PRODUCT DESIGN FOR A SUSTAINABLE FUTURE: A MATTER OF ETHICS?

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Summary

This paper reviews some of the fundamental political, economic, and ethical philosophical foundation stones of our society – John Locke, Adam Smith, and Jeremy Bentham. These philosophies, set in a virgin North American continent, abundant with untapped natural resources, combined with the emergence of engineering, science, and technology to produce our tremendously high material standard of living. Paradoxically, recent growth in engineering and scientific knowledge has also helped to make us aware of some negative consequences of our high technology material way of life. The late 20th century is quite different from that of our forefathers in the 17th, 18th, and 19th centuries. In the words of Thomas Wolfe "we can't go home again." Resource scarcity, environmental constraints, and new ethical ideas are combining to challenge our foundation values such that, in the author's view, we need to explore more diligently for means to reduce our consumption of virgin materials in ways that are less ecologically damaging. One such option is to conceive of products designed to enable a more sustainable future. Illustrations of product design for sustainability are given. The paper concludes with some questions on whether or not engineering education ought to concern itself more explicitly with these issues than it presently does.

Philosophical Roots and Some Questions

John Locke – Life, Liberty, and Property

The views of John Locke (1632 – 1704), an English political philosopher, are deeply embedded in our American political-economic ideology. It has been said that Jefferson derived much of the content of the Declaration of Independence from the writings of Locke (1).

Reacting to the tyranny of kings and autocratic rulers, Locke conceived of government as arising out of a social contract between the people of a society, in which a limited government derives its powers from the consent of the governed. In Locke's theory, men are by nature free, independent, and equal in the enjoyment of inalienable rights such as life, liberty, and property.

Locke gives much attention to property, and its protection as being one of the important functions of government. Writing on "property" in his *Second Treatise of Government* (and from a Biblical view of man's role in nature as one of God given dominion over all nature), ** he says,

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*The views expressed here are the author's at this point in time. In no way should they be construed as the views of the institutions with which he is associated. This paper is intended to provoke discussion – therefore, comment and feedback, whether negatively critical or creatively positive will be appreciated. Thanks to Ferol for her willingness to bear with.

**Locke was also heavily influenced by the emerging science of his time such as the work of Newton. He was a close friend of the chemist Boyle whom he assisted in experiments.

> "Though the earth and all inferior creatives be common to all men, yet every man has a property in his own person: this nobody has any right to but himself. The labor of his body and the work of his hands, we may say, are properly his. Whatsoever then he removes out of the state that nature has provided and left it in, he has mixed his labor with, and joined to it something that is his own, and thereby makes it his property. It being by him removed from the common state nature has placed it in, it has by this labor something annexed to it that excludes the common right of other men. For this labor being the unquestionable property of the laborer, no man but he can have a right to what that is once joined to, at least where there is enough and as good left in common for others" (1, page 17). (underlining by Overby)

Locke's statement " . . . at least where there is enough and as good left in common for others" is relevant to the content of this paper. We know today that there may not be enough and as good resources left in common for others, therefore one response that we might make, from an engineering perspective, is to more creatively address ourselves to the design of products that are less consumptive of resources – product design for a sustainable future.

Thomas Hobbes – His State of Nature

Should we be unsuccessful in addressing Locke's caveat we may be confronted with a holocaust driven by resource scarcity. Alternatively we might find ourselves forced into a society mold quite different from that of individualism and liberty outlined by Locke. A contemporary of Locke's, Thomas Hobbes (1588-1679), outlined such a society in his book *Leviathan* published in 1651 (2). Indeed, Locke's *Second Treatise of Government* (1690) can be seen as an attempt by Locke to present a happier societal model opposed to the totalitarian one presented by Hobbes, 39 years earlier.

Hobbes, also influenced by the emerging science and technology of his period, took a different view of the nature of man than did Locke. Hobbes argued that man is by nature a selfishly individualistic animal at constant war with all other men. Men are machines moved by two basic forces – the desire for power, and the fear of death at the hands of others. In this "state of nature," men in their self-seeking, live out lives which are nasty and brutish. Fear is what causes men to create a state through a different kind of social contract, whereby they surrender their natural rights and submit to an absolute authority. This dictator in return provides stability and guarantees a semblance of peace between greedy men.

Adam Smith – Laissez-Faire

If we consider John Locke as the political philosopher of our American system, then its economic philosopher, perhaps more than any other, was Adam Smith (1723-1790) – the famed laissez-faire Scottish economist whose book *The Wealth of Nations*, was published in 1776 (3).

Smith also wrote at the dawn of emerging science and technology – and as a reaction to old feudal institutions and vested interests who resisted adaptations and changes as is the case with human institutions when new reality threatens the old. Smith assumed individual self interest to be one of the prime psychological drives in man – and as a matter of faith, that a natural order existed in the universe, such that were all men free to pursue their own self interest in an unhindered fashion – the sum total of all these individual strivings would produce social good – the "invisible hand" idea. From these premises he concluded that this economic process was best when government interaction was kept to an absolute minimum – laissez-faire.

John Locke's and Adam Smith's 17^{th} and 18^{th} century milieu was one of small world populations, enterprises were small and not deeply interconnected. Both men were influenced by the emerging science and technology of their time. They undoubtedly had visions of an entire virgin American continent just lying there waiting to be tapped. In Locke's view, these dormant and bountiful resources of the new world could be mixed with labor and emerging science and technology to become property. To be sure, the American continent was thinly populated by savages who were not exercising proper dominion over nature as God had ordained. In any case there appeared to be plenty and as good left in common for others. Ecological consequences of technological applications could be ignored because scale and magnitude of implementation was small, and nature's resiliency was not seriously disturbed.

Jeremy Bentham – Utilitarianism

In harmony with the ideas of Locke and Smith, a new ethical theory was founded by another English philosopher, jurist, and political theorist, Jeremy Bentham (1748-1832). Bentham, in part arising out of the need to deal with legislative issues in the British Parliament, developed the normative ethical theory called "Utilitarianism" (4) (5). In utilitarianism Bentham saw the "greatest happiness of the greatest number" as the fundamental and self evidence principle of morality. He associated happiness with pleasure, and unhappiness with pain – and developed a moral arithmetic that has come to be called the "calculus of pleasure and pain."

Bentham assumed that in theory, one could assign numerical values to the amounts of pleasure and pain to be caused by different "acts" or "actions." These values could then be summed over all persons effected and the morally correct act would be the one that maximized the difference between pleasure and pain. For example, in choosing between two acts, if action (A) would produce a sum total of (+) 2000 units of pleasure and (-) 1400 units of pain, and action (B) gave (+) 1000 units of pleasure and (-) 200 units of pain – the morally right act would be action (B) because the net pleasure over pain in (B) is 800 units while it is only 600 units for action (A).

This utilitarian calculus of pleasure and pain sounds amazingly like what we attempt to do today in justifying legislation, or a particular governmental regulatory action. We convert all "pleasures" and "pains" to dollars and call it "Benefit/Cost" analysis. The calculus of pleasure and pain sounds like that which we teach our students in engineering economy and decision theory courses. Indeed the root foundation of benefit/cost and engineering economy lies in utilitarian ethical theory founded by Bentham 200 years ago. It is today the dominant ethical theory in Western society.

The quantification of morality with a "calculus of pleasure and pain" readily lends itself to a society in which economic values reign supreme. Thus we find as our roots a political theory of individual liberty (Locke), and laissez-faire economic theory (Adam Smith), and utilitarian ethical theory (Jeremy Bentham) compatibly merged as our value system.

Late 20th Century Differences

The contemporary scene is quite different from Locke's, Smith's, and Bentham's 17^{th}, 18^{th}, and 19^{th} centuries. It can be argued that the realities of our times are forcing a reevaluation of these fundamental values. Locke's, Smith's, and Bentham's views were reactions against entrenched institutions and vested interests of the old feudal society that was breaking up around them. Analogously it might be postulated, that a good bit of the ferment that exists in the world today over resource scarcity, environmental issues, food, and related problems such as inflation – is a part of the process of transition to new concepts and institutions more appropriately equipped to deal with this new reality. One author suggests that we are in process to a new "paradigm" (6).

We simply no longer live in Adam Smith's world where "free market forces" automatically work to our benefit. Benefit is a value concept that is being questioned today as never before. The scale of our institutions and technologies have grown to gigantic size with extensive interconnections and dependencies. Populations have exploded around the world, in large measure attributable to the fruitfulness of science and technology. These populations have ravenous appetites whetted by institutions that seek to convince us that salvation is to be had with the acquisition of the latest shiny new product. When consumption of these new products slacks off, we find it increasingly difficult to provide jobs for our people. All of this in a world where there are no more virgin continents exploding with untapped resources. Locke's caveat that there should always be enough and as good left in common for others – challenges some fundamental premises. The carrying capacity limits of the environment are being pushed by assaults of waste streams driven by our consumptions. Governmental actions to cope with health and environmental problems produced by our appetites, helps somewhat with the employment problem by creating government jobs to correct for "market deficiencies" and "external diseconomies." But, growth of government is bemoaned and said to be inflationary and inefficient. Some are suggesting that Adam Smith's "invisible hand" has turned into an "invisible foot" that threatens to destroy the common good (air, water and land) with pollution and other externalities (7).

Some contemporary economists and others, who are still not heard very loudly by their economics colleagues, are attempting to call our attention to the entropic nature of our economic processes (8) (9) (10). The economic process is entropic in that we extract high quality (low entropy) nonrenewable resources from nature and diffuse them in extraction, production, consumption, and disposal into irretrievable waste products (high entropy) in the air, water, and land. This process cannot go on forever. Unfortunately, as indicated above, the idea of growth in production and consumption is built into the entire fabric of our society including our philosophical premises. To suggest a slowing of the rate of consumption flies in the face of the glue that has held the system together in the past. So long as the "pie" has expanded, conflict within and between groups has been contained reasonably well.

John Rawls – Justice

Others, such as John Rawls with his *A Theory of Justice,* are questioning the justice dimension of our utilitarian ethical foundation (11). Gorovitz suggests that the basic objective of Rawls' *Theory of Justice* " . . . is to provide a coherent theoretical foundation for a conception of justice that can be offered in opposition to the utilitarian point of view that has been dominant since Jeremy Bentham" (12).

The publication of Rawls' book in 1971, has generated a storm of comment, criticism and support of his ideas by moral philosophers, and many others. For example, the question of justice in a Rawlsian sense is raised in connection with occupational health and safety issues by Ashford (13). Page, in his seeking for a "materials policy," attempts to reconcile traditional concepts of economic efficiency (utilitarian based) with intertemporal (long term) distributional issues of equity, fairness, and justice in a Rawlsian sense (14).

Moral philosophers have raised many questions as to the adequacy of utilitarianism as an ethical theory. Some are concerned at the clarity of the notion of "utility." Others wonder at the reality of quantifying all pleasures (happiness) and pains (unhappiness) in terms of one commensurable unit – money. Issues of justice and utilitarianism appear. Some ask whether it might not be possible in the summing of pleasures and pains, that the happiness of some groups gets more weight than that of other groups. In this sense it has been suggested that utilitarianism, could in theory be compatible with unjust institutions such as slavery.

The question of how well utilitarianism deals with the temporal issue of justice between generations, is of considerable contemporary concern – especially with respect to resource, environmental, and health issues – issues that have a considerable time dimension. In benefit/cost calculations we discount the future at some chosen discount rate. The higher the interest rate chosen, the less is the present worth of some future benefit (pleasure) or cost (pain). For example, a deposit of virgin ore (or an environmental or health cost) with a dollar value of $1 million, 30 years in the future, has a discounted present worth of $57,300 if we choose a discount rate of 10 percent. If we use an interest rate of 25 percent, its present value is only $1,200.

Some are asking whether it makes sense, in some cases, to place such a low present value on these future benefits and costs. They even suggest that for resource, environmental and health issues (and for future generations) we should find a way to use negative interest rates for our utilitarian decision making. In this way, the present value of future pleasure and pains would be magnified and not reduced as is presently the case. Thus, equity, justice, and fairness for future generations might be better served in a future of resource scarcity – so this argument goes.

Rawls conceives of justice as the prime virtue of social institutions. He speaks of "justice as fairness." Using a hypothetical construct "the veil of ignorance" as an "initial position," he conceives of two fundamental principles of justice. His two principles are –

> "First: each person is to have an equal right to the most extensive basic liberty compatible with a similar liberty for others. Second: social and economic inequalities are to be arranged so that they are both (a) reasonably expected to be to everyone's advantage, and (b) attached to positions and offices open to all" (11, page 60).

Having established in his first principle the importance of liberty, and that the distribution of liberty is to be equitable, Rawls focuses on the question of distribution of "other primary goods" in the second principle. Other primary goods are defined as wealth, position, income, opportunity, skill, health, and even self respect or self worth.

> " . . . the second (principle) holds that social and economic inequalities, for example wealth and authority, are just only if they result in compensating benefits for everyone, and in particular for the least advantaged members of society" (11, page 14).

Rawls deals with the problem of justice between generations and questions the morality of utilitarian approaches for discounting the future (11, page 284 ff).

Definition of Engineering

One way of relating some of the foregoing material to the contemporary practice of engineering is simply to look at a definition of engineering, and briefly explore one important word in that definition – the word "benefit."

Engineering has been defined as – the application of the fruits and knowledge of science to the benefit of humankind. Recently the word "benefit" has come to be one of the most interesting words in this definition. How do we determine whether a new or modified technology is truly beneficial to people? Is it proper to limit our concern with "benefit" so anthropocentrically to just humankind? As some have asked "Should not trees also have standing?" How do we distribute the benefits and costs of technology to various groups within our society and between societies? How should we? How do we and how should we assess the risks and benefits of new and emerging technologies? How have we in the past dealt with the concept of justice in spatial terms and justice between generations? Who makes the determination of costs and benefits, and is past practice adequate for the present and future? What costs and benefits get included in our calculus of pleasure and pain and which ones get left out? Why? We could go on with additional questions now asked about this word "benefit" in the definition of engineering – questions that were not asked in simpler times of less complex and more disconnected technologies of smaller scale and impact. Hopefully we have raised enough questions to illustrate the value and ethical issues complexly related to the contemporary practice of engineering in ways that were less bothersome in simpler times in the past.

Engineering and Science – The Two Edged Sword

We have reviewed some of the major 17^{th}, 18^{th}, and 19^{th} century philosophical roots of our value system – suggesting the we are in a period when these values are being challenged. Paradoxically, it is the very fruitfulness of science and technology in our domination of nature that is helping to bring about the challenge.

Without any doubt, engineering, science, and technology has been a major contributor to our high material standard of living – a standard that millions of others in less developed countries of the world seek to emulate. This high material standard has been possible because we have been able to tap our capital stocks of non-renewable resources (fossil fuels and other minerals and metals) at relatively low economic cost with seeming impunity. Gradually however we begin to perceive that living off our capital is fraught with potential disaster. Unfortunately the various institutional, social, behavioral, and economic inertias of our past make it quite difficult for us to transition quickly to new paths and patterns.

Paradoxically, this same engineering, science, and technology that has helped us to achieve high material living standards has also given us new insights and knowledge as to the connectedness of things in an ecological sense. When we unleash our technology on a gigantic scale, as we often do today, there are consequences, many of which may be quite undesirable. Knowledge of these consequences, limited and tenuous as some of them may presently be, is relatively new knowledge.

Temporal and Spatial Efficiency

This knowledge of consequences is new also in that it requires that we broaden our horizon to include temporal and spatial concerns – concerns that in former times of smaller less concentrated populations, smaller scale technologies, and smaller consumption appetites – we did not have to think about. Thus we are now confronted with the need to expand our ideas from narrow concern with economic efficiency to large domains of social and ecological efficiency which include a time and space dimension. Illustrative of the time dimension is our care for future generations as we expand our production of chemicals, many of unknown toxicity, and bury the residuals in "Love Canals."

The spatial aspect was recently demonstrated when the State of Ohio, in order to save Ohio coal miner's jobs, beat on the head of U.S. EPA to reduce the stringency with which it enforced sulphur-dioxide standards. Down wind states such as Pennsylvania, New York, and Massachusetts have began to look to the courts for reprieve and redress so as to save their lakes, property, and people from Ohio caused acid rains.

New Design Criteria?

Given this relatively new knowledge of the consequences of our technological implementations, can we ignore it and attempt to carry on "business as usual?" Or need we wrestle with new kinds of ethical questions in addition to pragmatic and creative adaptations of our approaches so that we might transition to what some have called a more sustainable future? (15) Do these broader awarenesses have implications for us as engineers in terms of design criteria for the products and technology that we create? Can we as engineers, if we do sense a need for "new design criteria," simply act on the basis of our awareness, or are we constrained by the paths and inertias of the institutions within which we labor, and from whom we receive the signals as to which design ctiteria are important and which are not?

Some Hopeful Signs

Hopefully, we see some evidence around us that a transition is in process. We find prestigious groups such as the National Academy of Sciences, Committee on Nuclear and Alternative Energy System (CONAES), and the Harvard Business School, now saying what many have said before – conservation efforts to reduce the growth of energy demand should be accorded the highest priority in national energy policy (16) (17). Lovins has been poking us to conceive of an alternative energy path (18). Schumacher had caused us to pause and reflect on our conventional economic thinking (19). As important, and perhaps more so, as Time magazine recently editorialized in "The Fall and Rise of U.S. Frugality" - the people of our society are beginning to respond with more frugal, less consumptive and wasteful life styles (20).

The major question is whether or not our inertias will enable us to transition to a path of sustainability quickly enough to avoid internecine regional conflicts within our own society, or more fearfully – international holocaust over resource scarcity.

Some Consumption and Waste Generation Figures

To illustrate the nature of consumption and waste generation patterns in the USA a few figures are given below. Following this data, we will look at one small part of a coping pattern for a future of resource scarcity and environmental constraint – namely, some ideas about product designs for a more sustainable future.

Consumption

Page cites figures indicating that the USA in 1972 used roughly 8.86×10^{12} pounds of basic raw materials (minerals, -- both fuel and non-fuel, metals and non-food fibers). This translates into 42,200 pounds per capita per year to sustain our lifestyle (14). Rampacek gives similar figures, and cites a U.S. Department of Interior 1978 materials policy study that projects non-fuel minerals consumption (presently 22,000 pounds/capita/year) to double by the year 2000 (21).

From another perspective, to illustrate the absurdity of everyone in the world achieving a consumption rate of 115 pound/person/day, the author once calculated the "half life" of the earth. Assuming that the present world population was to achieve 115 pound/person/day – at a growth rate of two percent it would take only 1,230 years to consume half the volume of the earth and turn it into high entropy wastes. At a five percent growth rate it would only take 500 years.

Import Dependence

As the USA has depleted its own high grade ores (or created technology that is dependent on minerals and metals with which we have never been abundantly blessed) we must apply more energy and effort to use lower grade remaining deposits and/or become increasingly dependent on foreign supplies.

Many of these foreign suppliers are third world nations who seek to emulate our life style. They note that their consumption of virgin materials is but a fraction of our 115 pounds/capita/day. Leiss raises an ethical issue when he asks whether it is equitable and just, that roughly one third of the people living in the developed world should consume 90 percent of the world's total resource production; while the two thirds living in the underdeveloped parts of the world get the benefit of the remaining 10 percent (22).

As these less developed countries (LDCs), who increasingly hold these resource cards, get smart from their perspective and form OPECS and potentially other materials cartels, our problems will probably get worse. Locke's caveat – "so long as there is sufficient and as good remaining in common for others" – haunts us.

To illustrate the nature of our present dependency, Table 1 below was abstracted from the U.S. Statistical Abstract (1977) edition, Table 1205.

Table 1
Percentages of 1975 USA Consumption
Which was Imported in 1975

Minerals	% Imported
Columbium	100%
Sheet Mica	100%
Stontium	100%
Maganese	99%
Cobalt	98%
Chromium	91%
Aluminum (Bauxite & Alumina)	85%
Platinum Group	80%
Tin	75%
Nickel	71%
Tungsten	54%
Iron	29%

Many of our suppliers of these minerals are third world countries or other unsure sources; Columbium (used for alloys) comes from Brazil, Thailand, and Nigeria; Chromium from South Africa, USSR, Turkey, and Rhodesia; Bauxite from Jamaica, Surinam, Australia, and the Dominican Republic. The above list when viewed in juxtaposition to the rhetoric of the "Group of 77" less developed countries (LDCs) in their demands for a new International Economic Order (NIEO) suggests some difficulties.

Improve Supply or Reduce Consumption

In looking at these problems, Rampacek takes a somewhat optimistic view that through substutition, mining the sea bed deposits of manganiferous nodules, etc., the USA will find ways to produce a fair share of our increased mineral needs from domestic resources (21). Obviously some of this will take place as materials costs rise. However, another approach to the problem that perhaps needs more attention is to seek for ways to reduce consumption levels without forcing us back to the caves, and to improve our recycling and recovery systems – both technical and institutional.

Waste Generation

To illustrate the waste end of our consumption pattern let us examine just two categories of waste – municipal solid waste (MSW) and hazardous and toxic waste (non-nuclear).

The National MSW generation rate is around 135 million tons per year (3.5 pounds per capita per day) and is forecast to grow as we find evermore innovative ways to package the items we consume. An examination of the contents of the garbage waste stream for 1975 indicated that MSW contained 12 percent of the total US consumption of ferrous metal; 22 percent of total aluminum consumption; 5 percent other non ferrous metals; 69 percent glass; and 67 percent paper (23). Traditional disposal and dispersion of MSW in thousands of landfills around the country represents a loss of availability of huge quantities of materials which we can no longer afford. Market forces have been deficient in correcting this problem – so government has had to fill the breech as best it can by legislating. Environmental problems from depositing this waste on the land are making traditional disposal methods less tolerable.

Hazardous and toxic wastes (non nuclear) from our industrial processes have recently been given considerable attention in the press as a result of Hooker Chemical's deposits in Love Canal 25 years ago. This case and more like it represent past failures of the “market” to account for “externalities.” This case also raises the issue of justice between generations, which cost/benefit analysis is ill equipped to handle.

To cope with these problems of market deficiencies and external dis-economies, the federal government passed a law (PL 94-580) – the 1976 Resource Conservation and Recovery Act (RCRA). This law, administered by U.S. EPA, deals with many dimensions of the solid waste problem in the USA. EPA, however, because the Congress has not appropriated sufficient funds to properly administer the law, has had to establish priorities. They are giving high priority to Subtitle C – “Hazardous Waste Management.”

Data is scarce and incomplete on the quantities of hazardous waste generated, however, as a spin off from RCRA, Battelle recently produced a report on this topic for Ohio EPA (24). They estimate that Ohio industry produces around 80 million tons of industrial waste/year. Of this they estimate (for planning purposes) that from 5 to 8 million tons/year should be considered hazardous. These figures translate into about 40 pounds per person per day of industrial waste, from 2.5 to 4 pounds per day per Ohio citizen of hazardous waste. Thus we see the magnitude of industrial waste far exceeds that of MSW. Hazardous waste about equals the quantity of MSW, at least in the industrial state of Ohio. Industrial waste disposal is less visible than municipal waste disposal, and until RCRA, had been left to the private sector to dispose of as it saw fit. A disturbing aspect of the hazardous waste problems is that no one really knows where all the past deposits reside. Thus we all may be asked to subsidize these past practices as new “Love Canals” crop up from time to time with cries of need for government help to indemnify injured victims.

Legislation Broadens Design Criteria

We have looked at a few dimensions of our consumption patterns of virgin materials, at some aspects of the waste end of things and at one piece of federal ligislation (RCRA) to try and help us cope. We can view this kind of legislative activity as another horrible example of excessive governmental involvement and over regulation of the private sector – or we can view it as an attempt (clumsy and fumbling as it may sometimes be) to change the signals that engineers and scientists receive in terms of important design criteria for products and technology they create.

RCRA (and several other pieces of energy, environmental, and health legislation) in a sense are asking engineers and scientists to broaden their perspective to include more of the temporal and spatial dimensions of efficiency when they conceive of and design things. This kind of legislation touches on the issue of justice between generations which we reviewed earlier in the work of John Rawls. Thus RCRA, for example, seeks to connect the original manufacturer with more of the life cycle of the product and the residuals from its production. As a consequence of this law, the engineer now receives signals from his employer that he or she should conceive of processes that (a) produce smaller quantities of hazardous wastes, (b) recycle and recover valuable materials from them; or (c) detoxify them before disposal. Indeed, as a recent communication from the ASME – Solid Waste Processing Division indicates, this appears to be happening, “ . . . DuPont feels the future of hazardous waste management lies in the elimination of waste generation, and this is the area which will receive the lion’s share of the hazardous waste efforts at DuPont” (25).

Relative to our rather extravagant consumption of virgin materials, we can place our effort on the supply end – trying to find new and more efficient ways to become self sufficient in extracting our materials needs from lower grade resources. We can, as has traditionally been the economist’s argument, use our technological genius to substitute scarce with less scarce materials. Alternatively we can seek to find improved ways, both technically and institutionally, to reduce our rate of consumption of virgin materials – without having to return to the caves. We need pursue both avenues. Unfortunately, as has been the case with energy, we give much lip service to the conservation route and dollars to the supply path.

In the contemporary world where we are confronted with John Locke’s caveat, perhaps if we in the advanced technological societies were to more vigorously apply our technical and social inventiveness toward the conservation route – we could demonstrate a model of sustainability – a new model that developing nations might be motivated to emulate rather than the old one we have shown them in the past.

Product Design for Sustainability

In the foregoing materials we have explored some of the philosophical and value foundations of our society. It has been suggested that because of issues of resource scarcity, environmental constraints, and changes in ethical and moral perceptions – our root values are in process of change – whether we like it or not.

Two Paths – Increase Supply

There are two paths we might follow in attempting to adapt to contemporary and likely future circumstances. (A) We can continue to believe that the future will be but a mirror of the past, and that use of virgin resources can grow to 200+ pounds/person/day by the year 2000. If we hold this view our focus will be on the "supply" end of things – how to arrange, through force if necessary to have a sufficient supply; how to improve and focus our science and technology so as to more efficiently extract needed materials from our own lower quality virgin deposits; how to find suitable substitutes for scarce materials, etc. Price increases will assist in this process.

Conservation

Alternative, (B) we can recognize that there are probably some limits, and ask ourselves as engineers and scientists how we might create products and technology so that they are less consumptive of virgin materials, and less destructive in an ecological sense. If we hold view (B) (a conservation view) our actions and focus will be quite different than if we hold view (A).

Since paths are usually never polar as outlined above, the direction we take will probably be some combination of A and B. Unfortunately, because of trajectories set in the past, view (A) still dominates even though much lip service is presently given to the conservation view.

Institutional Changes Needed Also

Even should view (B) grow in strength, we know that it is not sufficient that engineers and scientists apply their creative energies with new design criteria – products designed for a more sustainable future. Institutions and individual consumer patterns and attitudes must also change. Government is one piece of the "pie" (in addition to price increases) for bringing about institutional and attitudinal change. In our complex technological society, the basic framework within which economic and technological actions takes place is established by government with its tax policies, health and environmental regulation, energy and hosts of other policies. Governmental policies when appropriately focused and implemented can be helpful in encouraging the conservation view.

Product Design and Reduced Consumption

Taking the conservation view, there are many ways in which technology can be designed so as to be less resource consuming and less environmentally destructive. Several of these ideas are dealt with in earlier or other papers (26, 27, 28, 29, 30). To conserve space in this paper only a few broad outlines will be presented here. To list a few of these options, products can be designed so that – (a) less material is used initially – smaller size, more sophisticated design approaches, etc.; (b) they have greater durability, reduced wear, less corrosion, etc.; (c) they can be more easily repaired; (d) they are more easily adapted for alternative use after the primary design use has been fulfilled; (e) they can be more easily recycled as products (remanufactured – inner loop recycled); and (f) they can be more easily and efficiently recycled to basic reusable materials (outer loop recycling).

Product Recycling (Remanufacturing)

The author recently had the good fortune to be involved in a most interesting pioneering exploration of product recycling (remanufacturing) as a conservation option (30). A summary of some of the issues and findings are given in references (28) and (29). In brief, there appears to be some growth in remanufacturing within the USA. There are many issues in need of further exploration. Some of the areas in need of additional study relative to product recycling are: (a) life cycle energy dimensions; (b) material consumption implications; (c) waste and pollution reduction implications; (d) employment impacts; (e) quality and reliability characteristics; (f) life cycle cost from a consumer perspective; (g) standardization of components and parts; (h) product style updating; (i) leasing of products; (j) design criteria for remanufacturability; (k) international dimensions of product recycling; and (l) public policy considerations to encourage product recycling.

Public Policy for Product Recycling

Should further exploration of "product recycling" indicate desirability and feasibility for government to increase or change its involvement, there are several options – all of which need more analysis. These possibilities include: (a) deposit charges; (b) tax changes; (c) direct regulation; (d) labeling and warranty policy; (e) advertising and promotion; (f) education and information; (g) federal, state, and local government procurement; (h) governmental refurbishing of the durable products it uses; (i) capital availability; (j) labor force policy; and (k) others. For some discussion of the above, please see references (26) and (28.)

Disdelivery Systems

Earlier it was stated that engineering and scientific change was needed to help us move toward sustainability. Institutional change is also needed. Let us illustrate with one example. We have developed an amazingly effective distribution and delivery system for spreading and diffusing the products from our factories all across this nation – and the world. Unfortunately "market forces" have not worked to establish an equally effective "disdelivery" system – a collection system to channel the flow of old and discarded products back to appropriate centers for recycling to basic materials, or for recycling as products. Thus the governmental policy idea of "deposit charges" is of interest as a possibility for encouraging the development of an efficient "disdelivery" system. This idea is fundamental to all well designed beverage container deposit laws. It was implemental in Sweden in 1975 to channel the flow of old automobiles back to appropriate recycling centers.

A New Role for Engineering Education?

Since this paper was written for an engineering educator meeting, it seems appropriate to close it with some questions about engineering education for a sustainable future.

1. Should we in engineering education be doing more, or doing things differently in our education of fledgling engineers relative to theory and design for a sustainable future?
2. Should we be concerned with continuing education of practicing engineers relative to these ideas?
3. If the answer to questions (1) and (2) is yes, then what might we do in engineering education to strengthen the conservation ethic in engineers?
4. Is it appropriate to think of "design for sustainability" in terms of professional licensing?
5. If we think more could and should be done in educating engineers relative to these ideas, can we do it ourselves? Or, would some kind of governmental actions be helpful? If so, what kind?

The above are not idle questions. Indeed, it has recently come to the author's attention that the West German government is asking such questions relative to the education of engineers, architects, and skilled craftsman. The focus in German is on energy conservation. Should we not broaden the focus to include other virgin non-renewable materials in addition to energy substances?

Concluding Thought

Is the idea of product design for a more sustainable future a matter of ethics, or is it simply a response to pragmatic circumstance – or is it some of both?

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