

Efforts to extend existing ethical structures to the emergent characteristics of such complex systems generally fail. This is unfortunate, as such an extension might provide a mechanism for instantiating the requirements of sustainability for engineering professionals.

A common suggestion, for example, is to simply project individual ethical responsibility to the scale of these systems. This fails pragmatically, however. Trying to make individual scientists or engineers responsible for the behavior of systems to which they may have contributed, but which in many cases are unpredictable, simply does not work.

Similarly, rote formulations such as the "Precautionary Principle" (which in its strong form holds that no technology should be introduced until it can be demonstrated to pose no risks) fail because they require a state of knowledge about future events that is unattainable.[4]

In practice, many such efforts appear to be attempts to freeze scientific and technological evolution. These efforts have generally failed in the past and are even less likely to succeed today when technology is global in scope.

For the purposes of implementing sustainability, the unfortunate conclusion is that ethical admonitions—a seemingly logical place to embed sustainability directives—encourage consideration of sustainability but provide little objective (much less quantitative) guidance.

Myth as Design Criteria

This, then, is the fundamental dilemma of sustainable engineering: Sustainability is a myth, a cultural construct, and not—in spite of its characteristic rhetoric—a scientific or technological construct. It is expressed in exhortatory and qualitative terms, which (usually implicitly) reference utopian ideals that are difficult to define and virtually impossible to reduce to structured rules.

While engineering methodologies have been designed to quantify consumer preferences and other somewhat "fuzzy" values, there are no viable methodologies that can quantify mythic constructions.

Engineering, on the other hand, is a supremely applied, pragmatic, problem-solving process. It operates through a culture, and methodologies, that are quantitative, using algorithmic procedures to derive designs and technologies that, on some objective basis, can be ranked and thus enable decisions.

To understand the dimensions of the dilemma, consider a situation where a design team is asked to produce a "sustainable cellular phone." The immediate question is likely to be: What is it we are trying to sustain?

If it is the planet, or life, or the human species (as sustainability rhetoric often suggests),[5] then the degree of design freedom actually available to the team and the sustainability values at issue are obviously mismatched. It is highly unlikely that any design modification to a cell phone will change the evolutionary path of the planet over geologic time. And even if it could, it is yet more unlikely that the design team (or anyone else, for that matter) would be able to foresee the long-term evolutionary change, or understand it clearly enough to effectively address it as part of the design process.

In short, while engineering methodologies have been designed to quantify consumer preferences and other somewhat "fuzzy" values, there are no viable methodologies that can quantify mythic constructions. Moreover, even at the conceptual level, it can be argued that social myth and engineering activity simply occupy different spaces, and cannot be coupled without doing damage to the very values that constitute the myth as a myth.

Deconstructing Sustainability

But this does not mean that we should give up efforts at sustainable engineering. To the contrary, we can make progress by knowingly and deliberately creating mechanisms that generate rigorous, workable guidance that fits with what we as a society demand from our engineers and technologists.

To accomplish this, we must first deconstruct "sustainability" as it applies to technology systems—for example, by rejecting formulations such as the Precautionary Principle[6] that ignore the complexity of the world. Similarly, we must reject the many versions of sustainability that seek to elevate the importance of stasis over evolution, and which tend toward an antitechnology bias, thus providing little guidance except a generic and unhelpful critique of technological development.

Sustainability is often considered in three domains—economic, environmental, and social (the “triple bottom line”). We believe the last domain is too broad, however, and would break it into two categories: the social and the cultural, leading to a “quadruple bottom line.”

The Interface with Industrial Ecology

Over the past two decades, mechanisms and supporting institutions have been developed that encourage progress toward sustainability in all of these domains. For example, sustainable engineering may be thought of as the operational arm of industrial ecology. An engineer would thus first use the methodologies of industrial ecology (such as life-cycle assessment, material flow accounting, or product and process matrix analysis) to determine relevant social and environmental considerations, and then use existing design and engineering methods to integrate that knowledge into process, product, and infrastructure development.

Industrial ecology is even defined appropriately in the leading engineering textbook in the field as “the means by which humanity can deliberately and rationally approach and maintain sustainability, given continued economic, cultural and technological evolution” (Graedel & Allenby, 2003, p. 18). Certainly, the early history of industrial ecology is essentially a history written in terms of sustainable engineering: The first industrial ecology PhD (to our knowledge) was awarded in 1992, and the dissertation title was “Design for Environment: Implementing Industrial Ecology” (Allenby, 1992).

The longest publication record in industrial ecology and sustainable engineering is that of the *Proceedings of the IEEE Annual Symposium on Electronics and the Environment,* which has been held since 1993. Moreover, technology-intensive firms, especially AT&T and its Bell Laboratories, were critical early supporters of industrial ecology; many of its early tools were developed and tested by engineers in such firms. Institutionally, it is also noteworthy that the U.S. National Academy of Engineering not only was an early champion of industrial ecology, but also continues to support initiatives on sustainable engineering to this day.

This neat formulation—implement industrial ecology and you achieve sustainable engineering—may be adequate conceptually, but unfortunately it oversimplifies the challenge to both industrial ecology and sustainable engineering in at least two major ways.

Difficulty Addressing Social and Cultural Concerns

First, industrial ecology and related fields almost always have arisen from exclusively environmental concerns. Thus, they may be relatively mature in enabling environmental issues to be identified, but they remain fairly primitive in addressing social and cultural issues.

Environmental issues are difficult to define and quantify, but they can generally be understood with some objectivity.

In part, this reflects an underlying truth: Environmental issues are difficult to define and quantify, but they can generally be understood with some objectivity. Social and cultural issues, on the other hand, are invariably normative and conflictual.

For example, an engineer can, with some confidence, understand the environmental impact of creating demand for a trace metal that in turn engenders additional mining activity. But whether that activity can be considered “good” or “bad” from a social or cultural perspective is much less easy to determine.

Or consider the cell phone example mentioned previously. Through heuristics, an engineer may arrive at solutions (e.g., reduction in toxic materials, better energy efficiency during use, establishing a used cell phone takeback system) that allow for design of an environmentally preferable cell phone, but there are no heuristics for the social and cultural implications of a society that broadly adopts cell phone technology.

Changing Engineering Education to Emphasize Sustainability

A second and equally complex problem is posed by the effort that is required to shift engineering education toward more sustainable engineering. One barrier is simply the sheer size of the educational system, especially now that engineering education is a global, multicultural enterprise. The United States alone produces roughly 70,000 engineering graduates per year. India produces perhaps 350,000 and China around 600,000 (although such numbers should be treated with caution given the different standards and quality of graduates).

The nascent creep toward the master's as the professional-level engineering degree should be embraced, and courses that emphasize the quadruple-bottom-line context must be developed.

There is also a substantial barrier to change because engineering is perhaps the last profession where an undergraduate degree is also considered to be the professional degree. This has created a situation where institutions that educate engineers continually struggle with an overcrowded curriculum that lacks room for additional material.

Some institutions have cut back requirements and increased flexibility in recent years (Davidson, 2004). In addition, there is now some movement toward considering the master's as the professional-level engineering degree. Nonetheless, the scale of change needed to create a different kind of engineer has yet to be acknowledged.

Moreover, the antitechnology bias of much sustainability literature has had the predictable effect of reducing interest in the concept among engineers and professors. While this can be addressed to some extent by creating appropriately rigorous methodologies, it makes the teaching and institutionalization of sustainable engineering more difficult.

Conclusion

In sum, the path toward sustainable engineering is evident, but not trivial. Conceptually, it is time to recognize the mythic nature of the sustainability discourse, because only by doing so can applied professions such as engineering translate cultural imperatives into designs, products, and infrastructure.

Continued expansion of industrial ecology to include cultural and social considerations, and practice in reducing complex states to quantitative inputs, offers an important opportunity. But development of new tools, while necessary, is not sufficient. The engineering education community will need to revisit its current structure with a view toward principled reform.

In particular, the nascent creep toward the master's as the professional-level engineering degree should be embraced, and courses that emphasize the quadruple-bottom-line context must be developed.

Beyond that—especially given the rapid rates of change of technology systems, and the social, economic, and environmental systems coupled to them—explicit lifetime learning structures for engineers, and for engineering professors, need to be developed and institutionalized.

But perhaps the most important point at this developmental stage is not to overestimate either our knowledge or our capabilities. We can do better, and in doing so we must not let the hypothetical best become the enemy of the good we can do now.

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NOTES

1. As the journal *Nature* (424:709) put it in an editorial in 2003, "Welcome to the Anthropocene."

2. Interestingly, sustainability, like environmentalism before it, can also be traced to the changes in Christianity introduced during the Enlightenment as part of efforts to integrate Christian doctrine with the evolving findings of science, and the corresponding shift from authority to observation as the basis for statements regarding reality. As part of that process, it became constantly harder for the sacred to be centered in society and built environments, which were becoming secularized. The Romantics, especially Rousseau, shifted the realm of the sacred to nature and especially to "wilderness"—the one place where rationality could not dethrone it. This theme resonates in modern environmentalism. As McKibben (1989), speaking for many, notes, "Wild nature, then has been a way to recognize God and to talk about who he is. How could it be otherwise? What else is, or was, beyond human reach? In what other sphere could a deity operate freely?"

3. In the context of this discussion, it is worth noting that some have attempted to simply short-circuit the "nature as sacred" debate by attempting to establish biology and science as the modern substitutes for religion, in language strikingly similar to Walker's observation of sustainability as myth. Thus, for example, Goodenough (1998, p. xvii) takes as her goal in her book *The Sacred Depths of Nature* the establishment of a biology-based religion, "religious naturalism": "If religious emotions can be elicited by natural reality—and I believe that they can—then the story of Nature has the potential to serve as the cosmos for the global ethos that we need to articulate." In many ways, the sustainability myth is evolving to attempt to do just that.

4. For example, the UN General Assembly Resolution on the World Charter for Nature (1982), in addressing "activities which are likely to pose a significant risk to nature," declares that "where potential adverse effects are not fully understood, the activities shall not proceed." An admirably straightforward statement of the Precautionary Principle, this declaration illustrates the dynamic underlying it: Since the adverse effects of any activities that are not simply trivial are never "fully understood," the directive, if applied as written, essentially would be: "Don't do anything."

5. The point regarding "what is to be sustained" serves to illustrate the mythical nature of sustainability. Certainly the planet will continue to evolve regardless of human activity, as will life, although in different ways than might have occurred otherwise. Even "human life" is highly unlikely to be destroyed, because humans are a generalist species, and such species do well in periods of change. As some Marxist commentators have noted, what is more likely to be affected is the current social, economic, and power structure, which makes sustainability a mechanism for validating and maintaining the status quo. We need not reach this point since we understand sustainability as a myth, rather than as a direction to "sustain something."

6. The underlying idea that it is appropriate only to change as much as is required to accomplish the specified design objectives and constraints (so as to minimize unanticipated consequences) is, however, highly desirable and, in fact, constitutes a basic principle of earth systems engineering and management (Allenby, 2005a). Moreover, to the extent that it is possible to understand the implications of large shifts in technology so as to reduce their undesirable impacts, this should certainly be done. Unfortunately, neither governments nor nongovernmental organizations adhere to this principle any more than firms do. Examples include calls for bans on commodity materials such as PVC without the faintest idea of what the replacements might be, or encouraging industrial-scale biofuel production without understanding the land use and hydrologic implications, much less the implications of dramatically enhanced agricultural activities on the nitrogen and phosphorous cycles, especially the impacts on aquatic and estuarine systems. From a sustainability perspective, it is worth noting that even initial moves in the United States to generate significantly greater amounts of corn-based ethanol have resulted in changes to the market for maize in Mexico, significantly and negatively impacting poorer populations for whom the price rise in a staple is a serious challenge ("Tortilla Blues," 2007).

References

Allenby, B. R. (1992). Design for environment: Implementing industrial ecology. Unpublished doctoral dissertation in environmental sciences at Rutgers University, New Brunswick, NJ.

Allenby, B. R. (2005a). Reconstructing earth: Technology and environment in the age of humans. Washington, DC: Island Press.

Allenby, B. (2005b). Micro and macro ethics for an anthropogenic earth. AAAS Professional Ethics Report XVIII(2), 1–3. Available online at http://www.aaas.org/spp/sfrl/per/per41.pdf

Allenby, B. (2006a). The real death of environmentalism. Environmental Quality Management, 16(1), 1–9.

Allenby, B. R. (2006b). Macroethical systems and sustainability science. Sustainability Science, 1(1), 7–13.

Davidson, C. I. (2004). Changes in engineering education: Past, present, future. In D. P. Resnick & D. S. Scott (Eds.), The innovative university (pp. 63–72). Pittsburgh, PA: Carnegie Mellon University Press.

Dubos, R. (1968). So human an animal. New York: Charles Scribner's Sons.

Garreau, J. (2005). Radical evolution: The promise and peril of enhancing our minds, our bodies—And what it means to be human. New York: Doubleday.

Goodenough, U. (1998). The sacred depths of nature. Oxford, UK: Oxford University Press.

Graedel, T. E., & Allenby, B. R. (2003). Industrial ecology (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Hardt, M., & Negri, A. (2000). Empire. Cambridge, MA: Harvard University Press.

McKibben, B. (1989). The end of nature. New York: Random House.

More, T. (1965). Utopia (P. Turner, Trans.). London: Penguin. (Original work published in 1516)

National Academy of Engineering. (2004). Emerging technologies and ethical issues in engineering. Washington, DC: National Academies Press.

Reich, C. A. (1970). The greening of America. New York: Random House.

Roszak, T. (1972). Where the wasteland ends. Garden City, NY: Doubleday & Co.

Tortilla blues. (2007, February 3). The Economist, p. 38.

Walker, S. (2007). Sustainability: The evolution of a contemporary myth. Proceedings of the 5th European Academy of Design conference, Barcelona, Spain.

World Commission on Environment and Development (Brundtland Commission). (1987). Our common future. Oxford, UK: Oxford University Press.

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