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Engineering Sustainable Futures

Deanna J. Richards
California Polytechnic State University - San Luis Obispo

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"Technology... is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other."
-C.P. Snow

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology."
-Carl Sagan

I love scenes in Merchant-Ivory films like *Howard's End* showing the English countryside and uncluttered streets of London during the last century. The clip-clop sounds of horse-drawn carriages carrying people and goods with no evidence of gridlock, smog or urban sprawl transport me to a slower, less harried time. But then I think, "horse manure." The excrement from horse-drawn carriages was a pervasive source of pollution and complaint. In London thousands of "crossing sweepers" cleaned streets before pedestrians would pass. In England, at their peak, horses are estimated to have produced 6 million tons of manure per year.[1]

Technological Evolution and Environmental Change

Although the automobile is rightly associated with negative environmental impacts today, the first automobiles improved urban environments and liberated agricultural land used to feed the horses. They produced lower emissions than a horse and were twice as efficient. This is significant because feed–the energy input of horses–cost the equivalent of the entire agricultural production of England around 1900, and in the

United States, farm and urban horses in 1910 required nearly half as much agricultural land as was needed to feed the entire US population.[2]

The automobile was, therefore, for a time, an environmentally friendly technology. Early cars reduced emissions per mile driven by a factor of three compared to horses, and modern cars with catalytic converters reduce them by a factor of 10. The problem is the same as that with horses: too many people using too many cars, emitting too much pollution. By 1920, 25 million automobiles had replaced practically all the urban and farm horses in the United States. In 2002, 40.6 million automobiles were produced worldwide.[3]

There was a time when street lights burned oil rendered from whale blubber. Whales were hunted then almost to extinction with the primitive techniques described in *Moby Dick*, not with the modern technologies that environmentalists today try to regulate with global treaties in order to "Save the Whales."

What saved the whales in those days? It was black gold–petroleum. Petroleum is a fossil fuel–one made of dead animals and plants rather than live ones. The discovery of petroleum in 1859 by Edwin Drake from an underground pool in Pennsylvania led to an alternative fuel for illumination and substituted for three million gallons of sperm oil to light American lamps.[4]

Today there appears to be a resurgence of effort to reduce dependency on fossil fuel and to make a transition to cleaner non-carbon based energy systems. Current energy systems evolved from less efficient and more carbon-intensive systems. We used wood, long before we used coal and oil and natural gas. Throughout the world, there has been a decrease in the emissions of carbon molecules that wood, coal, oil and gas contain per unit of energy consumed, as we have learned better how to make, operate, and use energy.[5]

While we have been decarbonizing the energy system, world populations have been growing. Economic growth and consumption, particularly in the industrialized countries have increased. Rising carbon dioxide emission from this absolute growth and fears of global climate change dominate public discussion. The fact that natural resource inputs have decreased per unit output over a long period in the past provides a basis to discuss how engineering can promote sustainability in the future.

The era of coal–associated with the railroads and steamships—transformed nineteenth century society. The era of oil–associated with automobiles, roads, and petrochemicals—transformed the twentieth century. The development of information technology and biotechnology—associated with medicine, agriculture and materials technology—is likely to transform society even more in this century. There is little doubt that we can find the technological solutions to the problems we currently face, as we have before. What we do with the solutions, how we implement them, and what the final outcome of implementing them will be is unknown.

Nature, Technology and Society

We are a part of nature. Our technology is in nature. Changes in human populations, resource consumption patterns, and scientific and technological innovation affect natural systems. Global cycles of nitrogen, carbon, phosphorus, sulfur and water, atmospheric and oceanic systems, and the biosphere at all levels are influenced by human activities.

To engineer is human. We are all engineers, directly as participants in the profession of engineering, or as members of society that dictate what technologies are produced.

While it is human to err, it is too simple to blame technology and engineering for environmental problems.

Technology consists of hardware, that is manufactured objects or devices, and software, that is know-how, knowledge and skills. It requires larger systems of production that include machines, factories, labor, energy, materials, and capital. Institutions, including governments, corporations and markets, as well as cultural values and attitudes, are critical in determining how systems for producing and using objects function. The players in larger technological systems determine which objects are rejected, which are successful, and if successful, how quickly they are incorporated into the economy and society. Some of the most difficult problems we face, like air-pollution, climate change, and loss of habitat, are the sum effects of millions of individual decisions, the consequences of large-scale cultural patterns.

Even if there were a technological solution, such as solar power, to provide future generations resources to meet their needs, it would have to be economically viable, and it would have to be accepted by large numbers of people. Information about it would have to be accessible, and an effective organizational structure would have to deploy it, while political, legal and regulatory opposition based on antiquated knowledge would have to be overcome.

Transitioning to Sustainability

Change is an outcome, a goal, or an end state. When an organization changes from a hierarchical structure to a non-hierarchical one, the new state is the change. Transition is the process of going from an old state to a new one. It requires letting go of the old state, getting into a neutral zone, gathering information. It requires creating the new state.

The transition to sustainability can be realized in both the short term and the long term.

In the short term, we can tweak current systems and realize many environmental and economic gains by improving the efficiencies of the present technological system.

If Americans unplugged their televisions when they turned them off, they'd save 8.45 billion kilowatt hours of electricity a year. That's twice the amount produced by Hoover Dam. If SUVs complied with the same fuel-economy standards as ordinary cars, the US would save one million barrels of oil a day, more than the Arctic National Wildlife Refuge could produce at peak volume. Recycling one aluminum can saves enough energy to light a 100-watt light bulb for 3.5 hours. The average homeowner with an automatic sprinkler system over-waters his lawn by 112,000 gallons a year. A family of four can save up to 20,000 gallons of water a year by using a low-flow showerhead.

In the longer term we will need to transition to new systems of producing energy, food, transportation and shelter. We will need to engineer these systems to the specifications of sustainability determined by ecological constraints and changing social needs.

Sustainability and Cal Poly's College of Engineering

The transition to sustainable systems offers Cal Poly opportunities and challenges that are now being addressed. Environmental Engineering includes one course on sustainable development and another that covers green chemistry, of interest to students of Industrial, Mechanical, Materials and Electrical Engineering. Materials Engineering has developed a plan to integrate sustainability throughout its 4-year curriculum. Electrical Engineering faculty have adopted a resolution regarding sustainability, engaged their industry advisory board in their sustainability efforts and developed seminars related to sustainability engineering. Engineering students have long been involved with building and racing solar cars and demonstrating how automobiles can be made more fuel-efficient.

The College of Engineering has established a Center for Sustainability in Engineering (CSinE) to facilitate the transition to sustainable systems through Education, Research and Outreach.

Education

Sustainability principles are being incorporated into existing engineering curricula to make them second nature to future generations of engineers. Students will undertake learn-by-doing sustainable development projects. A distinguished guest lecture series will host at least one campus-wide lecture per quarter. A major conference on sustainability in engineering education will be hosted every two years. Rewards will be provided to faculty and students for projects-based learning proposals and modules related to sustainability.

CSinE will encourage Cal Poly Engineering students to reflect broadly on the world their technical work will transform. Funding is being sought for academic minors and double majors and individual courses integrating engineering and the liberal arts available to all undergraduates. A Minor Program in Technology and Values will treat themes like Environmental Science and Ethics, Biotechnology and Society, Technology and Public Policy, and Technology and the Environment.

Research and Application

In 2003, the US Environmental Protection Agency stated that "sustainability in both the developed and developing world requires scientific and technical innovation to create designs that enable the Earth and its inhabitants to prosper" in announcing a competition to "demonstrate to the nation and the world the possibilities of innovative, inherently benign, integrated, interdisciplinary designs to simultaneously benefit people, prosperity, and the planet." They include as part of that competition these areas:

- agriculture (e.g., irrigation practices; storage and handling of food products)
- built environment (e.g., green buildings; transportation and mobility; smart growth)
- ecosystem (e.g., protection of ecosystem health; protection of biodiversity)
- materials and chemicals (e.g., materials conservation; renewable, bio-based feedstocks; inherently benign materials and chemicals through green engineering, green chemistry, biotechnology; recovery and reuse of materials through product, process, or system design)
- energy (e.g., energy production; energy distribution; energy conservation; inherently benign energy through green chemistry, green engineering, biotechnology)
- resources (e.g., delivery of and access to educational, medical, information)
- water (e.g., water quality, quantity, conservation, availability, and access)

Through CSinE, The College of Engineering will pursue such opportunities for applied project-based research related to sustainability that will build on Cal Poly's competitive advantage as a center for applied research while also providing students with a rich "learning-by-doing" experience.

Outreach

Csine will sponsor conferences, publications and a web page. It will also offer ways for faculty to provide sustainability-related solutions beyond the campus, locally and around the world, both through joint studies and exchanges with other institutions.

Why Sustainable "Futures"

I speak of "futures" because the transition to sustainability will vary by time and place, as have transitions in the past. Humans have always succeeded in creating the technologies and social systems to solve problems, even problems of their own devising. Engineering sustainability is not just building artifacts. It is generating ideas that will fire the imagination of students, the university community and the world outside. It is a quest both humbling and exhilirating that will challenge the ingenuity of engineers from now on.

Notes

1. Thomson (Economic History Review 29(1)60:-81).
2. Waggoner (Waggoner in How Much Land Can be Spared for Nature pp: 56-73 in Technological Trajectories and The Human Dimension, National Academy Press, Washington, DC, 1997).
3. (American Automobile Association Manufacturers Association 2003 Motor Vehicle Facts and Figures. AMMA, Detroit. MI).
4. (Ausubel, J.H., The Liberation of the Environment, pp: 1-13 in Technological Trajectories and the Human Environment, National Academy Press, Washington, DC, 1997).
5. Nakicenovic, (in Freeing Energy from Carbon, pp74-88 in Technological Trajectories and the Human Environment National Academy Press, Washington, DC, 1997).