LIFE CYCLE ASSESSMENT OF ENERGY SYSTEMS

Closing the Ethical Loophole of Social Sustainability

NICHOLAS SAKELLARIOU

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Scrivener Publishing
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106
Publishers at Scrivener
Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

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To the Divine Mother

Om Bolo Shri Sat Guru Bhagavan ki Jai

To my Teachers

To Tilemachos Sakellariou, the one who never ceased to believe in me; to Rafaela Sakellariou, the one who continuously shows me the way of the Light; and to Rusty Wells, the one who opened my heart and stretched my imagination.

Contents

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Part I

ENGINEERING AND SUSTAINABILITY

1

Engineering Sustainability, Sustaining Engineering

Engineers are the unacknowledged philosophers of the postmodern world

Carl Mitcham, "The Importance of Philosophy to Engineering"[1]

Introduction

In light of "undeniable realities of acid rain, reduction in the ozone layer, and (now) CO_2 emissions," wrote the New Zealander engineer David Thom, chairman of the World Federation of Engineering Organizations (WFEO) Committee on Engineering and Environment from 1991 to 1999, "we see the dangerous failure… [of the position that]… the engineer is the servant of political processes." Thom, echoing many past and present

[1] Mitcham, Carl. "The Importance of Philosophy to Engineering." *Teorema: Revista internacional de filosofía* 17, no. 3 (1998): 27–47, 28.

engineering leaders, suggested that political arrangements could hardly be expected to settle the social impacts of technology. In this regard it was "incumbent on the engineer (in professional self-interest, if no for other reason) to become fluent in the analysis of [such] consequences" through adopting the tools and fundamental precepts of sustainability.[2]

Six years after Thom distinguished between engineering service and political servitude, he asserted that the profession had "a choice between two paths." Engineers, he elaborated, could either "trail behind the accelerating pace of events…until… [they] *are no longer relevant*," or they could "accept challenge, change, trauma and travail and march in the vein of the new Industrial Revolution."[3] This preoccupation with meeting the sustainability challenge so that engineers are not "left behind in the decision-making process that will influence the future shape of this world" not only prompted Thom's article, but also the 1993 American Association of Engineering Societies (AAES) statement on the "Role of the Engineer in Sustainable Development."[4]

This realization is how sustainability became an engineering ideology of assessing environmental impacts throughout a product or project's life cycle. At the same time, this ideology converged with the vision of engineering professional transformation conceived by practitioners as a response to a perceived societal demand for conservation. In the larger society of the late 1980s, there were growing concerns that technologies were causing massive environmental damage—this was an environmental crisis. At one level, because engineers work with technologies, their very work and worldviews were suddenly being endangered and questioned from the outside. At another, due to their professional practices and cultures, some engineers identified themselves as culturally and politically "invisible." A small minority of creative engineer-philosophers thus sought to rescue their profession's technology crisis through integrating "sustainability" into their principles and work.

In the late 1980s, engineers were confronted anew with the dominant image of a shrinking environment. Spokesmen for the profession suggested that engineering work was admired for creating an urban, technological civilization using the world's natural resources, while it was simultaneously blamed for exploiting such resources to the verge of extinction.

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[2] Thom, David. "The WFEO Code of Ethics." *New Zealand Engineering*, June 1, 1988.
[3] Thom, David. "Engineering to Sustain the Environment." In *The Role of Engineering in Sustainable Development*, edited by Monica D. Ellis, 62–79. Washington, DC: AAES, 1994, 78, emphasis added.
[4] AAES. "Statement of the American Association of Engineering Societies on the Role of the Engineer in Sustainable Development." Washington, DC: AAES, 1993.

By the 1990s, some engineers were writing about both ongoing evidence regarding environmental constraints and resource deficiency, and a need to apply root engineering values, expertise, and practices in a process of transformation. The prevailing image of growth-driven change gone awry, and development fraught with ecological disaster, substantially mobilized international and US engineering organizations and elite practitioners, who wanted to keep pace in the race to a technological future.

Responding to the economic-environmental challenge, the 1990s produced two distinct engineering ideologies of sustainability—one emphasizing engineering innovation, and the other emphasizing socio-cultural change. The first ideology, based on creativity, resembles an *ideology of technological change,* as characterized by engineering historian Matt Wisnioski in his analysis of American engineering in the 1960s. The technological change ideology of sustainability refers to *engineering reform* controlled and directed by engineers themselves—in other words, technological practices can be improved through the application of expertise. In this book I am building on Wisnioski's dialectical framework adding to it another dimension for the 21st century; I highlight how the dialectic between sustainability and engineering has been defined largely by the ideology of technological change.[5]

Wisnioski's compelling argument is that an intellectual crisis of technology within American society (between 1957 and 1973) presented a conceptual lens through which engineers could interpret technology as modernity. He shows that an ideology of technological change served as the counter-paradigm to an ideology of *technopolitics* while positing that technology was neither good, nor bad, nor was it neutral. Since the 1970s, Wisnioski contends, the solution that American engineers have favored for the dilemmas of technology and social progress has been that "[t]hrough rational management,… technology's unintended consequences could be minimized and its positive capacities maximized."[6]

The second and less influential ideology of engineering sustainability, with its emphasis on socio-cultural change, stems from a minority of practitioners and academics during the 1980s and 1990s who self-identified with the conceptual framework of social responsibility. Engineers associated with organizations like Engineers for Social Responsibility (ESR), the subaltern US group

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[5] Wisnioski, Matthew H. *Engineers for Change: Competing Visions of Technology in 1960's America*. Cambridge, MA: The MIT Press, 2012.

[6] Wisnioski, Matthew. "How Engineers Contextualize Themselves." In *Engineering in Context*, edited by Steen Hyldgaard Christensen, Bernard Delahousse, and Martin Meganck, 403-416. Aarhus: Academica, 2009.

of American Engineers for Social Responsibility (AESR) discussed in chapter 3, and later the International Network of Engineers and Scientists for Global Responsibility (INES) mindfully suggested a more culturally and politically sensitive vision for engineering sustainability. The technopolitics ideology of sustainability is about *engineering challenge*: it places more emphasis on the devolution of expertise from the existing model of engineering and society, and it questions the dominant values of engineering practice.

Ideology, then, is important for understanding the current problem with how sustainability is defined in engineering. It is defined predominantly in a narrow way, such that a particular type of scientific investigation is considered valid to answer questions of sustainability. And the way sustainability is framed bears resemblance to other cultural patterns in engineering—it gets stripped of power issues, of people, of alternative ways of thinking about the topic in general, including environmental justice, class issues and a free-market critique. A sustainability engineer who is not paying attention to power relations is likely to reproduce social injustice; we see that, for example, in terms of who becomes an engineer and in terms of the entire experience of technical education as one that delivers a certain conformity to a set of values and a set of applications in engineering. It is my hope that some engineers who do not or cannot identify with an alternative professional culture will start to feel as though they *have* a relationship with non-traditional philosophies into discussions about sustainability. Indeed one reason for examining the history and politics of sustainability engineering in ideological terms is that it extends an understanding of the current co-existence of corporate system approaches along with a reformist movement in considering a redefinition of the profession and its practitioners.

Three points need to be emphasized regarding the growth of sustainability identity in engineering. First, as I will show in detail in chapter 2, "sustainability engineering" did not come about naturally, but required substantial ideological and institutional transformation. Technological change as the dominant engineering ideology is largely confined to the narrow limits of technical problem solving. Advocating for apolitical expertise, most engineers conceptualize themselves as mathematical problem solvers and society as a set of discrete problems, to be solved through the application of scientific principles and mathematical theorems.[7] In

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[7] Seely, Bruce E. *Building the American Highway System: Engineers as Policy Makers*. Philadelphia: Temple University Press, 1987. Keniston, Kenneth. "The crisis of the engineering algorithm." Paper presented at the Institute of Advanced Studies in Humanities, Politecnico di Torino, Torino, Italy, 1996, manuscript.

other words, many engineers have an identity based on technical problem solving within narrow horizons.

The backbone of Life Cycle Assessment (LCA), for example, is a computational puzzle: a cradle to grave (i.e., life cycle) inventory analysis that construes an accounting balance of material, energy and chemical flows for the entirety of an industrial process or product system. The very term "system," as discussed in chapter 2, derives from a sustainability engineering-specific ontological assumption and worldview that is inherent in the design and execution of LCAs. Life cycle thinking is used by technical experts—primarily engineers—to draw path models of raw material extraction, to component or commodity transportation, manufacturing, use, to end-of-life for different production processes. Depending on the "scope" of a typical study undertaken, different researchers may draw *different* models that correspond to the *same* production process or system. LCAs identify environmental—and more recently social—"footprints," thus establishing industrial benchmarks against which engineering progress can be imagined and quantified. Corporations, governmental agencies and other technical expert constituencies supported LCAs as means to counteract environmental criticism and to substantiate "responsibility" and "transparency" to critics, stakeholders, consumers and the society at large. The scope (the choice of boundaries for an LCA) and the methodology (an engineering exercise of collecting and reporting about the "impacts" and "benefits" of industrial activity) are examples of why a conventional LCA might embody ideological assumptions and societal/political boundaries.

Here I show that technopolitics and technological change have co-evolved and have challenged each other; yet stories like that of the AESR told in chapter 3 reveal the power of the dominant engineering ideology. The co-evolution of engineering ideologies of sustainability has shaped not only technical methodologies like LCA, but also the way engineers experienced societal politics and conceptualized themselves as technical professionals.

Importantly, the efforts to foster sustainability identity in the engineering profession reflected a politics of alliance-making and connections with the corporate world. The 1980s—especially in the US and the UK—were dominated by a philosophy of voluntary industry action and neo-liberal economics that introduced the idea of public-private partnerships, the Trojan horse of "sustainable development" premising a synergy between communities in the Global South and private corporations overseen by the public sector. Contemporary developments like the emergence of Social Life Cycle Assessment (SLCA), detailed in chapter 4, attest to the importance of the larger political economy of the 1980s and 1990s as the economic (neo-liberalism) and institutional bases of the co-evolution of the technological change and technopolitics ideologies of sustainability.

Second, the contributors to the sustainability engineering discourse in the 1990s represented only a very small fraction of the engineering community in the US. Set forth by a minority of vocal proponents—a handful of enlightened environmental consulting managers, members of powerful professional elites and the US Corps of Engineers, some engineering educators, and a few radical professional voices including a subaltern engineering group like the AESR—the ideas of "sustainability engineers" and their relation to the larger profession were not common or widely shared by their rank-and-file colleagues. In some part, this is explained by the fact that the sustainability engineering luminaries possessed either one or a combination of qualities: degrees or expertise beyond engineering, background in professional organization leadership, political activism, and conduct of intellectual life beyond engineering interests or research. But while sustainability engineering in the 1990s was grounded in the historical conditions of voluntary industry action and neo-liberalism and in the support of professional elites, it simultaneously coincided with the efforts of more visionary engineers to provoke change in a very static and conservative profession. Thus in 1999 Edgar Woolard, former CEO and chairman of DuPont, spoke for many in the engineering profession when he wrote that "environmentalists" have been viewed as promoting "very radical change—based on what many in industry perceived to be philosophical or ideological grounds at best and pure emotionalism at worst."[8] The development of the sustainability identity in engineering, then, has been contentious. On the one side, during most of the 1990s, the engineering minority who expressed concerns regarding the environmental crisis received either skepticism or was rejected on the ground that it produced a deviant culture. On the other side, the 1990s also generated debates between those engineers who advocated for sustainability but differed in how they approached it. As these debates between sustainability enthusiasts—regardless of ideological orientation—unfolded, the identity of the sustainable engineer underwent integration between technological change and technopolitics.

Third, that the dialectic between sustainability has created various sites where engineers are struggling to reshape professional identity. These sites, I show in chapter 3, include the development of technical methodologies and tools, professional codes of practice, and educational reforms. These

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[8] Woolard, Edgar S. "Creating Corporate Environmental Change." *The Bridge* 29, no. 1 (1999): 8-11.

sites are important because they make the politics of sustainability visible: they reveal, for example, how some practitioners resisted the idea that engineers have a responsibility to lead as politicizing their work.

Entangled with the politics of sustainability is the question of what epistemologies are valued in engineering. When, for example, there is the presumption that engineering suggests an evaluation of technical expert knowledge, which is seen as objective over "lay knowledge," there is a political choice being made about what counts as legitimate sustainability expertise. The case studies presented in chapters 6 and 7 illustrate how a reductionist sustainability epistemology of greenhouse gas emissions held by renewable energy engineers has resulted in a tendency to downplay the environmental and social justice considerations of solar and wind project development in California's Western Antelope Valley.

The idea of sustainability officially entered the US engineering profession with the then Chief of Engineers' Hank Hatch's keynote speech at the American Society of Civil Engineers (ASCE) convention on October 8, 1989—by 2004-2005 the term had acquired a substantial stake in engineering cultures around the world.[9] The sustainable technology crisis (1989-2003), I found, was similar to previous technology crises within the US engineering profession in that it comprised a renegotiation of engineering's cultural and epistemological confines and a reconsideration of the scope of engineering servitude. The very idea of engineering being *ipso facto* a potent force to enhance human welfare was yet again in doubt, in light of the manifest negative effects of engineering projects on the environment.[10] In this book I argue that sustainability has become meaningful in an *engineering context* through a historical process of inserting considerations into engineering cultures and technical methodologies, particularly LCA, that have progressively challenged dominant views of what engineering practice should be. Thus I recount how the growth of "sustainability" concerns has driven an expanded engineering discourse.

Engineering contextualizations of sustainability together with calls for professional leadership emerged as a response to the emerging dominant

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[9] Hatch, Hank. "Keynote speech at the ASCE Convention on October 8, 1989," manuscript, courtesy of Hank Hatch.

[10] See respectively, Layton, Edwin T. Jr. *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession*. Cleveland, PA: Press of Case Western Reserve University, 1971, and Wisnioski, Matthew H. *Engineers for Change: Competing Visions of Technology in 1960s America*. Cambridge, MA: MIT Press, 2012. In all the aspects in which engineering leaders in the 1990s deviated from their predecessors they are closer to "the challenge of reorienting technology" (Thom, 1994, 78).

image of a collapsing planet from the late 1980s onwards. From the perspective of engineering elites and their organizations, and often from the viewpoint of anonymous professionals, there was a solution to the perceived environmental crisis of the late 1980s and early 1990s: they would demonstrate to themselves and to everyone else that—through sustainability engineers' diagnoses—nature's recovery was achievable. They saw the environmental crisis as an opportunity to create a unifying force around the concept of sustainability and to invest more engineering expertise into public policy.[11] Engineering contextualizations of sustainability were developed so that professionals could "attain the proper status they deserve."[12] In short, sustainability ensured a functioning of professional power; the narrative of sustainable technology deeply grounded in the 1980s political economy and cultural order became essential to the relevancy and social image of engineering.[13] Thus, as the case study of the US AESR group illustrates, engineering sustainability bore resemblance to interpretations of "social responsibility" and "humane technology" in the 1930s and 1960s, respectively.[14]

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[11] "[Engineering] constitutes a powerful force that is presently fragmented into various subdisciplines and areas of specialty." Hence, "[t]here is the need to unify the global engineering community, particularly around the issue of sustainability." Carter, Archie N. "Editorial." *Journal of Professional Issues in Engineering Education and Practice* 119, no. 3 (1993): 213. See also, Sanio, Michael. "The Role of Engineers in Sustainable Development." Paper presented at the 1997 AAAS CAIP Meeting, AAAS Headquarters, Washington, DC, 1997. The same year Thom argued that "[i]t is the wider concept of sustainable development itself that embraces all engineering activity" (Thom, David. "The Role of Engineers to Promote Cleaner Production." In WFEO, *The Engineer's response to sustainable development*, 36-45. Washington, DC: WFEO, 1997. Another 1996 report by the Civil Engineering Research Foundation (CERF) read: "The American Society of Civil Engineers (ASCE) recently reported that over the past two decades there has been a marked decline in the number of civil engineers who have held leadership positions in public policy development in the United States…Policy in this context is taken to include the establishment of infrastructures to support sustainable development." Civil Engineering Research Foundation (CERF). "Engineering and Construction for Sustainable Development in the 21st Century: Assessing Global Research Needs." Washington, DC: American Society of Civil Engineers, 1996.

[12] Wiggins, John H. "Challenge for Engineers." *Journal of Professional Issues in Engineering Education and Practice* 121, no. 3 (1995): 199.

[13] See, for example, Hank Hatch, Sustainable Development, excerpts from an address to the Presidents' Circle of the National Academies—quoted in ASCE, *Sustainable Engineering Practice: An Introduction*. Reston, VA: American Society of Civil Engineers, 2004, v.

[14] See footnote 10 above.

By monitoring the interplaying ideologies of technological change and technopolitics in the period between 1989 and 2003, this book continues a reflection on engineers as the "unacknowledged philosophers" of postmodernity. Engineers "build" postmodernity, we are customarily told by technology scholars; Wisnioski's thesis indicates that equally important is the creation of collective culture in a postmodern world and how engineers express themselves through their developing philosophies, intellectual histories, and social theories.[15] We generally assume that engineers rally around technical facts and methods to avoid political or philosophical gridlock. In reality, engineer-leaders have appropriated non-engineering discourse to renegotiate engineering knowledge and identity in addressing some of the most pressing existential dilemmas facing their discipline. To sustain engineering and reclaim normative control over technological matters, visionary engineers have transcended their traditional intellectual province and in the process "engineered" social and political theories of sustainability into terms that speak to engineers.

The Sustainable, Yet Invisible, Engineer

In the late 1980s and early 1990s, a period in which "sustainable development" became the defining conceptual framework in global environmental policy, articles were written independently of each other by an engineer-historian and an engineer-anthropologist. They featured the same alarming title: "The Invisible Engineer."[16] Henry Petroski, professor of civil engineering and history at Duke University, was deeply concerned about engineers remaining all but invisible *in both the cultural sphere and the social consciousness*. To combat engineering invisibility, fueled by professional specialization and "independent agendas" that have "robbed the profession of a single voice," Petroski contended that engineers "must seize every opportunity" to interact directly with the public. Others shared his concerns, such as Gary Downey, professor of science and technology studies at Virginia Tech: his view was that the isolation of engineers and engineering work *from most social studies of technology* has been due to the perceived division between the social and knowledge contents of engineering, as well

[15] Wisnioski (2012).
[16] Petroski, Henry. "The Invisible Engineer." *Civil Engineering—ASCE*, 60, no. 11 (1990): 46-49; Downey, Gary L., Arthur Donovan, and J. Timothy Elliott. "The Invisible Engineer: How Engineering Ceased to Be a Problem in Science and Technology Studies." *Knowledge and Society* 8, (1989): 189-216.

as an apparent division between structures (e.g., corporate, scientific) and professionals' everyday, contingent practices. Both authors invoked the invisibility metaphor to warn that there was a real danger of the "essential features" of engineering being missed by the public and by non-engineers.

Around that time, and twelve years after the publication of the environmental classic *Our Common Future*, the National Academy of Sciences (NAS) Board on Sustainable Development lamented that the relatively little input on sustainability by the engineering community contributed to their invisibility. In their 1999 report *Our Common Journey*, the NAS described an interdisciplinary overview of scientific scholarship and engineering practice at the intersections of environment and development; they lauded how "a broader systems perspective" has become the centerfold of "research programs on global change" in the US and abroad. The NAS therefore embarked on the seemingly urgent task of reinvigorating the engineering dimensions of sustainability amidst an internal debate on why development discourse had "increasingly" drifted "from its scientific and technological base". "In the last decade," they noted, sustainable development had been influenced more "by political than by scientific perspectives."[17]

Whether or not prior to 1999 "political" perspectives on sustainability were ignored or suppressed in favor of "scientific" perspectives, many engineers were championing explicitly social, cultural and political perspectives on sustainability, beginning around 2004-2005. To some extent, this was due to initiatives promoted by reputable engineering institutions such as the National Academy of Engineering (NAE) and the ASCE. The lamentation, then, that extra-engineering elements have influenced the sustainable development trajectory fails to acknowledge that many engineers, indeed, have not only engaged in sustainability work but have linked together the political and scientific perspectives of sustainability.

Far more a philosopher of sustainability engineering than an invisible engineer, the then vice president of international environmental engineering firm CH2M Hill Don V. Roberts was "getting tired" of reading about scientists' contributions toward the sustainable future. "As engineers," he cautioned, "we have poor visibility in the environmental community."[18]

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[17] World Commission on Environment and Development (WCED). *Our Common Future*. Oxford: Oxford University Press, 1987. National Research Council. *Our Common Journey: A Transition Toward Sustainability*. Washington, DC: National Academy Press, 1999, 275 and 283.

[18] Roberts, Don V. "Sustainable Development—A Challenge for the Engineering Profession." In *The Role of Engineering in Sustainable Development*, edited by Monica D. Ellis, 44-61. Washington, DC: AAES, 1994, 46.

Indeed, another American practitioner in the mid-1990s bemoaned in the *Journal of Professional Issues in Engineering Education and Practic*e that the Rio Conference consigned to oblivion everything engineering.[19] Their failure to engage with environmental politics made engineers claim they were deemed to remain poised on the outskirts of relevant expertise.[20] In response to such fears, Maurice Strong, the Canadian businessman and former United Nations (UN) environmental official, promised that adopting sustainable development ideas would "result in a profound change in the public perception of the engineer, as well as for the individual engineer's perception of his or her own professional role."[21]

In sum, Petroski's argument fits the circumstances of sustainability engineering in the 1990s. The politics of engineering identity formation in the period between 1989 and 2003 relied on, and helped to produce, the sustainable, yet invisible engineer. On one level, the critique from within the profession has conceded the perceived decline of engineers' status and their influence in setting policy. At another level, engineers' cultural and political marginalization may be a direct result of their resistance against what some engineering professionals disdainfully describe as the "political perspectives" of sustainability.

But how have issues of engineering identity and visions of sustainability interfaced? How did professionals condemning the social dimensions of sustainability as "unrealistic" still find socio-political philosophies to legitimize their views of sustainable development? And how have opposing assumptions about the role of technology and engineering professionals in society fed on each other to determine the main stakes in sustainability

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[19] Wiggins (1995): 199. Along similar lines, Hatch remarked to a 1998 World Bank audience that "[s]cientists have played a significant role in helping us to understand the fundamental impact of human interactions on the global environment and developing policy to support the decision-making debate. But it is engineers who use that science to plan, build, and operate the infrastructure that will directly contribute to-or detract from-the goals of sustainable development." Hatch, Henry. "Panelist Remarks." In *Partnerships for Global Ecosystem Management Science, Economics and Law. Proceedings and Reference Readings from the Fifth Annual World Bank Conference on Environmentally and Socially Sustainable Development*, edited by Ismail Serageldin and Joan Martin-Brown, 70-73. Washington, DC: The World Bank, 1998.

[20] Rubin, Debra K. "FIDIC delegates debate new ecological activism." *Engineering News Record* June 28 (1990): 15–16.

[21] Strong, Maurice. "The Engineer as Agent of Global Change." Speech delivered at the American Association of Engineering Societies and Engineering Foundation Conference, entitled "Sustainable Development: Creating Agents of Change," held at Snowbird, Utah, August 4, 1995.

engineering? To understand these questions one need to turn first to the ideologies of technological change and technopolitics.

What Prompts the Sustainability Engineer? The Ideologies of Technological Change and Technopolitics

Recasting Engineering Progress as the Golem-Like View of Sustainability

The first of a series of books published after 1989 by the NAE's Program on Technology and Sustainable Development (TSD) addressed "the paradox of technology."[22] The "paradox of our time," argued Massachusetts Institute of Technology (MIT) president Paul Gray, was best captured in the metaphoric tale of the Golem of Prague. Hailed as proof of engineering progress, environmental technology was really "[a]n artificial creature *created to serve* [;]…, [one which] exhibited *a mind of its own*, acting in mischievous ways *unanticipated* by its maker."[23]

This conception underlay all technological change articulations of sustainability. It represents technology as a product of engineering servitude to society that, alas, has acquired the properties of a self-governing force, the application of which has often had second-order consequences that were neither anticipated nor understood by its designers. The Golem-like view of sustainability engineering also regards effective engineering management as the force needed to maintain the global growth machine running without social costs. Sustainable development à la technological change thus became the principal engineering ideology for imagining both society and self.[24] Top engineering functionaries, engineering society leaders, and executives of environmental consulting companies propagated the notion that sustainability and the ideology of technological change were complementary. What is more, sustainability *meant* traversing the unintended consequences of technical change.[25]

Sustainability and technological change, combined, became the working model for making engineering progress in the 1990s. Accepting that

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[22] The same year Hatch talked about the "irony" that "further development is needed to handle both the problems of growing population and the problems of past development." Hatch, Hank. "Keynote speech at the ASCE Convention on October 8, 1989," manuscript.
[23] Jesse Ausubel H., and E. Hedy Sladovich, eds. *Technology and Environment*: National Academy of Engineering, 1989, 192.
[24] Ibid., 201.
[25] See for example, Frosch, Robert. A. "Sustainability Engineering (editorial)." *The Bridge* 29, no. 1 (1999): 2–3.

sustainable technology engenders a dialectic between unintended consequences and effective management of environmental impacts "free[s] us [engineers] from the futility of searching for magic bullets… It allows us to embrace progress and take steps to improve the quality of life of humans and the environment."[26]

The Rationalities of Engineering Ideologies of Sustainability

The more we understand the rationalities of technological change and technopolitics, respectively, the more we recognize the ideological underpinnings of sustainability in an engineering context. Despite their shared concerns with systemic interdependence, the technological change view of sustainability thrives on the assumption that it is both rational and objective, while the technopolitics view is based on challenging such claims to objectivity and questioning the value of sustainability's political ends. The technological change's twin claim to rationality and objectivity is directly linked to the engineering identity of the "doer" and her ability to depict and manipulate material balances—"engineers must focus on the what and the how tos," contended Hatch in a 1992 speech entitled "Relevant Engineering in the 21st Century."[27] And whatever their differences, for the most part, both ideologies of sustainability assume a certain level of engineer autonomy in the operation of sustainable technology.[28] The typology in Table 1.1 classifies the rational bases of the engineering community's ideologies of sustainability by listing them under two headings: a) Premises, and b) Core assumption.

Throughout the 1990s, sustainability engineering was consistently discussed on the assumption of allegedly definable technological foundations.[29] The technological change ideology of sustainability was the

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[26] National Research Council, 1999.
[27] Hatch, Henry J. "Relevant Engineering in the 21st Century." *Journal of Professional Issues in Engineering Education and Practice* 119, no. 3 (1993): 216–219.
[28] For example, a conference entitled "Preparing for a Sustainable Society," co-sponsored by the IEEE Society on Social Implications of Technology and IEEE Toronto Section, took place in Canada (Ryerson Polytechnical Institute, Toronto, Ontario, Canada, June 21–22, 1991). The conference's Call for Papers read: What is a sustainable society? How will the relationship between technology and society change if a strategy of sustainable development is adopted? Can society control and redirect the technological system it has created or is this system now controlling society? Burkhardt, Helmut, and H. Willem Vanderburg. "Preparing for a Sustainable Society." *IEEE Technology and Society* 10, no. 4 (1991): 6–8.
[29] For example, see Rajagopalan, Visvanathan. "The Engineer's role in sustainable development." *Civil Engineering* 62, no. 8 (1992): 6.

Table 1.1 Rational bases for engineering ideologies of sustainability

Engineering ideologies of sustainability	Premises	Core assumption
Technological Change	Engineering creates prosperity—yet engineers have unintentionally contributed to environmental problems; "Sustainable," means "environmentally sustainable"; Environmental problems can be eliminated by technological means without requiring a sacrifice of prosperity.	The reorientation of environmental technology is autonomous, thus the exploitation of natural resources should neither be decreased nor increased, but ought to be effectively managed.
Technopolitics	The design and social integration of engineered systems reflect normative, though not readily recognizable, assumptions and values; therefore, "development's" effects on the social order are equivalent to any other form of political action; Engineering and science play a supportive, not central, role in the quest for sustainability; The logic of competitive productivism must be reconsidered.	Provided that technology is autonomous, the urgent focus of sustainability engineering is reconceptualizing and redirecting democratic control of technical means and technical expertise.

dominant influence in the sustainable development debate at least during the fourteen years from 1989 to 2003—a period I define here as the sustainable technology crisis. This position, advocated by the most vocal and powerful engineering constituencies, maintained that engineering and technology had created prosperity and improved the quality of life but that engineers, as Don Roberts put it, "unintentionally contributed to global environmental problems."[30] In celebrating innovation while defending the dominant business and economic culture of the 1990s US sustainability engineering leaders like Roberts and Hatch referenced the profession's well-intentioned obliviousness, thus paving the way for the rise and legitimation of environmental metrics.[31]

At least until 1998, most spokesmen of professional societies, engineering leaders in general, or codes of ethics in engineering argued that sustainable development signified environmentally sustainable development.[32] "On a scale of one to ten, with one signifying 'strictly development with modest modifications' and ten signifying 'strictly environmental protection,' I am probably about a three," said Hank Hatch in a 1992 interview.[33] Engineering leaders, like Hatch or ASCE's executive director, James E. Davis, embraced the oxymoronic predicament of "sustainable growth"

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[30] Don Roberts quoted in Rubin (1990).

[31] Hatch, Henry J. "Sustainable Development." Manuscript from talk given at during a mini-symposium on sustainable development, Tufts University, March 8, 2000. Edgar Woolard, who spent most of his career working for General Motors and DuPont, recalled: "Environmental metrics were not much of an issue when I started as a young engineer at General Motors 36 years ago. The metrics we used were the number of cars we produced and how good their quality was…It is not that we were not responsible. I think we were…. Environmental performance was not a key factor in whether or not we met our business objectives." Woolard (1999).

[32] "That is, our goal is clearly development, but is heavily modified by the expression 'environmentally sustainable,'" ibid. See also Ausubel and Sladovich (1989); Leonard, Raymond S. "Information Systems for Engineering Sustainable Development." Paper presented at the Workshop on Engineering Partnership for Sustainable Development: A Workshop in Conjunction with Prep Con IV of the United Nations Conference on Environment and Development. March 1-3, 1992, New York, NY; IEEE. "White Paper on Sustainable Development and Industrial Ecology." Hoboken, NJ: IEEE Electronics and the Environment Committee, 1995; Council of Academies of Engineering and Technological Sciences (CAETS). *The Role of Technology in Environmentally Sustainable Development: A Declaration of the Council of Academies of Engineering and Technological Sciences*. Washington DC: CAETS, 1995.

[33] Atkisson, Alan. "Green Engineering and National Security: The US Army Corps of Engineers looks to the future and embraces the concept of sustainable development, an interview with Lt. General Henry J. Hatch." *In Context* 32 (1992): 40.

which was, in fact, part and parcel of the professional discourse of sustainability in the late 1990s.[34]

Hence when the late Roy Weston, pioneering environmental consulting engineer and founder of US environmental company Roy F. Weston Inc., first articulated an engineering vision of sustainable development as "the economic model of the future" in 1994 he also assumed that sustainability implied unbounded prosperity.[35] And engineering elites projected this view onto the developing world casting growth as an international management responsibility: "We simply must address the needs of the developing world, or sustainability will be impossible. The market is the best way to do this," remarked the industrial engineer and NAE member Chad Holliday, DuPont's then CEO, in 1999.[36]

On a broader scale, the technological change axis maintains that the reorientation of technology is autonomous.[37] Parallel to the assumption that technology is neither good, bad, nor neutral, runs the idea that exploitation of natural resources should neither be decreased nor increased, but ought to be effectively managed. Thus the technological change advocate's argument for sustainability is: although development "inevitably cause[s] some harm to the environment," halting or diminishing it is "clearly unrealistic."[38] Continued development is needed, argued the Council of Academies of Engineering and Technological Sciences (CAETS) in the mid-1990s, to mitigate the impacts of past engineering projects, and economic growth is inevitable to protect natural resources.[39]

The dominating feature of the ideology of technological change, this section has showed, is that sustainability engineering essentially combines

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[34] Charles, Michael. "Sustainable growth: administration pursues 'livability agenda.'" *Civil Engineering* 69, no. 3 (1999): 10. "Reducing wealth (or rather consumption) appeals to some as a way to encourage sustainability," wrote Deanna Richards, then director of NAE's program on Technology and Sustainable Development, "but it is an unlikely outcome." "It may even prove to be foolhardy." Richards, Deanna J. "Harnessing Ingenuity for Sustainable Outcomes." *The Bridge* 29, no. 1 (1999): 16–22.

[35] Weston, Roy F. "Sustainable Development: The Economic Model of the Future." Paper presented at the New Mexico Conference on the Environment, Albuquerque, NM, United States, April 25, 1994.

[36] Reisch, Mark S. "Striving for Sustainability: Chemical industry leaders wrestle with sustainable development, Responsible Care." *Chemical and Engineering News* 79, no. 36 (2001): 17–22.

[37] See, for example, Thom, David. "Engineering Education and the New Industrial Revolution." *International Journal of Engineering Education* 14, no. 2 (1998): 89-94.

[38] Coates, Geoffrey H. "Facilitating Sustainable Development: Role of Engineer." *Journal of Professional Issues in Engineering Education and Practice* 119, no. 3 (1993): 225–229.

[39] CAETS (1995).

business as usual and environmental stewardship.[40] A different picture emerges, however, when a closer investigation is made of the qualities of engineering expertise and the end results of innovation. In the rest of this section I demonstrate how the sustainability ideology of technological change emphasized certain qualities to the exclusion of others and how advocates of technopolitics warned that the unchallenged adoption of economic growth has led the engineer to serve a contestable set of social and political values.

Nowhere is the interlocking relationship between sociopolitical change and sustainable technology manifested more than in the writings of technopolitics proponents. The ideology of technopolitics assumes that sustainability decision making is a normative model for making engineering choices regarding social and political futures. In addition, technopolitics theorists argue that the emphasis on efficiency—spelling out essentially political priorities on the basis of metrics of input and output—masks profound questions about the compatibility of human life, institutional structures, and nature. This orientation is evident in the work of UK-born chemical engineer John Peet, who has been active with ESR for almost three decades. In 2002, Peet thought that "most applications of science and technology are not governed by a philosophy of science, but by political economic philosophies." Consequently, he argued, "sustainability is at base the reflection of a social and moral problem that can only be solved by addressing the dominant values of society, especially materialism and growth."[41]

Robert Hudspith, a professor of mechanical engineering at MacMaster University, has furnished a clear expression of the precepts of a technopolitics ideology of sustainability:

> There are several barriers that hinder an understanding of the role of technology in sustainability. The first barrier concerns the concept of neutrality…For example, the automobile is considered to be inconsistent with sustainability only if it is used without adequate pollution controls or is used inefficiently…It is pointed out that *technologies have characteristics that reflect certain underlying assumptions about what is valuable in life*. However, the barrier to working this through is the inability to be specific about these characteristics; vague

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[40] This feature was described by an engineer as "[l]ike the Wall Street Journal meets Mother Earth News." Tracey, Dennis. "Sustainability and Environment: Art vs. Science." *EFS Newsletter*, December 2001.

[41] Peet, John. "Chemical Engineering & Sustainability: Is Green Processing Enough?" Paper presented at the APCChE (Asia-Pacific Conference on Chemical Engineering) Conference, Christchurch, NZ, September 30 - October 3, 2002, Proceedings paper #235.

> generalizations do not get translated into new design criteria. For example,…*little is done to show how this tendency gets built-in to the technology.* A third barrier concerns our *tendency to evaluate technologies as isolated entities* without acknowledging overall trends or how technologies are linked in systems. The effect of a technology often depends on the degree to which it has become systematized.[42]

These themes have been repeated by other technopolitics ideologues. The Canadian engineer academic Helmut Burkhardt, John Peet, and Sharon Beder—the prolific Australian engineer-writer, educator and ESR member—all subordinated technological and economic means to cultural and political ends. As Peet put it in 2000, "technology and economics can and must contribute to its [sustainability's] resolution, but are unlikely to assist in its identification."[43] For "neither Science nor Economics can tell us what should be. That is the key issue of sustainability," he declared two years later.[44] Technopolitics ideologues advanced the idea that sustainability begged a more radical reexamination of engineering cultural worldviews. In 1991, while directing a firm called the Altruistic Engineering Consultancy, the female engineer Chantal Toporow cautioned that sustainable development had become coercion: engineering apolitical mindsets had led to the growth and diffusion of a monolithic culture. [45] A year earlier she had been the lead author along fellow members of the Los Angeles Institute of Electrical and Electronic Engineers (IEEE) of a volume entitled "Delicate balance: technics, culture and consequences."[46]

In many instances, technopolitics advocates of sustainability engineering reconsidered the very logic of competitive productivism: i.e., the assumption that there is an inherent economic determinism embodied in sustainable technology. "[T]he extent to which economic democracy has

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[42] Hudspith, Robert. "A teaching tool that exposes the non-neutrality of technology as it relates to sustainable development." In *Preparing for a sustainable society*, edited by Helmut Burkhardt and H. Willem Vanderburg, 294-301. Piscataway: Institute of Electrical and Electronic Engineers, 1991.

[43] Peet, John. "Being Fully Human and Creating a Better Future: Sustainable Development from an Integrated Systems Perspective." Paper Presented at the Workshop on Sustainable Development, Sigtuna Foundation, Sweden, 8-9 June 2000.

[44] Peet (2002).

[45] Toporow, Chantal C.M. "Values-led Technologies." In *Preparing for a sustainable society*, edited by Helmut Burkhardt and H. Willem Vanderburg, 228-235. Piscataway: Institute of Electrical and Electronic Engineers, 1991.

[46] Toporow, Chantal, McCagie Rogers, Nik Warren, and Justin Biddle. "A Delicate Balance: Technics, Culture, and Consequences." California State University, Los Angeles, October 20-21, 1989. Torrance, California: Los Angeles Chapter IEEE SSIT-30, 1990.

been weakened," noted Helmut Burkhardt and Willem Vanderburg in *Technology and Society,* is directly related to corporate decision making guided by international competition. In other words, "development begins unquestioningly out of the fear that if one corporation does not develop the technology, their competitors will."[47] Through their writings, engineering sustainability advocates of an ideology of technopolitics presented a societal vision that made direct links between the dominance of the modern economic system and the proliferation of engineering identities based on growth driven by technical expertise: they recognized, for example, the role engineering education has played in mystifying sustainability by normalizing environmental and social decline as unintended consequences of industrialization and engineering progress.[48]

These ideas were intended to provide support for the fundamental assumption of a technopolitics view of sustainability engineering. The "real issue," declared Richard Devon of AESR, "is exploring options in the social relations of expertise, not just exploring the moral dilemmas of individuals."[49] In other words, technopolitics ideologues linked environmental protection to broader questions concerning the politics of technology and engineering identity formation, especially the need for a participatory, deliberative design of engineered systems. In their arguments, sufficiency-based definitions of sustainability mingled with discussion of engineering tools, methodologies and structures that would corroborate participatory modes of technological governance. Much technopolitics work has explored "expert and stakeholder inputs into technology choice decisions."[50] By conscious, self-reflective engineering effort, these proponents believed, professionals could accomplish the "both possible and desirable goal" of integrating quantitative and qualitative approaches in sustainability engineering decisions.[51] In accomplishing this task, Peet postulated that engineers are challenged by the fact that notions of sustainability expertise are continuously expanded beyond engineering professionalism.[52] His view was in stark

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[47] Burkhardt and Vanderburg (1991). See also Sharon Beder. "Engineers, Ethics and Sustainable Development." Paper presented at the 10th International Congress of Logic, Methodology and Philosophy of Science, Florence, Italy, 1995.
[48] Bazan-Arias, Cathy. "Readers respond: Ethics and sustainable development." *CENews* January 6, 2009.
[49] Devon, Richard. "Towards a Social Ethics of Engineering: The Norms of Engagement." *Journal of Engineering Education* 88, 1 (1999): 87-92.
[50] Herkert, Joseph R., Alex Farrell, and J. James Winebrake. "Technology Choice for Sustainable Development." *IEEE Technology and Society* 15, no. 2 (1996): 12–20.
[51] Ibid.
[52] Peet (2000): 8.

contrast to some technological change ideologues' perspective that "so much [development] needs to be done that some countries cannot afford the luxury of democracy and public debate."[53]

Conclusion

In this chapter I defined analytically the politics of sustainability engineering in terms of a dialectic relationship between two ideologies: technological change and technopolitics. I grounded the rational bases of the engineering ideologies of sustainability in a set of premises and core assumptions. I then anchored historically the development of a sustainability discourse in American engineering in the metaphor of the "invisible engineer" to introduce the identity politics on which that discourse depended. This chapter's analysis of rational bases of sustainability engineering situated the ideology of technological change—the dominant engineering ideology of sustainability—in the capacity of engineering professionals and their organizations to recast engineering progress in the 1990s. Sustainability as effective management of natural resources was thus located in the notion of technology's unintended consequences.

Chapter 1 argued that to the extent that technological change and technopolitics suggest the foundation of the identity of the "sustainable engineer," the various visions of sustainable technology become contingent on the dialectic between these two ideologies—thus setting limits on the engineer's capacity to challenge the boundaries (ideological, cultural, professional, and methodological) of her discipline. The next chapter goes deeper into the history and the evolving politics of sustainability engineering beginning not with the conflicting aspects of technological change and technopolitics, but with their common departures.

[53] Cottell, Michael N.T. "Facilitating Sustainable Development: Is Our Approach Correct?" *Journal of Professional Issues in Engineering Education and Practice* 119, no. 3 (1993): 220–224.

2

A Critical History of Sustainability Engineering

Common Departures

"The central theme of our age is interdependence," Maurice Strong declared in 1972 when he was appointed the first executive director of the United Nations Environment Program (UNEP) as well as secretary-general of the UN Conference on the Human Environment, which took place in Stockholm in June 1972.[1] The Stockholm conference expressed a particular worldview that had taken shape amongst UN officials. It asserted that "there can be no fundamental conflict between environment and development."[2] This stance evolved through a series of UN events, such

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[1] Strong Maurice, "Introduction." In Rowland, Wade. The Plot to Save the World. Toronto: Clarke, Irwin & Company Limited, 1972, x.

[2] Ibid., x. In 1969 secretary-general of the UN, U Thant, was advocating that a "global partnership" was needed to "improve the human environment, to defuse the population explosion, and to supply the required momentum to development efforts." Quoted in Meadows Donella H., L. Dennis Meadows, Jørgen, Randers, and W. William Behrens

as the UN General Assembly adopting the World Charter for Nature in 1982, where it recognized that "due account shall be taken of the long-term capacity of natural systems…; [that]… impact[s] on nature shall be controlled, and [that] the best technologies that minimize significant risks to nature or other adverse effects shall be used."[3] These events culminated in the 1987 report put out by the World Commission on Environment and Development (WCED). In this report, sustainable development was defined as "meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs."[4]

Three months before the UN's Economic and Social Council recommended that its General Assembly convene a conference on the problems of the human environment, an interdisciplinary group of thirty industrialists, economists and academics were summoned independently in the Academia dei Lincei in Rome. The "Club of Rome"—as the group's initiators decided to call themselves—was organized by the Italian economist Aurelio Peccei, at the time manager of Italconsult, an engineering consulting firm active in developing countries.[5] Dedicated to shedding light on "the global system in which we all live," the Club of Rome operated on the

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III. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe Books, 1972, 17.

[3] UN General Assembly, *Draft World Charter for Nature*, October 30, 1980, A/RES/35/7. <http://www.refworld.org/docid/3b00f1a938.html>
Accessed November 12, 2013.
Two years earlier, in 1980, the International Union for Conservation of Nature and Natural Resources (IUCN) published the World Conservation Strategy in collaboration with the UNEP and the (then) World Wildlife Fund (WWF). According to the Strategy, "Two features characterize our time. The first is the almost limitless capacity of human beings for building and creation, matched by equally great powers of destruction and annihilation…The second is the global interrelatedness of actions, with its corollary of global responsibility. This is turn gives rise to the need for global strategies both for development and for conservation of nature and natural resources." The Strategy also includes a definition of sustainable development that engineers and non-engineers have more recently referred to as the "triple bottom line": "For development to be sustainable it must take account of social and ecological factors, as well as economic ones…"
<https://portals.iucn.org/library/efiles/edocs/WCS-004.pdf>
Accessed November 14, 2013.

[4] WCED (1987): 8.

[5] The meeting's roots are traced in a 1965 speech Peccei gave promoting industrialization in Latin America, which caught the attention of Alexander Kind, at the time Director General for Scientific Affairs for the Organization for Economic Co-operation and Development (OECD). Peccei's talk was given during the first meeting of the Atlantic Community Development Group for Latin America (ADELA), an international pro-industrialization institute focusing on Latin America.

premise that "the major problems facing mankind are of such complexity and are so interrelated that traditional institutions and policies are no longer able to cope with."[6]

Two years after the first Rome gathering, an academic from MIT named Carroll Wilson, who was a founding member of the Club of Rome, suggested to Peccei that a colleague's methodology of "system dynamics" may be appropriate to address the "world problematique."[7] Peccei agreed, and Wilson's fellow professor Jay W. Forrester of the Alfred P. Sloan School of Management flew to Switzerland to attend a June 1970 meeting organized by the Club in Bern, where he first presented his ideas to the group. The prospect of applying his computer model-based method to the Club's "Project on the Predicament of Mankind" excited Forrester, who started working on the first equations of a world system model on his flight back to the US. Though he did publish that work as *World Dynamics* in 1971, Forrester himself did not undertake the investigation set forth by Peccei and his colleagues. This assignment was passed on to his closest disciple, Dennis L. Meadows. Under the auspices of a $250,000 fund from the Volkswagen Foundation, Meadows pushed the accelerator of sustainability engineering.[8] His "MIT Project team" conducted the research published just a few weeks before the Stockholm conference under the title *Limits to Growth* (1972), a book popularly recognized as launching the sustainable development movement.[9]

Meadows *et al.* explained that system dynamics begins with the "recognition that the structure of any system—the many circular, interlocking…relationships among its components—is often just as important

[6] Meadows *et al.* (1972): 9–10.

[7] Wilson was the first general manager of the Atomic Energy Commission.
Cook, Joan. "Carroll L. Wilson, Science and Energy Expert." *New York Times*, January 13, 1983.
<http://www.nytimes.com/1983/01/13/obituaries/carroll-l-wilson-science-and-energy-expert.html>
Accessed November 25, 2013.

[8] Simmons, Harvey. "Systems Dynamics and Technocracy." In *Models of Doom: A Critique of the Limits to Growth*, edited by H.S. D. Cole, Christopher Freeman, Marie Jahoda, and K.L.R. Pavitt, 192–208. New York: Universe Books, 1973.

[9] Parenti, Christian. "'The Limits to Growth': A Book that Launched a Movement." www.thenation.com, December 5, 2012.
<http://www.thenation.com/article/171610/limits-growth-book-launched-movement#>
Accessed December 6, 2014.