Sustainability for Engineers

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> *"All other lands were surpassed by ours in goodness of soil, so that it was actually able at that period to support a large host which was exempt from the labors of husbandry. And of its goodness a strong proof is this: what is now left of our soil rivals any other in being all-productive and abundant in crops and rich in pasturage for all kinds of cattle; and at that period, in addition to their fine quality, it produced these things in vast quantity . . . And, just as happens in small islands, what now remains compared with what then existed is like the skeleton of a sick man, all the fat and soft earth having wasted away, and only the bare framework of the land being left. ….*
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> *…… Moreover, it was enriched by the yearly rains from Zeus, which were not lost to it, as now, by flowing from the bare land into the sea; but the soil it had was deep, and therein it received the water, storing it up in the retentive loamy soil; and by drawing it off into the hollows from the heights the water that was there absorbed, it provided all the various districts with abundant supplies of spring water and streams, whereof the shrines which still remain even now, at the spots where the fountains formerly existed, are signs which testify that our present description of the land is true.*
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> *Such, then, was the natural condition of the rest of the country, and it was ornamented as you would expect from the genuine husbandmen who made husbandry their sole task, and who were also men of great taste and of native talent, and possessed of most excellent land and a great abundance of water, and also, above the land, a climate of most happily tempered seasons".*

Plato in *Critias* written 2,400 years ago comments on the impact of deforestation and farming on Attica

1. Summary

Sustainability is discussed in various ways as intra- and inter-generational equity – meeting present the needs without compromising the needs of future generations. But what is meant by future generations? We do not currently have a sense of concern or obligation for future welfare, beyond say four or five generations. But many societies have existed for much longer than that – several thousands of years and major cities in Europe, north Africa, the middle East and Asia have been in existence for at least two thousand years. Thus at the very least we should be considering a period of 1000 years.

We can then determine what we have to consider over 1000 years: Land use, food production, soil health, water quality and quantity, human habitation, ecosystem health, evolution and robustness, biodiversity, waste disposal (particularly hazardous waste), climate change, resource use and even technological direction are all suitable for long term consideration.

The probability and consequences of negative impacts on the environment and society over the short, medium and long term can be assessed and mitigated, particularly those risks which have major consequences.

In assessing risks, systems thinking is critical to enable the linkages between systems to be identified and for planning to take all systems into account. the current global situation already provides some risks with high probabilities and major consequences:

- Global warming
- Global population
- Fossil fuel energy depletion
- Water resources
- Soil health
- Urbanisation
- Resource depletion
- Waste management
- Production resource use

Sustainability has major implications for engineers. Long term thinking on resources and paradigm shifts in economics and technology design are necessary. Improving the quality of life without merely increasing the quantity of goods is required. Engineers must become more effective at identifying real needs rather than wants, particularly technology driven "needs". This will require them to become problem framers, so they help decide on the most effective directions that technology takes.

2. Time Concepts of Sustainability

First a basic concept of what we mean by sustainability needs to be considered. Although it is discussed in various ways as intra- and inter-generational equity – ensuring that the needs of the current generation are met without compromising the needs of future generations and 'ensuring quality of life', the definitions lack a sense of future – there is no clear understanding of what is meant by future generations. Economists argue that we care about our children, their children and possibly their children, but beyond four generations, we do not have a sense of concern or obligation for future welfare. Maori would identify five generations as the minimum period of thinking.

However, in the context of future society, four or eight generations (100-200 years) is relatively short. Many societies have existed for much longer than that – some for thousands of years (Europe, Middle East, China, India, Egypt). Many of the major cities in Europe, north Africa, the middle East and Asia have been in existence for over two thousand years; some for over 5,000 years. Some environmental impacts can last for thousands of years, particularly loss or salinisation of soil, loss of resources, degradation of ecosystems and loss of biodiversity. Some impacts can take long periods of time to develop or occur – loss of soil or biodiversity, desertification, deforestation and depletion of resources. Thus at the very least we should be considering a period of 1000 years and looking to the type of future we want at that point. As Tonn [1] points out, this concept is being recognised and needs to be incorporated into current urban and regional planning.

We cannot, of course, know what technologies we will have available 1000 years into the future. However, we can make some assumptions and use these to guide sustainable thinking.

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[1] Tonn, B., 2003. Integrated 1000-year Planning. *Futures (in press)*.

These assumptions include:

a) humans will be here;
b) current cities will be here;
c) food will still be grown;
d) materials and energy will still be required to meet human needs;
e) human basic needs will not have changed; these include (Peet and Bossel, [2]) :
    - Existence – provision of the basic biological needs of its members: food, drink, shelter, and medical care;
    - Effectiveness – provision for the production and distribution of goods and services;
    - Freedom of action;
    - Security - provision for the maintenance of internal and external order;
    - Adaptability – able to change;
    - Coexistence – able to exist peacefully with other races and species;
    - Reproduction – provision for the reproduction of new members and consider laws and issues related to reproduction;
    - Psychological needs – provision of meaning and motivation to its members;
    - Ethical reference – provision of definitions of right and wrong .

On this basis, we can then determine what we have to consider over 1000 years. Land use, food production, soil health, water quality and quantity, human habitation, ecosystem health, evolution and robustness, biodiversity, waste disposal (particularly hazardous waste), climate change, resource use and even technological direction are all suitable for long term consideration. Once we have started to plan for these factors, we set the framework for our future direction and how we can enable future generations to meet their needs. Long term planning for cities, regions and countries becomes important as it is within that framework that infrastructure of human habitation can be developed and managed for the long term. Limitations of land, water, food, soil and materials can be identified and ways of managing them developed. Areas that are suitable for human habitation, for agriculture, for transportation corridors and for green areas can be identified and managed. In addition, such backcasting will enable identification of technologies which are essential for future survival.

3. Risk

Having identified these issues, we certainly cannot predict with any certainty what will happen in the future. However, we can evaluate the risk of our activities on the needs of future generations and reduce those risks. Thus we can look at the probability and consequences of negative impacts on the environment and society over the short, medium and long term and move to mitigate those risks, particularly those which have major consequences.

The identification of risks requires that we understand more fully the systems we are affecting – environmental, social and even economic. Systems thinking is critical to enable the linkages and feedbacks between systems to be identified and for planning to take all systems into account. It also requires us to identify and recognise the limitations of those systems, not only for the short term but also for the long term. Those are the limitations which we must live within if we are to achieve sustainability. At this point, we have identified some critical species or

[2] Peet, J. and H. Bossel, 1999. Ethics as the grounding of a new paradigm of ecological economics for community. *ANZSEE Conference*, Brisbane, Australia, 5-7 July, 1999.

ecosystem levels, the points at which species or ecosystems will crash. However, the causes and factors leading to such crashes are not well known and the critical levels of many species and ecosystems remain unknown.

An evaluation of the current global situation provides some clear risks which have high probabilities and major consequences:

Global warming is occurring and global temperatures will continue to rise at a level of 0.1°C per decade at a minimum; over 1000 years, this could result in a rise of 10°C which will certainly make life impossible in many regions of the world. Even a rise of 3-4°C will result in significant impacts. Sea level rises, increases in storm events, increases and decreases in rainfall and increases in temperature will require changes to local building and infrastructure requirements.

Current global population is 6 billion people and it is likely that we are beyond the capacity of this planet to sustain this number of people at a reasonable quality of life (food, shelter, clothing, education) for the next 1000 years. Engineers need to consider ways and means of providing basic amenities for such populations.

Fossil fuel energy will be depleted probably within the next 100 years; current reserves of oil, gas and coal, when increasing rates of consumption are taken into account, only provide for approximately 40 (natural gas) – 100 (coal) years of supply. It is likely that these reserves will be increased but even if the reserves are doubled, with increasing rates of consumption, this will only allow for an additional 20 years of natural gas and 30 years of coal. Oil production is estimated to peak about 2040 and rapidly decline over the next 50 years – if liquefied coal takes its place, that would then reduce the long term supply of coal. Locally, this could have significant impact for transportation in particular, but also to industrial productivity, agriculture, fishing, construction and supply of basic amenities.

Water resources are being rapidly depleted and polluted; it is expected that water shortages will be experienced by 2/3 of the world's population within another 25 years (UNEP, 2002 [3]). This will have significant effects on human health but also on ecosystems, biodiversity, agriculture and soils. Local water supply will require evaluation to determine the population, industry, agriculture and other needs that it can support, as well as the risks to that supply.

Soil health is rapidly declining due to poor agricultural practices and overgrazing. Loss of topsoil and the urbanization of prime agricultural land is also of major concern. Local production of food could be seriously affected by degradation of soil health. Soil contamination also affects water quality and human health and thus limits the use of the land for the future; therefore measures to eliminate or remediate such contamination need to be established.

Urbanisation is increasing rapidly; by 2007 50% of the global population will live in urban areas (UNEP, 2002). This will have benefits in terms of increased density but such cities must focus on providing sustainable living spaces for people, not just on

[3] UNEP, 2002. *Global Environmental Outlook 3*. Earthscan Publications, London.

producing goods and services. Engineers will need to work with city planners and managers to define appropriate living areas within the city landscape and how the population can be accommodated within that area while still providing quality of life.

Resources may also be depleted over a millennium of extraction – careful attention needs to be paid to renewable resources to ensure that the long term supply will be maintained. As a result, local industries, particularly for those areas which are reliant on specific resources for supply, could fail, thus affecting the sustainability of the local community. For resources which are required to meet infrastructure and other needs other sources will have to be found. Products whose manufacture relies on such resources need to be redesigned to eliminate such reliance.

Over-population is resulting in increasing conflict for water, arable land and valuable resources such as oil and diamonds. As populations increase, such conflict will only increase, resulting in damage to environmental and social systems. Populations are predicted to continue to increase at least until the middle of this century and then stabilise at a level 50% greater than today. The increase will be primarily in developing countries, placing pressure on developed countries to accept immigrants which increases ethnic conflict as new immigrants and native inhabitants struggle to accommodate different ways of life.

Waste disposal of existing consumer goods is posing a major problem throughout the world. China is facing a legacy of tens of millions of redundant electronic and electrical appliances, with five million computers and tens of millions of mobile phones already obsolete and five million televisions, six million washing machines and four million refrigerators slated for disposal every year.
In China alone, consumers own an estimated 370 million TVs, 190 million washing machines, 150 million refrigerators, 20 million computers and 200 million mobile phones (Basel Action Network, 2003 [4]). The disposal of consumer goods, particularly electronic waste, is a major problem due to the hazardous materials they contain and the sheer quantity expected to be discarded as they wear out or become obsolete.

Material and energy flows in the production of goods are becoming significant which has significant impact on the environment and, consequently, on society. Recent assessments of the changes needed to achieve sustainability indicate that efficiency and reduction in material and energy use must improve by a factor of 10-50 (Weaver et al. [5]); some research is indicating that factors of 50-75 may be necessary.

4. Implications for Engineers

The implications of sustainability for engineers are major. Long term thinking on resource availability and infrastructure planning are essential. Paradigm shifts in economics and technology design are necessary. Clearer and better understanding of provision of quality of life without quantity of goods is required. Individual responsibility for the future also needs to be clarified and accepted.

[4] Basel Action Network, 2003. Chinese Consumers Building “E-Waste” Mountain, Officials Warn. http://www.ban.org/ban_news/chinese_mountain.html
[5] Weaver, P., L. Jansen, G. Van Grootveld, E. Van Spiegel and Ph. Vergragt, 2000. *Sustainable Technology Development*. Greanleaf Publishing Limited. Sheffield.

Engineers need to become more effective at identifying the real needs of consumers and clients, rather than wants, particularly technology driven “needs”. This will require them to become problem framers – asking the client to identify the core of the problem, rather than just the solution. It will also mean deciding on the most effective directions that technology takes, rather than relying solely on market drivers.