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Sustainable Solutions for an Environmentally and Socially Just Society*

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1. Introduction

Increasing per capita resource consumption in developed nations on one hand and global poverty, hunger, and poor sanitation on the other hand require efforts directed at both environmental and social sustainability. A model is presented for addressing sustainability in society. In this model, society, environment, and technology are interlocking parameters that dictate the nature and types of efforts for sustainability. Society provides for all its citizens the very basic necessities: potable water, food, education, housing and sanitation. Environment (or ecosystem) includes the natural resources to be exploited economically in service to society, and determines the value of the resource. These factors must be considered simultaneously in developing appropriate and sustainable solutions for an environmentally and socially just society. The model is applicable for any country that seeks sustainability and justice for its citizens. Distinctions between technology and energy-intensive production in developed countries and labour-intensive production in developing countries are made, considering the United States, India, Ghana, and Nicaragua as examples.

It is obvious that the state of a society's economic system influences the production systems that are appropriate to that society, and the production systems and standard of living further impact the ecosystem. The ecosystem contains the resources that support our standard of living. While we depend on it, the ecosystem is autonomous and will continue even as it changes under the pressure of human activity. The ecosystem has been viewed as a commons that can be tapped for production; production often is motivated by the profits to be had, with degradation of the commons ignored to the degree possible. Increasing per capita consumption of resources, and the resulting pollution, waste and global warming have led to the widespread recognition that we must not deplete and/or pollute the ecosystem to the extent that the ability of future generations to meet their needs is compromised. Such a view accepts human-induced change to the ecosystem, but recognizes that environmental problems are now of such magnitude that they require concerted global efforts. This concern has been expressed and articulated in many ways and through many international conferences (World Council on Economic Development, 1987, Peter et al 1997, Earth Summit, Rio, 1992). Terms such as "sustainability," "renewability," and "sustainable development" are attracting worldwide attention. The key thrust which

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emerges from all these deliberations is the notion of “sustainable development,” which is closely tied to “economic development” and thus does not reflect a shift away from the present view that the commons is available to support further development. It is not clear that the standard of living that we have become accustomed to can be supported sustainably.

The calculus of sustainability has not truly entered into decision-making about production and engineering. Therefore, there is a need to change the curricula to explicitly teach engineers to consider sustainability in their design decision-making. Sustainability is a cross-cutting theme that should be present throughout an engineer’s education rather than being contained within a single dedicated course. Thus, it is useful to have examples that can carry the essential themes and background to support the emergence of a calculus of sustainability in engineering design. At San Clara University, sustainability concepts are taught using some of the examples that follow in some of the undergraduate courses: Engineering (for juniors), Civil Engineering Materials (for juniors), Green Construction Design (for seniors), and Sustainable Water Resources (a new elective course).

2. Sustainable development

The term “sustainable development” is being interpreted differently by developed nations on one hand and by developing countries on the other. For example, a measure against pollution in a developed country may make sense, but will be a luxury for a developing country. Developing nations may insist on more attention to economic growth than to environmental problems. In developed countries, a check on economic growth to protect ecosystem is often considered a check on freedom and free enterprise. How then to resolve the conflict between a desire to develop, and the need to maintain the integrity of ecosystem?

Figure 1 presents a simple schematic model for a country, which can help guide sustainability decision making. The big box represents a country. As the growth accelerates/cranks faster to further the development of a country, (i) the balance between ecosystem and economic prosperity becomes more delicate for developed nations; and (ii) the balance between economic prosperity and social development becomes more delicate for developing countries. For example if development is linked only to gross national product (i.e. GNP should rise every year), the society may be headed to the depletion of its ecological base, and therefore society may be becoming poorer (Warner, 2006). This means that developed countries must recognize limits to their growth and should look for alternate but sustainable resources or alternate ways of obtaining pollution-free energy.

Mario Belotti, an internationally known professor of economics at Santa Clara University, argues that “resource is a function of technology” (Belotti, 2006). Accordingly, developed nations should focus on advancing technology to find alternate ways to meet the requirements of society while preserving the balance of ecosystem. For example, resources in developed countries should be used to develop bio-based and fusion energy sources, while also improving the efficiency of current renewable energy sources such as wind, hydro, geothermal, and solar technologies. Improved energy technologies would benefit both developing and developed countries.

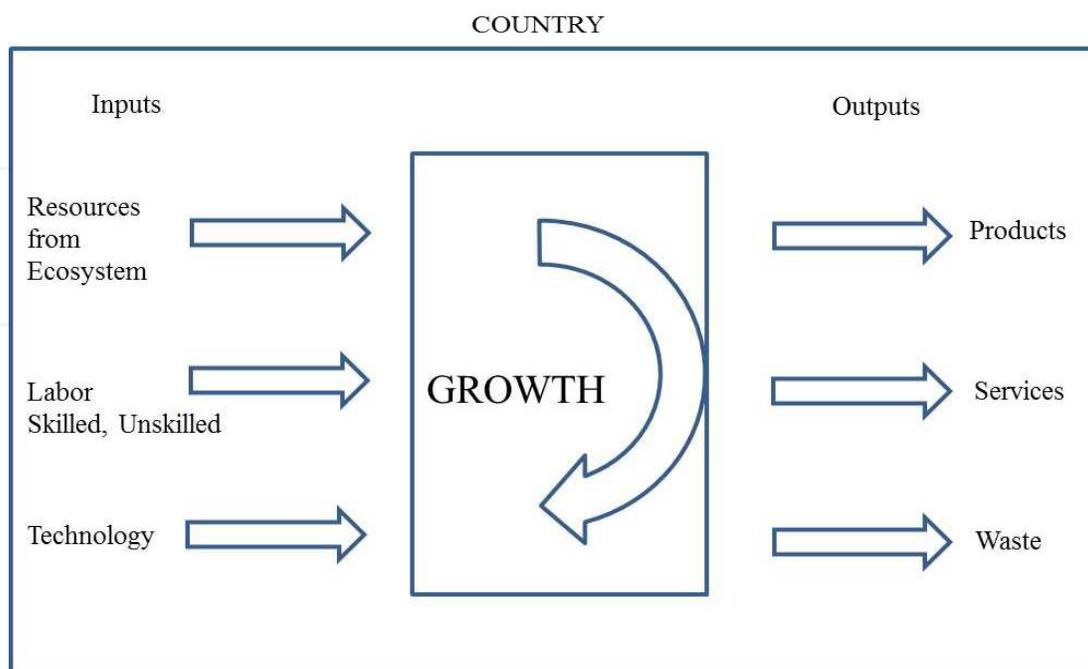


Fig. 1. Schematic model for sustainability decision making.

In developing countries where production is not highly advanced, indiscriminate expansion of production systems may not only lead to an undue burden on the ecosystem, but also to the concentration of wealth in relatively few hands. Sustainable development, however, must consider three dimensions: 1) protection of eco-system, 2) social development and 3) economic prosperity (Earth Summit, 1992). In some poor countries where poverty, hunger and poor sanitation exist, both environmentally acceptable, economically accessible, and socially sustainable solutions must be found to bring about a developed and socially just society. These solutions ought to be simple, inexpensive and environmentally safe. Examples of such solutions are presented below.

3. Mass production versus production by masses

In developing countries, where rice production is the main crop, for example in India and China, large scale burning of rice straw (harvest waste) often creates widespread emissions of CO₂ and other pollutants all over the countryside. This straw, however, when shredded and mixed with clay, can be molded into bricks. Thus a mixture of the shredded straw and clay can be used to produce both lightweight and insulating building materials. Shredding, mixing and molding can be achieved using cheap manual labor; with small scale-kilns or ovens employed to bake these bricks. This will provide employment to a large number of persons as well as minimize pollution caused by burning rice straw. Such a labor-intensive process can be termed as “production by masses” in contrast to “mass production”. Labor-intensive processes also may be more sustainable; in this case, waste rice straw available at the harvest time is harnessed each year.

Another example is from the upper east region of the country of Ghana. Though Ghana is one of the most stable countries in Sub Sahara Africa, the rural parts of this country are still struggling to push past the poverty line. Many of those struggling people are spending more of their time, energy and money on housing than necessary.

Their construction methods include two types: mud huts, and under block structures with corrugated tin roofing. The most impoverished of the community use the local clay soil for walls and millet straw roofing to build their huts/homes. These huts do not survive multiple seasons of rain fall and must be re-constructed every few years. This is due to the make-up of local soils which are laterites. Laterites are residual soils and are notoriously known for their loss of strength upon reworking and cycles of wetting and drying.

Because of the general poverty, people cannot afford a traditional house made of well baked bricks of good imported soils or of reinforced concrete. Setting up of manufacturing plants for mass production of high quality bricks of local material is an option which, because of extensive availability of local soils, is a sustainable solution. But this may not be an affordable as well as a just solution for the poor people. The concept of production by masses using inexpensive way to produce bricks by local people can not only provide an employment base for the people but it will also be an environmentally and socially just solution.

Over the past two years, students of Santa Clara University undertook senior design projects to produce designs and build houses made up of specially produced bricks of local lateritic soils. The aim was to develop inexpensive procedures for making bricks that could be easily learnt/adapted by local people. Similarly, the design and the construction of the houses were to be simple for easy adaptation of the methodology by local people. The brick-making equipment uses a simple lever system to apply pressure to produce well-compacted bricks. These bricks were sun baked. The design and construction used an arch shape (see Figure 2) to avoid the use of expensive materials such as cement and reinforcing bars not available in that area. In Figure 3, local people can be seen taking part in the construction of the houses. Further details can be found in the report entitled "Sustainable House in Ghana," submitted by Daniel Lawrie and William Sommer, Dept of Civil Engineering, Santa Clara University (May 2011).

There are several NGO's looking for appropriate technology applications to help people in marginal or developing regions of the world. And efforts are often directed towards solutions that are relatively inexpensive and are sustainable. However, it is important that an employment base should also be provided through mass employment of local people who can be trained through a skill-based education in the production of the appropriate technology solution. For example in Nicaragua, in the city of Managua, several teens, even younger children, work in the city dump under extreme un-hygienic and polluted environment for collecting plastic cans, etc. to sell and make a living (Fig 4). NICAHOPE, an NGO has set up a program next to the dump. This program motivates children away from the dump to receive skill-based education to make jewelry (Fig 5), selling of which they make more money in a shorter time than what they make in the dump; whereby they can remain in school also run by the program. This skill-based education leading to production of jewelry by impoverished children is sustained through donations. Such solutions which are both just and sustainable should be encouraged.

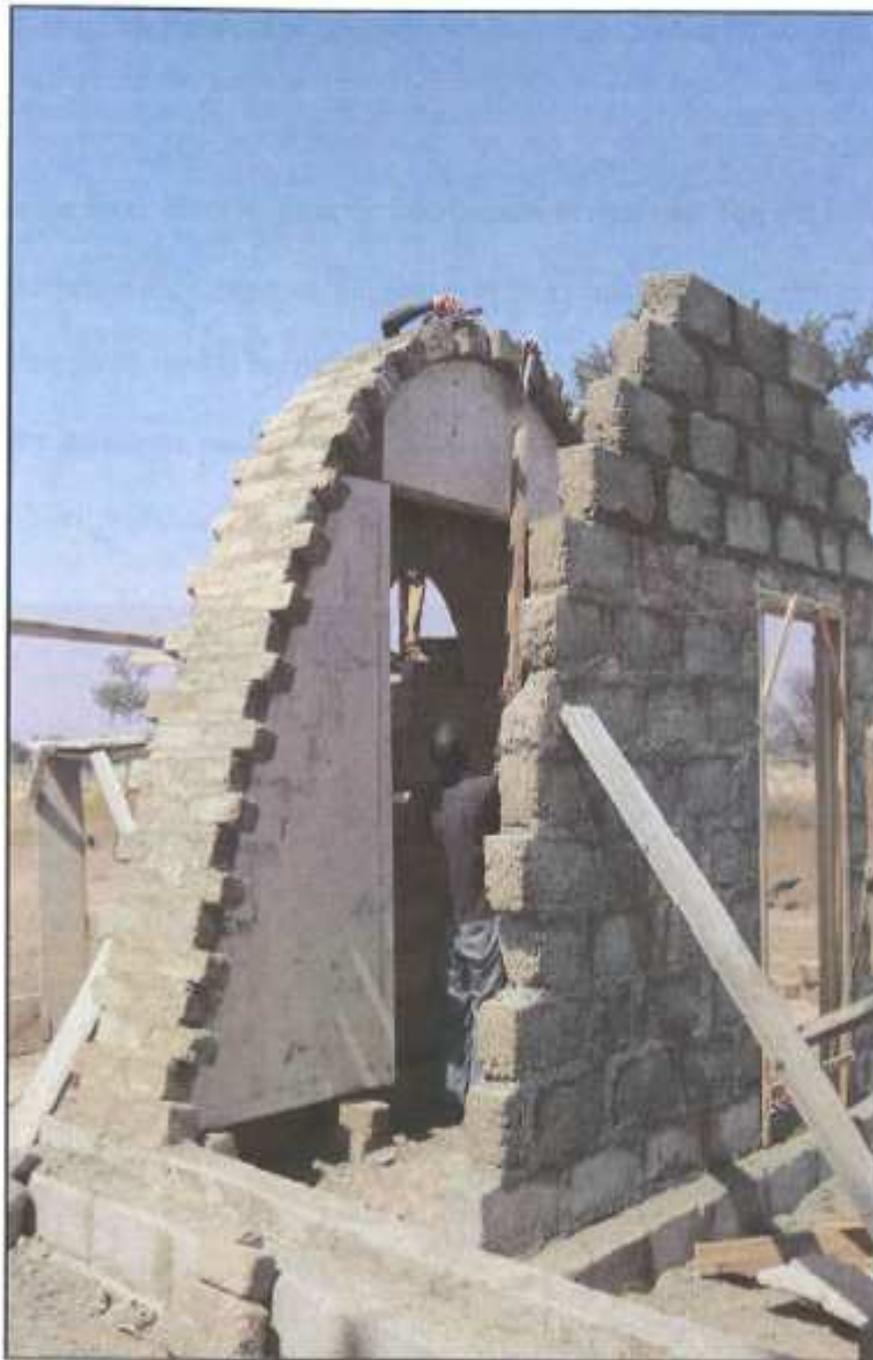


Fig. 2. Arch-Shaped Brick House.

An arch shape is used to avoid use of expensive materials such as cement and reinforcing bars not available in the area.



Fig. 3. Community Building Efforts.

Local people of Ghana are seen taking part in the construction of the house.



Fig. 4. City Dump Collecting. Three children collecting bottles and cans at the city dump.



Fig. 5. Activities for Local Children. NICAHOPE helpers training the local children in jewelry-making.

4. Sustainable building materials

Construction materials represent a large percentage of the raw materials used in developed countries. Figure 6 illustrates relative amounts of materials used in the United States, with construction materials by far being the largest of the categories listed. The environmental consequences are significant. For example, in both the United States and globally, the manufacture of Portland Cement for use in concrete accounts for approximately 8% of anthropogenic emissions of CO₂ (Wagner, 2002). Thus, alternative, more sustainable materials must be found.

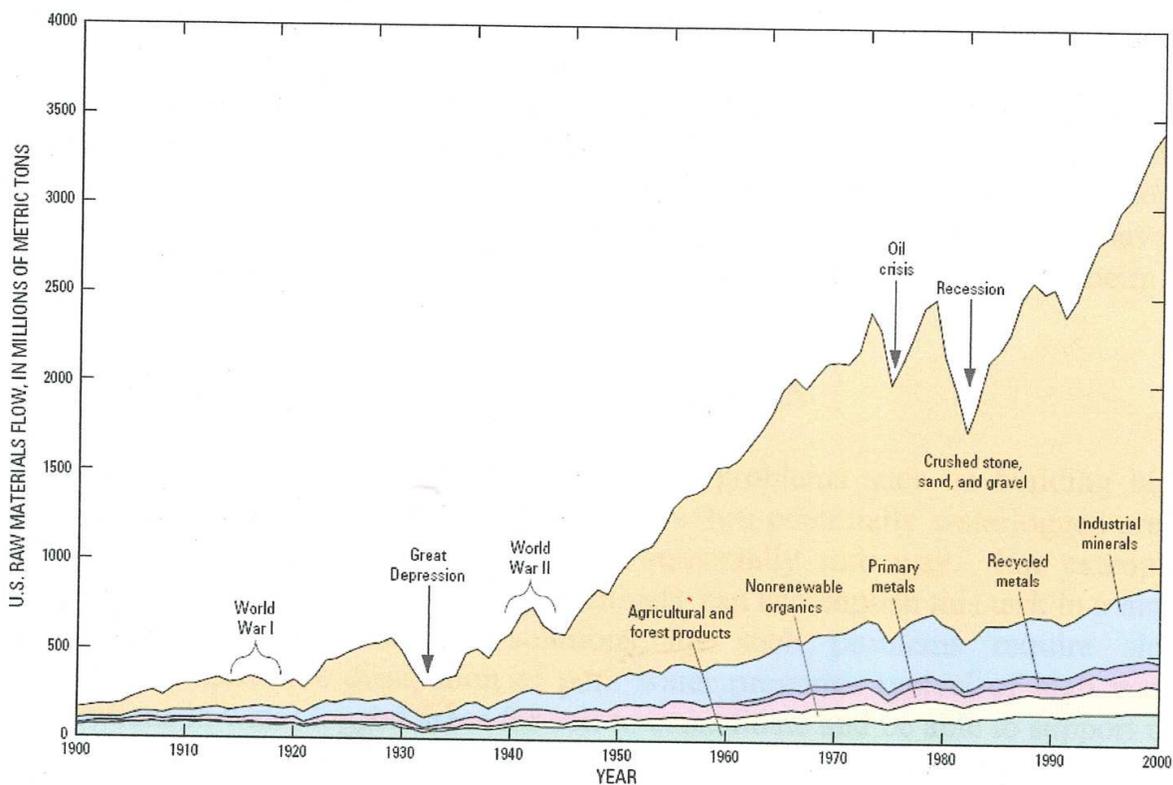


Fig. 6. Raw materials consumed in the United States: 1900-2000. (Wagner, 2002).

In developed countries, high labor costs relative to materials costs tends to result in high performance products that embody significant amounts of energy and technology. Examples include very strong chemical adhesives used for making engineered lumber and plywood. Sustainable alternatives may make use of sophisticated technologies to allow a savings in energy but possibly with some reduction in performance. Thus, it may be feasible to use manufactured biocomposites in place of steel or concrete. An example is the use of engineered lumber or a new alternative in which beams are made from harvested bamboo. The bamboo is attractive because it is stronger than wood and rapidly renewable, since the stalks can be harvested every 3 to 5 years. The bamboo beams may be formed from strips of bamboo assembled together into solid section I-beams or by extruding a beam made from bamboo chips and a bonding agent; the latter being especially appropriate in developed countries where labor is costly, while the former being more applicable in developing countries. Technologies to allow more sustainable adhesives to be used would be especially valuable; lignin resulting from anaerobic digestion is one binder that is currently being explored.

In developing countries, low labor costs and high needs may dictate solutions in which even basic technologies are employed to make production processes more efficient. For example, the firing of clay bricks in developing countries often relies upon relatively simple technologies implemented widely by small businesses. In some cases, the kilns are very crude and inefficient, leading to excessive consumption of wood and emissions of CO₂ and other pollutants. At the same time, there may be little or no quality control and the strengths of the bricks may be far in excess of the strengths required for dwelling construction. Businesses operating at this scale are often unaware of better technologies already in existence which can be employed for production by masses as suggested earlier to reduce pollution as well as to provide employment to local people.

Consequently, the application of relatively simple technologies could dramatically reduce wood consumption, CO₂ emissions, and the cost of masonry construction. Lower costs would allow this form of construction to be more widely used, displacing cheaper alternatives that have a worse history of performance in natural disasters such as earthquakes (Aschheim et al, 2007).

Another renewal and sustainable building material is strawbale. Construction with straw bale is now well developed. The bales of straw are stacked like bricks to form walls, which are then covered with plaster or gunite. Reinforcing mesh used within the plaster confers strength and ductility, while the bales themselves provide ample thermal and sound insulation. The use of good details can provide durability of a hundred years or more, as evidenced by buildings built in Nebraska beginning in the late 1800s. Bales composed of rice or wheat straw are used most often. The straw is a waste product resulting from the production of grain. Since burning in the fields has been prohibited, the bales have to be disposed of. The use of a waste product from food production as a material of construction reduces the need to dedicate land to forestry, and the use of this particular material provides significant savings of energy required to maintain comfortable indoor temperatures. Most strawbale buildings (see figure 7 for example) are approved under the alternative means and methods provisions of the building code, but efforts are underway to have provisions for strawbale construction adopted into mainstream building codes (Aschheim, 2011).

5. Social concerns in geotechnical design

Application of solutions to certain geotechnical problems such as building high earthen enhancements to raise highways that pass thru potentially waterlogged areas can be handled in a both socially and environmentally safe way. For example, although high-technology earth-moving machinery can accomplish this task in a more time efficient way, geotechnical solutions for such problems require slow construction to allow the dissipation of pore water pressures typical of high water table situations in water logged areas for soil to consolidate and be able to support the load of the highway embankment and the traffic. Use of manual labor (usually a large number) for hauling and placing fill on the embankment is a very common practice in India and in many developing countries. This can, not only, be economical on fuel consumption thereby minimizing pollution, but can also be a socially and geotechnically acceptable solution.

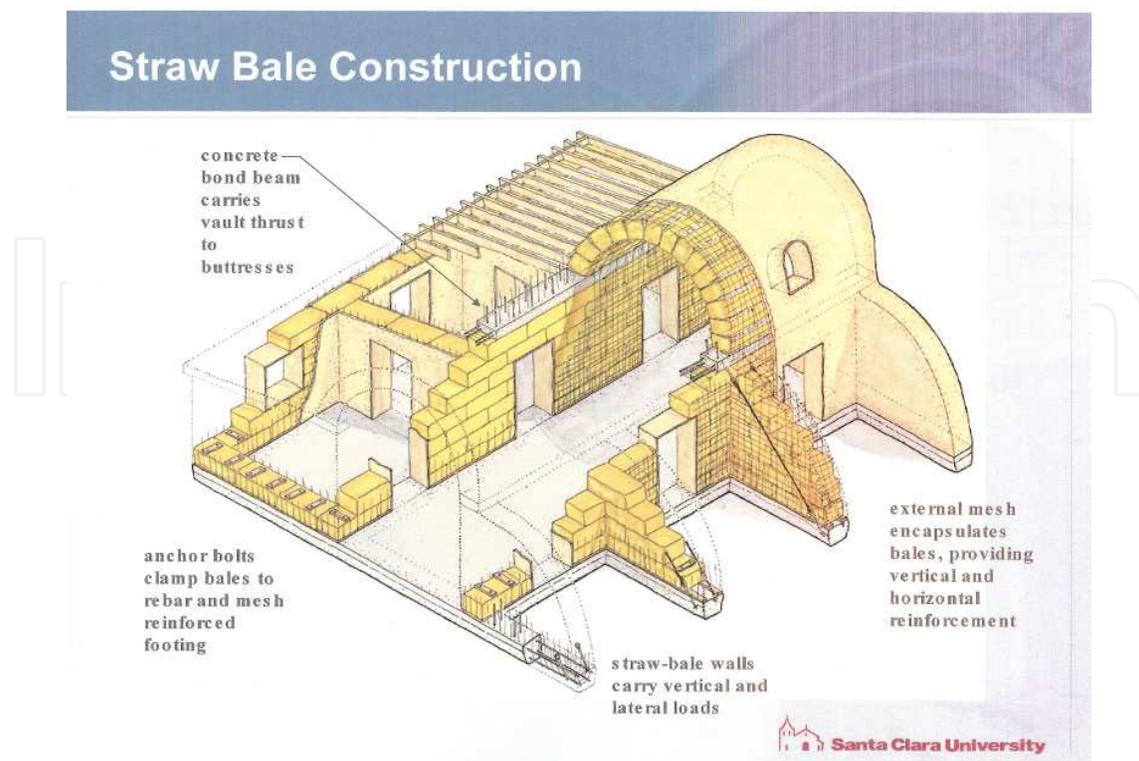


Fig. 7. Strawbale Construction.

Geotechnical engineering often require clearing, excavating, or moving large amounts of earth for the construction of highways, dams, tunnels, and housing construction. Whereas large highly advanced machinery is to accomplish these tasks, it may be possible that the geotechnical construction can be achieved in a more environmentally friendly way. Instead of one large dam two small dams requiring lesser environmental damage may be considered. Use of lightweight construction material for housing construction may help in reducing deep side hill cuts often made to build large view homes. Use of bamboo for housing has already been discussed. Since building in, on, and with earth is what geotechnical engineers do, the aforementioned considerations can help preserve the health of the earth (NRC 2006).

6. Entrepreneurship and social contract

In developing sustainable solutions for developing countries, engineers can play a leading role. But they have a special responsibility in making sure that their innovation or the technology that they have developed should not be exploited by rich /eager/self-made entrepreneurs for money/profit. There is the concept of social contract. According to which, since all entrepreneurs rely on existing infrastructures and existing services in order to function and succeed, it is therefore ethical to expect them to contribute to the society not in a philanthropic way, but in a structured way and that is what is called social contract. Elizabeth Warren of the New York Times has rightfully stated, "There is nobody in this country who got rich on his own. Nobody." She declared, pointing out that the rich can only get rich thanks to the "social contract" that provides a decent functioning society in which they can function (New York Times Sept 23, 2011). This social contract should be so

structured as to make it mandatory for the entrepreneurs to train and engage the local community. In some cases it may not be easy and could be time consuming. But it is worth it for the confidence and employment base it will create in the community/people.

Several NGO's over the years have come up with appropriate technology solutions for clean water. Application of these solutions is though for people of developing countries, but they should be guarded against exploitation by self-made entrepreneurs for profits by the above noted concept of "social contracts." Framing of 'social contracts' can vary from country to country to accommodate the social and culture climate of the country, so that the appropriate technology solutions remain sustainable.

At the time of writing this article (2011), no appropriate technology has emerged to clean water of metal impurities of lead and mercury from fertilizers and from industrial wastes dumped in streams.

Several social entrepreneurs are developing affordable technologies to help marginal communities all around the world. These technologies are mostly based on the concept of sustainability. For example in the area of affordable renewable energy to the underserved customers, they are tapping sustainable power from the sun and renewable power from biomass to provide cleaner cooking and off-grid lighting. These are the most renewable power sources found everywhere in the world (Center for Science Technology and Society, CSTS, Santa Clara University, SCU 2011). Solar power is well known but power/energy from biomass is relatively less understood. Biomass can be turned into energy in the form of heat by processing it into cooking fuel, or charring it into charcoal or a cleaner cooking method can be adopted, for example in India (Fig 8).



Fig. 8a. Old Fashioned Cooking Producing Pollution.



Fig. 8b. Cleaner Cooking Method.

There are several outfits across the world that develop biomass power. There are many more working on solar power to provide off-grid lighting and electricity, cleaner cooking, bio powered engines and generators, portable lanterns, efficient stoves, etc. There are about 40 social entrepreneurs/enterprises which are trying to deliver energy solutions to the underserved populations of the world (Center for Science Technology and Society, CSTS, Santa Clara University, SCU 2011). Some of these are for profit, some for nonprofit and still others are hybrid. These are all highly commendable. But whereas local assets in the form of renewable materials like plants or biomass waste (rice husks, manure, and animal waste) have been utilized, assets of untapped/untrained local human skills have been ignored. Employment can be provided by the entrepreneurs, by training and employing local people to build/make these products. This will further local people's progress towards prosperity or getting out of the poverty line.

7. Overall sustainability in developed nations

With reference to the schematic model for a country (Fig 1), and to repeat that as the growth accelerates in a developed country, to further the development and to raise the standards of living, two possible outcomes can be expected.

First, since the development should not be pushed at the cost of depletion of nation's ecological base, the developed countries must recognize limits to their growth and should look for alternate but sustainable resources of energy. As pointed out earlier, the developed nations should focus on advancing technologies to find alternate ways to meet the requirements of the society while preserving the balance of the ecosystem. Such

technologies are to focus on renewable energy resources like wind, hydro, geothermal, and the sun. A lot of progress has been made on these fronts, and efforts are to be directed to improve the efficiency of the technology in using these resources. Bio-based and fusion energy sources can also be developed.

The second outcome is related to the impact of the technology based growth/progress upon the societal values which may not be sustainable due to the onslaught of the technology. Developed nations' ever increasing hunger for energy through technological advances for a more fulfilling life may be a *fallacy*:

A Fallacy:

Back in the early seventies, steel plants in Pittsburg were introducing automation and mechanization and consequently laying off employees who were going on strikes for losing years and years of family tradition. Newspapers, however across the nation carried prominently news headlines that "Three-Day Weekend is coming because we will be producing so much more due to the automation and mechanization, and we will be so much richer that we will not have to work for 5 days." Have we? These new innovations and gadgetry are supposed to relieve us of the drudgery of doing by ourselves so that we will have more free time. Have we? No. Clearly, there is a fundamental fallacy in this line of thought. An average engineer in Silicon Valley is working 60 to 70 hours a week.

In fact the concept of weekend seems to be disappearing. To be successful here as an engineer, one has to optimize not only one's intellectual asset, but asset of family time with one's family, asset of social time with friends and so on. In fact in other walks of life, too, modern society seems to drive us to exhaustion, with continuous frantic activity and busy behavior, leaving hardly time for reflection. Is this then a "moral" problem and not an "energy" problem which ties into reflectiveness? In the reflective vacuum there is an opportunity for fascination with and immersion into all kinds of technology at the expense of human relationships and general well-being. Negative influences seem to have at their root a money-making enterprise. No one makes money on societal values, moral behavior, or ethics, and so the tools of influence (advertising, role models) are not engaged in promoting these perspectives – they are silenced merely by the lack of an individual's profit mongering to promote them. In this milieu when the negative influences out compete the positive, can we sustain societal values. If depletion of the ecosystem requires sustainability efforts, erosion of societal values also require sustainability efforts to guard against the loss of moral values. It is not fair or just to drive a society into a highly technological set up at the cost of its moral values.

Increase competitiveness is creating ruthless climate such that we no longer have colleagues or class fellows, but rivals in all walks of life. And in this ruthless climate, we seem to be more willing to compromise our principles. How, then, can we resolve this fallacy brought about by science and technology? We need to bring reform in our science education. Education in science and technology should include its interface with ethical, moral, social and economic aspects of the society. We must teach the relevance of advances or innovations in science and technology to socio-political as well as cultural aspects of our lives. Science and technology has stridden way ahead and our ability to use these advances wisely has lagged behind. By developing skills and understanding of the interface between science, technology and society, we can minimize negative impacts of science and technology and can sustain societal values.

Since we are never subjected to a feeling of contentment in a climate where catchy commercials are continuously showered on us, inflaming greed or a feeling of left-out if we cannot buy and use the latest, a certain kind of unhappiness creeps in us. Some bad elements in the society may be driven to getting these by unfair means (robbery, stealing, etc). We need to teach a balance between business education and societal values. How to interface these so that each can sustain and go hand in hand to benefit society.

8. Conclusion

- Sustainable solutions to protect ecosystems can vary from country to country and are influenced by economies and social constitution of the country.
- Sustainable development, which includes both environmentally and socially sustainable solutions, for example, can be achieved by incorporating available material, and local labor.
- Solutions in developed countries often involve high technology approaches at times at the cost of erosion in societal values. An understanding of the interface between technology and society can help sustain societal values while developing technology based sustainable solutions.

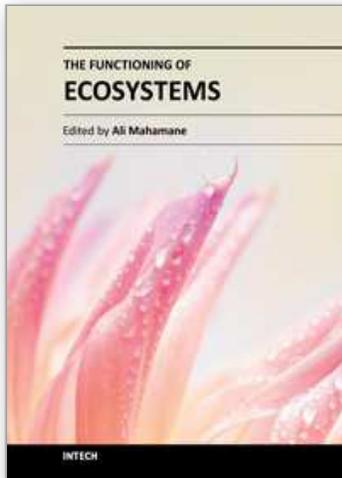
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The Functioning of Ecosystems

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The ecosystems present a great diversity worldwide and use various functionalities according to ecologic regions. In this new context of variability and climatic changes, these ecosystems undergo notable modifications amplified by domestic uses of which it was subjected to. Indeed the ecosystems render diverse services to humanity from their composition and structure but the tolerable levels are unknown. The preservation of these ecosystemic services needs a clear understanding of their complexity. The role of the research is not only to characterise the ecosystems but also to clearly define the tolerable usage levels. Their characterisation proves to be important not only for the local populations that use it but also for the conservation of biodiversity. Hence, the measurement, management and protection of ecosystems need innovative and diverse methods. For all these reasons, the aim of this book is to bring out a general view on the biogeochemical cycles, the ecological imprints, the mathematical models and theories applicable to many situations.

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