SUSTAINABILITY – A TASK FOR ENGINEERS

REPORT FROM THE PRESIDENTIAL TASK COMMITTEE ON SUSTAINABILITY

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IPENZ PRESIDENT 2003-2004

THE INSTITUTION OF PROFESSIONAL
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Report from the President's Task Committee on Sustainability 2003-04

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One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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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. ….*
>
> *…… 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.*
>
> *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 on the impact of
> deforestation and farming in 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.

These assumptions include:

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

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 ecosystem levels, the points at which species or ecosystems will crash. However, the causes

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[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.

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.
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> **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.
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> **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 producing goods and services. Engineers will need to work with city planners and

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

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.

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[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.

SUSTAINABILITY PRINCIPLES

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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Introduction

Sustainability is the focus on the long-term survival of humanity. It must recognise that decisions made today must enable both those in the present, and in the foreseeable future to make effective choices about their quality of life.

Three key principles are the basis of sustainability. The overarching problem is the need to manage change in the environment, many of which are increasingly human induced, and need to be addressed to avoid long term degradation of the environment.

Each of the key principles has a set of guidelines as to how best to achieve the desired result. Any human sourced problem, can be considered against these guidelines, to see whether sustainability is being enhanced by the proposed solution.

Principle 1: Maintaining the viability of the planet.

1. Humans need to maintain the integrity of global and local biophysical systems to ensure that the irreplaceable life support functions upon which human well-being depends are retained.
2. Non-renewable resource depletion rates shall equal the rate at which renewable substitutes are developed by human invention and investment.
3. Renewable resources must be managed to ensure that they can be produced over the long term within sustainable harvest rates (i.e. that do not exceed the regenerative capacity of the natural system that produces them), and without long term damage to the environment.
4. Technological options selected for engineered products, processes or systems, shall be weighted in favour of choices that, for a given expenditure, minimise the use of resources, particularly non-renewable resources such as fossil fuel-based energy and metals. They should also be based on the precautionary principle and reduce risks as much as practicable or foreseeable.
5. The material and energy intensity of engineered products, processes or systems needs to be reduced significantly (10 to 50 times), and the efficiency of those that use energy must be improved to achieve sustainability. To achieve this requires the use of recycling and other resource reuse and minimisation techniques.
6. All waste streams from the life cycle of engineered products, processes or systems shall be minimised, preferably at the source. Waste discharges should be kept within the assimilative capacity of the local and global environments.

7. The use and production of environmentally hazardous materials shall be minimised and, wherever possible, eliminated. In particular, the use of materials and chemicals that accumulate in the environment needs to be reduced to a level that does not exceed acceptable or natural levels.

Principle 2: Providing for equity within and between generations.

8. Humans, now and in the future shall have equal rights to achieve an acceptable quality of life. They shall have choices in life that reduce significant gaps in health, security, social recognition, political influence, etc. between people.
9. Consumption of resources needs to be balanced between the affluent and those yet to fulfil their basic needs, while ensuring total resource use is within the environment's sustainable capacity.
10. Resource use and development must be considered over a sufficiently long time scale that future generations are not disadvantaged economically, socially or environmentally by present actions.
11. Those directly affected by engineering projects, products, processes or systems need to be consulted and given the opportunity to voice concerns without repercussions. Their views shall be incorporated into the planning and decision making process.

Principle 3: Solving problems holistically.

12. Problem solutions shall be appropriate and based primarily on human needs and ecosystem viability rather than the availability of a particular technology.
13. Solutions to issues of growth in demand shall involve its realistic assessment and management, rather than merely predicting and providing the means for meeting growth targets.
14. A holistic, systems-based approach shall be used to solve problems rather than focussing on technology alone.
15. Methods shall be implemented that provide solutions with optimum outcomes for all stakeholders, rather than expedient or narrowly focussed solutions.
16. The use of unsustainable practices, or practices that present a risk to sustainability shall be minimised and reduced to zero over time. Where it is practicable or desirable, past degradation shall be reversed.
17. Problem solutions shall be based on prudent risk management approaches, and not by solving one problem at the expense of, or by creating another problem.

Sustainability & Engineering Practices Overview

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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1. Introduction

This paper translates *sustainability principles* [1] into overarching practical tasks and requirements for the engineering profession. These apply to a greater or lesser extent to all sectors, and have not necessarily been repeated in each sector paper.

Because sustainability has a long-term focus, beyond the life of most engineering projects, products, processes or systems – generically called projects – the methodology and resource use by projects needs to focus on both short and long term factors. This is often far beyond the duties imposed by professional codes of ethics.

Key sustainability factors for engineers are:

- The need to **manage changes in the environment** (both local and global) as the consequence of any engineering activities to ensure the continued viability of the planet (Principle 1).
- Ensuring the **equity and safety of engineering activities** for both current and future generations is also of high importance (Principle 2). Wherever possible this also means **improving the quality of life**, particularly for the poor and those in developing countries.
- **Problem solving**, one of the key aspects of a professional engineers skills, needs to be done in a holistic way (Principle 3), so that solving one problem does not create another, and the solution arrived at is the optimum one from many viewpoints.
- Where practicable engineers need to consider **making good problems already caused** by failures to follow sustainability principles (Principle 3).

These factors are explored further below, from an engineering perspective.

2. Key Sustainability Factors

Managing changes in the environment.

1. Maintain the **integrity of global and local biophysical systems** engineers must thoroughly consider any project or plan that will have a significant impact the life support functions upon which human well-being depends, many of which are irreplaceable. For example the use and placement of dams on waterways, or the deployment of a technique, material or process with unknown side effects – such as nanotechnology assembly processes.

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[1] Task Committee Document 1: Sustainability Principles

2. Ensure that the **true cost of resource depletion is included** in all feasibility studies and estimates. Usually the market cost is assumed to include all costs, but this is often not so, and where alternatives exist, the more sustainable product or material should be used. For example a recyclable or reusable container is inherently more sustainable than a single-use container, whatever the apparent cost.
3. Minimise the absolute use of resources, and to convert the energy source from fossil based to renewable energy requires a **constant awareness of optimisation processes on a life cycle basis.** For example engineered products, processes and services should be designed to minimise the initial use of resources and to provide for maximum recycling and reuse of resources. This applies both to scarce resources, and apparently abundant resources such as concrete and timber, all of which have an embedded energy content.
4. **Maximise the use of renewable resources** but always within sustainable extraction or harvest rates and taking account of environmental damage. For example biomass from sustainable forests used as a boiler fuel instead of oil or gas.
5. **Minimising waste products**, particularly hazardous ones, from the total life cycle of engineered products, processes or systems, preferably as near to the source as practicable. Ensure that any waste discharges are within the short term assimilative capacity of the environment, without long term accumulation.

Equity and safety of engineering activities.

6. Engineering projects, products or processes should be aimed primarily at **improving the overall quality of life** for humans and other life forms, but not at the expense of the environment.
7. **Any increased consumption** of resources and energy, must be **weighed against the improvement in quality of life** to be achieved.
8. Resource use must be **considered over a sufficiently long time scale** so that present and future generations are not disadvantaged economically, socially or environmentally, by excessive and unnecessary consumption. This may be considerably longer than an anticipated project lifetime.
9. **Positively weight projects, products and processes that decrease significant gaps** in health, security, social recognition, political influence between groups of people. Those that do the opposite should be carefully considered before embarking on them in whole or in part.
10. All **those affected by engineering projects shall be consulted where practicable** and given equal opportunity without repercussions to voice their concerns. Their relevant opinions shall be considered and where practical incorporated into the planning, decision making and implementation process.
11. Where outcomes cannot be accurately foreseen choices shall be **based on risk reduction and the precautionary principle** – where in the absence of data, new risk is avoided – as much as practicable or foreseeable.

Holistic problem solving

12. An integrated systems, or an **overall holistic approach shall be taken** including all stakeholders and the environment when attempting to solve problems. Rather than

focussing solely on the technology aspects, and solving one problem at the expense of another, a coordinated solution shall be aimed for.

13. Problem solutions shall be based primarily on existing or new human needs rather than finding a use for a newly available technological means.
14. Approaches that are multi-faceted, and synergistic are preferable to single issue approaches. For example using transportation in such a way that viable loads are available for both journeys, is more sustainable than single load journeys.

Making good problems already caused

15. Where desirable and technically and economically practicable, past environmental degradation should be remedied. For example land degradation and groundwater contamination, and hazardous waste sites should be considered at a minimum for stabilisation, and wherever possible total clean-up to current or foreseeable standard.
16. Past hazardous practices shall cease and be cleaned up in a cost effective way and time frame. These include for example hazardous materials such as asbestos, lead, mercury, and PCBs.
17. Reduce the use of non-sustainable practices (such as burning or using petroleum and fossil fuel products for feedstocks) to zero over a relatively short time frame.
18. Support social and economic accounting methods which disclose, identify and quantify previous or developing environmental problems.

3. Implications for IPENZ Members and Engineers in General

A policy framework is emerging in New Zealand for sustainable development to be implemented in certain specific areas. Engineers have many opportunities to be involved in this process. They also have professional responsibilities to do so, as noted, for example, in the IPENZ Code of Ethics:

> *"Members shall be committed to the need for sustainable management of the planet's resources and seek to minimise adverse environmental impacts of their engineering works or applications of technology for both present and future generations."*

Members of IPENZ and of its various technical groups and societies are encouraged to learn more about sustainability and apply it in their day-to-day actions at work and in other aspects of their lives. Further information is readily available both from New Zealand and internationally. The engineering profession should lead the way and be seen to lead the way towards a more sustainable future.

There a number of specific ways in which engineers and the engineering community can move New Zealand towards sustainability. The following checklist will give some guidance on this.

4. General Sustainable Engineering and Technology Checklist

1. Have you thoroughly considered any project or plan that will have a significant impact on the life support functions upon which human well-being depends? ☐
2. Have you ensured that the true cost of resource depletion is included in all your feasibility studies and estimates? ☐
3. Have you minimised the absolute use of resources on a life cycle basis, and used renewable energy as much as possible? ☐
4. Have you maximised the use of renewable resources within sustainable extraction or harvest rates and taken account of environmental damage? ☐
5. Can you minimise waste products, particularly hazardous ones, from the total life cycle of engineered products, processes or systems, as near to the source as practicable? ☐
6. Does the project, product or process improve the overall quality of life for humans and other life forms, without large increases in the consumption of resources and energy, or at the expense of the environment? ☐
7. Has resource use been considered over a sufficiently long time scale so that present and future generations are not disadvantaged by excessive and unnecessary consumption? ☐
8. Does the project, product or process decrease comparative gaps in health, security, social recognition, political influence between groups of people as much as it could? ☐
9. Have those likely to be affected by the project been consulted if practicable, and will any relevant opinions be considered and where practical incorporated into final planning? ☐
10. If outcomes cannot be accurately foreseen, is your planning based on risk reduction and the precautionary principle? ☐
11. Have you taken an integrated systems, overall holistic approach including all stakeholders and the environment in your proposed solution? ☐
12. Is your project, product or process based on human needs rather than just finding a use for some newly available technology? ☐
13. Does the project, product or process involve past hazardous practices, and if so can these be eliminated and cleaned up in a cost effective way and time frame? ☐
14. Does the project, product or process contribute towards reducing non-sustainable practices to zero over a relatively short time frame? ☐
15. Can social and economic accounting methods be used at the planning stages to disclose, identify and quantify previous or developing environmental problems? ☐

Sustainable Resources and Production in New Zealand

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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1. Summary

Engineers are involved in all aspects of resource use – from resource extraction, through to technology and product design, manufacture, operation and even in the management of wasted resources and products. While the specific issues related to water, energy, transportation and wastes are addressed in other discussion papers, this paper focuses on resources in general and the overarching considerations that must be given to achieve sustainable resource management.

The increasing use of resources in the manufacture of technology and products raises serious questions regarding the sustainability of that use. For every kilogram of final product, kilograms of material are moved, energy is consumed and pollution is released which contaminates soil, water and air. The use of resources results in five major effects – contamination, degradation, dispersion, consumption and loss and each effect has different risks to the environment, society and business. Overall, our use of resources needs to be reduced significantly, by factors of 10-50 fold, in order to achieve sustainability and this reduction will only occur through cleaner production, recycling, servicising (see 7.8) and, most importantly, through sustainable technology design. This will require engineers to better understand the services technologies and products are providing and finding new ways of providing those services.

2. Introduction

The use of resources by humans is massive and, in developed countries, is higher than any previous time in history and is increasing. We purchase huge quantities of clothing, food, household appliances and furniture, vehicles, recreational toys, property and houses and many of these items are used once or twice and then stored, left to decay or discarded. We throw out huge quantities of goods, including uneaten food, disposable products, unfashionable clothing and furniture and appliances which may still be in working order. We waste huge quantities of energy and water through poor infrastructure design. Technology is changing so fast that computers, TVs and other electronic goods are discarded while still functioning simply because new technology has made goods which are only two years old obsolete.

In much of the developing world, resource use is increasing rapidly as people strive to consume at western standards. Cars, TVs, cell phones and modern buildings are replacing more traditional modes of transport, communication and buildings, resulting in higher resource consumption levels.

The concept of sustainability is based around equity of both current and future generations; those in the future should not be disadvantaged by the actions of those today. Fundamental to this discussion is the issue of use of resources, particularly resources which are currently being depleted due to short term economic gain. This is not surprising as current political economic thinking basically ignores natural capital (materials provided by nature), considering it to be replaceable with human capital (labour) (Daly[1]). Moreover, as Hardin [2] points out, immediate consumption is more profitable to the consumer and provides a competitive advantage to the consumer's immediate descendants. However, such consumption disadvantages those who are unable to indulge in the current consumption and future generations.

There has been much discussion regarding the requirement for resource efficiency and how it is to be achieved. The concept is a nebulous one, as the cost of many resources is quite low, the resources used in a product may be only a minor portion of the resources used in the manufacture of the product and the impact of extraction of resources on ecosystem resources is often ignored. Moreover, there is also the view that there will always be a technical solution to any resource depletion problem, thus efficiency is not necessary. In addition, the economic and environmental costs of a product's disposal at the end of its economic life are often not factored into decision-making or pricing.

The purpose of this paper is to assess the requirement for sustaining resources, discuss how this can be achieved and outline the role of engineers in sustaining resources.

3. Defining a resource

From a traditional engineering perspective, resources are often considered to be those materials which are used in the manufacture of products – water, energy, metals, wood, limestone, chemicals, raw food etc. However, when the range and sources of products that are produced today are considered, the definition needs to be well beyond such a minimal concept, which is what the Resource Management Act (1991) (RMA) attempts to do in its definition of natural and physical resources:

> "Natural and physical resources" includes land, water, air, soil, minerals, and energy, all forms of plants and animals (whether native to New Zealand or introduced), and all structures.

Thus resources are anything which has an existing or potential use to humans. This includes other species, ecosystems, soil, water, land, surface and subterranean deposits of minerals and fossil fuels, even geological structures which may, as a structure, provide a use or benefit. The benefit or use may satisfy any human needs – basic survival or psychological, cultural or social.

The RMA does not cover all resources however, as extraction of mineral and petroleum resources are, instead, legislated by the Crown Minerals Act (1991) which does not require sustainable management of those resources. The RMA, however, does cover the environmental impact of that extraction and the use of resources such as water which are used in the extraction and processing of minerals. However, from a sustainability perspective, all resources, including mineral and petroleum, must be considered.

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[1] Daly, H., 1997. Georgescu-Roegen vs. Solow/Stiglitz. *Ecological Economics* 22:261-266.

[2] Hardin, G., 1968. The Tragedy of the Commons. *Science* 162:1243-1245.

4. Types of resources

In assessing the sustainability of resources, the loss, recycle and renewal of the resource must be considered. Resources can be classed as property preserving or property losing and as renewable or non-renewable. Property-preserving resources are those materials whose properties are not lost as they are used, such as elements and minerals. Elements can be readily recycled, often at a cheaper cost than extraction and processing and, although they can be dispersed, ionic properties often enable them to be recollected, although at a cost. Although many minerals have been mined extensively, the actual limits of deposits are still not known and production is still easily meeting demand (Mining, Minerals and Sustainable Development (MMSD) Project, 2002 [3]). Although such limits may be determined within the next 500 – 1000 years, the minerals that are already in use will still be available for reprocessing into new products. Although there is a risk of depleting the geologically-stored reserves, there is no risk of depletion of the elements although the cost of their extraction and recovery may increase.

Property-losing resources, however, includes complex materials which are broken down, consumed or lose their useful property during their use. They must be replenished at the rate of consumption or will be depleted. The crash of a number of fishing stocks within the past ten years throughout the world is a good example. Other geologically-stored energy resources, such as oil and gas, are also at risk, as are radioactive materials, since the properties of these resources are depleted as they are used. The USGS has recently produced estimates of total global oil resources and, using these results, the U.S. Energy Information Administration [4] suggests that production will peak in 30-40 years, with the majority of resources being depleted by the end of the current century.

Renewable resources are usually property-losing resources which can be produced on an ongoing basis, thus mitigating the loss of their properties. Agricultural products, fish and timber are common, renewable resources. Two aspects must be considered – the timeframe for a renewable cycle and the potential loss of the resource altogether, which could, in the case of organisms, remove any potential for renewability.

Even oil and gas can be considered renewable as crops can be grown to produce both fuels. However, the rate of consumption far surpasses the rate of current production and, as a result, the stock of fossil fuels is being depleted. Moreover, the return on energy investment for agricultural production of oils is much less than for extraction of fossil fuels (Hall et al [5]).

Non-renewable resources are those which have a finite supply on this planet. Some of these resources, such as carbon, iron, silicon and aluminium, are very common and it is unlikely these resources will be depleted within the next thousand years. Other resources such as copper, nickel and zinc, are more limited in supply although there are questions as to the extent of their total supply and the current major limitation is the cost of recovery for those metals (Mining, Minerals and Sustainable Development (MMSD) Project, 2002).

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[3] Mining, Minerals and Sustainable Development (MMSD) Project, 2002. *Breaking New Ground: Mining, Minerals, and Sustainable Development.* Earthscan Publications Ltd., UK.

[4] Energy Information Administration, 2003. International Energy Outlook, 2003. Office of Integrated Analysis and Forecasting, U.S. Department of Energy, Washington, DC.

[5] Hall, C. et al., 2003. Hydrocarbons and the evolution of human culture. *Nature* 426:318-322.

For those resources which can be renewed within a short timeframe, an assessment of the sustainability of the consumption, the renewal of such resources and the risks posed by current renewal practices is necessary. For those which are not renewable, an assessment of the availability of substitutes must be considered. The risk then to future production of the resource from current management practices and to future generations due to the loss of that resource requires assessment.

5. Effects of using resources

There are five effects on resources from use: contamination, degradation, dispersion, consumption and loss. Some of these effects can be mitigated through technology, time or effort but some, particularly loss, may be non-recoverable. Different resources are affected by different effects and to different extents.

5.1 Contamination

Contamination involves the introduction of a foreign, unwanted material into the desired substance or resource. This can include pollution of a river stream, introduction of non-endemic species into an ecosystem and even windfarms which have a visual or noise effect. It should be noted that while contamination is an anthropogenic concept, it can have major effects on the environment, causing significant changes, and, if severe enough, ecosystem collapse. Some forms of contamination, such as visual effects, may be considered contamination only by some groups in society or by a specific culture; others may view the effect as positive.

Remediation of contamination requires the removal of the contamination and prevention of further contamination. For water or air contamination, the usual practice has been dilution of the polluted material until it is no longer a problem, followed by prevention. Contaminated soils may be removed and treated or stored in secure facilities. Removal and treatment of the contaminating material can, however, be very expensive and, in some cases, impossible. As a consequence, contamination of ecosystems by non-endemic species is a global problem which is likely to increase with globalisation. Some aspects of contamination, particularly that of noise or visual contamination, are a result of increased technology, increasing population and increasing consumption of resources. Societies must decide how much visual and noise contamination they are willing to accept as a trade for their lifestyle.

While contamination is viewed as having an anthropogenic source, this is not always the case; in fact, natural contamination such as volcanic releases, faeces of wildlife or birds, natural high heavy metal levels in soils or even natural territorial expansion by species may cause significant environmental disruption. While some natural contaminations can be treated, others cannot and the only way of managing them is to understand and reduce the risk involved.

Acceptable levels of pollution or contamination are usually defined by legislation, either through standards or discharge consents. However, such levels may not take cumulative or synergistic effects into account and may be based more on technological capacity than ecosystem limits.

5.2 Degradation

Degradation involves the loss of quality of a material or resource. Usually degradation occurs with complex resources and the loss of quality may result in an increased risk of performance failure. For example, the fibre length of paper is shortened once it is recycled, causing a decrease in strength; used building timber may be brittle or fractured; roading or water infrastructure requires ongoing maintenance to provide effective service; as species within an ecosystem are lost, the risk of collapse of the ecosystem increases and as the gene pool within a species is reduced through loss, the risk of losing the species increases.

Remediating degradation usually involves replacing the degraded material with non-degraded material or changing the cause of the degradation, thus slowing or stopping it. Ecosystems or species, once the degradation has been stopped, may be able to recover from degradation. However, the degradation of some products cannot be remediated, such as the decline in timber quality due to fungus rot.

Degradation is usually the result of ongoing use of a resource and may take some time to become apparent; for example the loss of soil, the loss of species or the results of overgrazing. For materials which are to be recycled, standards must usually be met by all input materials which ensures that any degradation is within allowable limits. For ongoing, long-term degradation, there is often little legislation which actually ensures that degradation is monitored or resolved.

5.3 Dispersion

Dispersion occurs when a material loses small amounts over time due to wear and degradation, thus resulting in the dispersion of small portions of the material in the environment. The material is not destroyed and, where it is heavily used, can accumulate in the environment; for example, lead from petrol is now found in most roadside and urban soils while zinc and copper from galvanized roofs and copper gutterings are found in stormwater runoff and accumulate in the receiving aquatic environment. Legislation governing the use of heavy metals or materials which could be detrimental to human health or the environment usually prevents such materials being used in an easily dispersed fashion.

Elements are, of course, unevenly dispersed throughout the environment and, under the right conditions and with sufficient energy and technology, can be collected. The issue, of course, is the cost required to recover the dispersed element but the environmental contamination must also be considered.

5.4 Consumption

Energy is stored in fossil fuels and can be released as heat, thus ‘consuming’ the fossil fuel. While sunlight is continually available, the energy required for current lifestyles is sufficient to make current solar technologies unfeasible for supplying energy. Energy is also released during the decay of some radioactive materials and, for the most part, the decayed material is no longer usable as an energy source.

Other complex materials or ecosystems can also be ‘consumed’ through the breakdown of the complex materials into simpler elements or the elimination of ecosystem species. Currently technology is insufficient to enable replacement of many consumed materials. However, species can be replaced if they have not been made extinct or are past their critical limit for breeding.

5.5 Loss

Loss occurs when there has been sufficient consumption of a complex material or species that the resource is no longer available. This can be a local or a global loss. Once loss has occurred, particularly of a species, it is currently impossible to recover the species. It should be noted that many important ecosystem species occur at the small to microscopic level and it is estimated that there are significant numbers of species that have not been identified. As a consequence, it is not clear how many species have been lost in the past 50 years.

In considering the sustainability of a resource, it must be clear what the risks to that resource are before its sustainability can be determined. Thus a resource that is being contaminated still exists but the question is whether it needs to be decontaminated, can be decontaminated and the cost of that contamination. Resources that are dispersed are not destroyed and therefore sustainability must be considered in the light of the energy and cost of collecting the dispersed materials, as the existing stockpiles are depleted. Recycling, of course, assists in this process. Renewable resources must be evaluated as to the balance between extraction and renewal and whether that renewal can continue indefinitely. If there is no renewal and the resource can be consumed, then the duration of that resource for the future must be considered.

The local loss of a resource, such as water or aggregate, may require that the resource is brought in from other resource rich areas. However, consideration must be given to the economic cost and the risk of such a move for future generations. For example, shipping in water for an urban centre will not only increase the cost but also put the city at risk of water shortages and high shipping costs should the supply source be depleted.

6. Current use of resources

While we see the quantities of goods which are purchased and discarded, what we don’t see are the quantities of materials and resources which contribute to the manufacture of those goods nor do we know the extent of the impacts resulting from the extraction, manufacturing and operating processes. The extraction of resources such as minerals, metals and energy requires significant quantities of equipment, chemicals, water and energy, releases wastes into the environment and also displaces or removes plants, animals, soil and water, thus disrupting or destroying ecosystems. The amount of material moved in nature to obtain a kilogram of a resource has been termed the material intensity of a resource or the rucksack factor and provides an indication of the stress that production of that resource requires (Table 1).

The material intensity, however, does not include the energy used to produce the material, known as the embodied energy or emergy. Both measures need to be considered if some concept of the resources which go into production of a product are to be measured. It also does not include the contamination of air, water and soil, nor does it consider the loss of species or ecosystems as a result of any environmental impact.

Table 1. Material intensity or the amount of material moved to produce one kilogram of the resource (Wuppertal Institute, 2003 [6]). Water is not included in this assessment as it is often simply returned to the source.

Resource	Material Intensity
	kg material moved / kg product
Steel (rebar, blast furnace)	8
Aluminium	37
Recycled aluminium	0.85
Gold	540,000
Diamond	5,260,000,000
Ammonia phosphate fertiliser	7
High density polyethlyene	2.5
Rubber	6
Portland cement	3
Bleached paper	9
Diesel oil	3.2

Life cycle assessment tries to include material and energy intensity as well as environmental effects by considering the environmental impacts of a product over its life cycle, from cradle to grave. The problem is that it is difficult to compare two products and the results of a life cycle assessment require some level of interpretation to understand.

Overall, however, the above measures do not fully indicate the sustainability of a product. They do not take social or economic issues into account and to do that requires a systems analysis, identifying the basic process and the environmental, social and economic systems which are affected by that process. Once this has been done, the risk to those systems can then be identified.

7. Efficient use of resources

Cleaner production, eco-efficiency and pollution prevention has been used for over ten years to reduce the amount of resources and energy used in processes. From a resource and waste audit, an initial step is to focus on basic inefficiencies such as poor management, leaking valves, old or poorly functioning equipment, poor storage of chemicals and other inefficient practices, leading up to complete redesign of process equipment or products to reduce the use and waste of resources, including energy. It is estimated that cleaner production technology can potentially achieve 2-3 fold improvements – 200-300% increases in efficiency (Weaver et al [7]).

Such efficiencies will go a long way towards reducing resource consumption but it is not clear if it will be sufficient. Research by Weaver et al. (2000) indicates that, in order to achieve sustainability, efficiencies will have to improve by factors of 10 to 50 fold, much higher than can

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[6] Wuppertal Institute, 2003. Material intensity of materials, fuels, transport services. www.wupperinst.org/Projekte/mipsonline/download/calculation-sheet.xls.

[7] Weaver, P., L. Jansen, G. Van Grootveld, E. Van Spiegel and Ph. Vergragt, 2000. *Sustainable Technology Development*. Greanleaf Publishing Limited. Sheffield.

be achieved using cleaner production technologies. This will require a new concept of design, new thinking and new methods of producing and harnessing energy.

Energy is probably a major limiting factor due to current reliance on fossil fuels. Even if we are not facing an imminent shortage of fossil fuels, the release of greenhouse gases from their use is posing a major threat to the environment and to society. In a worst case scenario, a Pentagon report foresaw global anarchy, nuclear war, famine and ecosystem collapse within the next 30 years as a result of global warming (Schwartz and Randall [8]). Even in the best case scenario, there will be significant impacts due to changes in climate.

Society's reliance on energy, particularly fossil fuel energy, to supply food, water, all goods, heat and light buildings, construct buildings and other infrastructure, and, in fact, undertake most modern activities, leaves it highly vulnerable to any interruption in energy supply, as evidenced by recent breakdowns in the electricity grid in California and in Auckland. Yet the supply of fossil fuels still continued; if that had been disrupted as well, the situation would have been much more serious.

Although conservation will enable supplies of fossil fuels to last longer and will reduce greenhouse gas emissions, it is not clear what conservation will achieve in the long term. Certainly, the increase in energy consumption shows no sign of abating, even during an economic downturn (Energy Information Administration, 2003). With society firmly based on fossil fuel energy, all conservation will do is to increase the length of time fossil fuels are available for consumption. Thus, unless there is a major shift in political will and in technology, consumption of fossil fuels is likely to continue until they are beyond economic recovery levels.

As a result, the major issue is not that the temperature will increase to levels that are likely to cause severe ecosystem disruption but how fast the temperature will rise. The estimated 50-year time lag between emissions and effect on climate means that we are still feeling the effect of greenhouse gas releases from the 1950s and 1960s. Rapid increases in releases from the 1960s to the present likely means that increases in temperature will occur more rapidly and we will see greater and greater effects and more and more extreme events and storms. The only ways to prevent this from occurring would be to cease emissions of greenhouse gases from combustion of fossil fuels and find some way to reduce greenhouse gases in the atmosphere. However, it is not even clear if we can actually mitigate changes which are going to occur over the next 20 years due to the time lag.

Climate change aside, since fossil fuels are a consumable resource if used for energy, the conservation of those fuels for the future leads to a number of questions. How much should be conserved for future generations? How far in the future is it essential to consider the concept of equity, since fossil fuels are a finite, consumable resource which can only be parcelled out so far?

The Natural Step [9] states that we should:

> eliminate our contribution to systematic physical degradation of nature through over-harvesting, depletion, foreign introductions and other forms of modification. This means drawing resources only from well-managed eco-systems, systematically pursuing the

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[8] Schwartz, P. and D. Randall, 2003. An Abrupt Climate Change Scenario and Its Implications for United States National Security. U.S. Defense Department. Available at http://www.ems.org/climate/pentagon_climate_change.html.

[9] The Natural Step, 2003. Four Simple Principles of Sustainability. http://www.naturalstep.org/learn/principles.php

most productive and efficient use both of those resources and land, and exercising caution in all kinds of modification of nature.

New, renewable sources of energy need to be developed which can sustain quality of life. The stored fossil fuel resources could then be used in cases of emergency, when solar energy levels are not sufficient to provide power as could happen with a meteor strike, a nuclear winter or even a large, super volcano eruption. Developing and implementing technologies which can use solar, wind and tidal power efficiently and at a level which will supply the developed world's needs is therefore imperative. This will reduce the risk to society from both climate change and from loss of fossil fuels due to social disruption, war or even depletion.

7.1 Use minimisation

Minimising the use of resources reduces the amount of extraction required and thus the environmental impact of extraction and processing. It also enables the resource to be extended to produce more product. However, it must be noted that this is linked to the number of products produced and used – for example cell phones have been reduced dramatically in size thus reducing the resources used per phone; however the number of phones has dramatically increased, thus increasing overall the resources used in manufacturing cell phones. In addition, as the developing world improves, it will increase its use of technology, thus increasing the consumption of resources.

As a product technology matures, the changeover of products slows, thus reducing the consumption of materials. An example is computer printers; the top level of technology, laser printers, was achieved 10 years ago and, as a result, printer turnover is not as high as that of computers. Computer technology is still maturing and has a long way to go; the latest technology will see the computer reduced to a roll-up screen, either a virtual or a roll-up keyboard and a computer the size of a pack of playing cards which communicates without cables to the accessories but has a memory much greater than available today. This will further turn most desk top computers obsolete and the change is likely to occur within the next five years as the technology is already available.

7.2 Durability

Product durability has been considered to be a positive factor, particularly when considering sustainability. However, some items such as take-away containers are not needed for long term use. Moreover, fashions change and thus clothing often goes out of fashion before it wears out. Ongoing improvements in technology also render previous technologies obsolete, even when only a few years old. Thus there are thousands of obsolete computers which have been discarded, with components which are difficult to recycle and are still functioning but are now in landfills throughout the world.

Durability poses an economic conflict for manufacturers which is why they embraced the disposable concept of the 1960s so readily. Whiteware manufacturers sell items which are expected to last 10 to 15 years; they thus have only limited annual sales available compared to vehicles, which turn over more frequently due to the 'fashion' factor. Moreover, a family usually only has one refrigerator or washing machine per household whereas nowadays it is not unusual for a household to have at least one vehicle per driving adult.

7.3 Recycling

Recycling resources from products also assists in extending the availability of resources but contamination and energy consumption must also be taken into account. Recycling, however, uses significantly less energy and resources and moves less material than primary extraction. A major problem with many products is that they are not constructed to be recycled and thus are difficult to diassemble into recyclable components. Computers and other electronic goods and whiteware are good examples of such products. However, Xerox has designed its photocopiers to be recyclable to enable them to recycle components and materials, thus reducing the requirement for new resources.

7.4 Servicising

Servicising has been touted as a means of reducing the use of products. The concept involves the provision of a service rather than a product. Examples include providing farmers with a pest control service rather than pesticides; leasing of electronic goods or whiteware rather than the purchase of them; a needs based use of vehicles rather than the purchase of them.

Care must be taken in the design of a servicised system that it does not encourage a greater consumption of products rather than a reduction in their use. For example, by leasing whiteware, consumers could be encouraged to upgrade more frequently, thus increasing the turnover of products. Most servicising requires the use of some products and care must be taken to ensure that the system does actually reduce consumption.

8. Engineering Considerations

The issue of sustainable resource use and product design is highly complex. It must be considered over the product life cycle and the resources must be considered in the light of the type of resources and how they are being affected through human use. The limits of systems and of resources is also of importance in making decisions about resource use and product design. A further consideration is that the risk to the environment, society and the business of using a resource must be considered over the short, medium and long term. In this case, however, the long term is not the standard 5-10 years of business strategies; it must be a long term focus, up to 1000 years when considering resources such as soil. Such a focus recognises the needs of future generations over the long term, not merely 50 to 100 years in the future.

For engineers, this means a greater responsibility in the design of products and the use of resources. Complex issues regarding environmental impact, resource availability, renewability, recyclability and the potentials for providing a service rather than a product need to be considered. Engineers need to work closely with planners, designers and decision-makers to influence the design and manufacture of products, the use of resources and in ensuring that the life cycle of products is fully taken into account in the design process. Companies also need to recognise their responsibility in producing products and ensure that they plan for the product end-of-life.

Engineers have to realise that current consumption is already likely greater than the global carrying capacity and it must be reduced. However, the issue is not necessarily one of resources and energy per product but total resources and energy consumption and the effect on the environment and society and on future generations. A major focus is needed to start the development of products that use significantly less resources and energy. Such products and technology will require new solutions to problems which will enable 10- to 50-fold reductions in energy and resource consumption. Finding these new solutions will require engineers who are able to think innovatively rather than incrementally in designing new technologies.

Regardless of the business engineers are in, they must take responsibility for the technologies and products they design and manufacture and the risks to the sustainability of the environment, society and the business from unsustainable designs. Engineers need to recognise this professional responsibility and also to start taking a leadership role in this field. Only when leaders in society begin to accept the responsibility for achieving sustainability will society be on the path to that goal.

Changes in thinking are necessary to achieve sustainability of resource use in product and technology design. Decision-making for sustainable use of resources and design of technologies and products may be aided by the following checklist as a framework:

9. Sustainable design of technologies and products Checklist

1. Is the service provided by the technology or product clearly identified, and based on a real need that will improve the overall quality of life? ☐
2. Is the service provided by the technology or product actually necessary, i.e. based on needs rather than wants, and not technology driven? ☐
3. Can the resources needed to produce the technology or product that provides the service be clearly defined ? ☐
4. Can the limitations (both local and global) to those resources over the short, medium and long term be accurately assessed and defined? ☐
5. Can the short, medium and long term risks to the environment, society and the business from the life cycle impacts of the technology or product, be assessed and defined? ☐
6. Is it possible to determine how sustainable the resources available to provide the service (solar, wind power; locally abundant renewable resources etc.) will be? ☐
7. Can you assess if the existing technology can be adapted to use those resources sustainably? ☐
8. Have you assessed the short, medium and long-term risk to the environment, society and the business from such an adaptation? ☐
9. Have you identified what new technologies exist or can be developed to provide the service which use only sustainably available resources? ☐
10. Have you considered whether a service rather than a product or technology can be used to provide the same result? ☐
11. Can any resources used in existing technologies and products be recycled back into those technologies and products (lease and take back systems)? ☐
12. Can a life cycle product stewardship programme be developed to ensure that manufacturers take responsibility for resource use and waste production? ☐
13. Have you identified how to minimise and mitigate risk to the environment, society and the business over the short, medium and long term for this product or technology? ☐

Sustainable Buildings in New Zealand

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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1. Summary

There has been significant interest and debate in the concept of sustainable buildings worldwide. One major issue is the definition of a 'sustainable building' and what that actually entails. Most of the focus to date has been on green buildings which may feature energy conservation in construction and operation, recycled or native/natural/low tech materials used in construction or even use of high tech concepts to reduce energy and water consumption. Since so many materials are used in building construction, the issue of sustainability of the building becomes highly complex. This is exacerbated by the short term nature of current aesthetics, architectural design and style which contrasts with the requirement for long term thinking for sustainability. The impact of construction on the environment can be quite high, especially considering the amount of construction which occurs. Moreover, embodied energy has often been used as a measure of sustainability but this fails to take into account other significant impacts from construction. This paper will discuss the concept of sustainable buildings, tools for measuring sustainability and the application of those tools to buildings.

2. Introduction

Much emphasis has been placed on green buildings over the past two decades. The concept began with the environmental movement in the 1960s which started a 'back to nature' concept in the design of houses then moved to energy conserving office buildings in the 1970s. The concept of a green building is, today, so diverse, that it is difficult to define what is meant by the term.

Guy [1] outlines five varying visions of green buildings that are found throughout society – the ecological, smart, comfort, aesthetic and community visions – each with competing discourses (Table 1). While the specific discourses can be argued, each has a differing vision of what constitutes a green building and, consequently, the resulting building not only looks substantially different but functions in a different way.

Today the focus has shifted from green buildings to sustainable buildings. The concept of sustainability has developed considerably since its introduction by the Brundtland Commission in Our Common Future [2]. It is now used by professionals throughout society for many purposes and with many meanings, each delivering a subtly different connotation to the term. Overall, however, there is agreement that inter- and intra-generational equity are important and

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[1] Guy, S., 1997. *Alternative developments: the social construction of green buildings.* Royal Institution of Chartered Surveyors, available at http://www.rics.org.uk/ (May, 2003)

[2] Brundtland Commission, 1987. *Our Common Future*. Oxford University Press, Oxford, UK.

that sustainability of environment, society and economics are also important. The complexity of sustainability is recognised but not yet fully understood.

Table 1. Five competing discourses of green buildings (Guy, 1999)

1. Discourse	Ecological	Smart	Aesthetic	Comfort	Community
Emblematic Issue	sustainability	flexibility	new millennium	sick buildings	democracy
Building Image	polluter	asset	symbol	healthy	home
Risk	planetary survival	market survival	survival	cultural life	individual alienation
Life Cycle	inter-generational	business cycle	design fashion	daily	generational
Rhetoric	ethical	commercial	architectural	medical/ scientific	societal
Design Strategy	reduce footprint	max. efficiency	express nature	living building	create identity
Urban Scale	de-centralised	urbanised	contextualised	contextualised	centralised
Mobility	ban cars	virtual travel	hide car	lessen car-use	minimise trips
Networks	autonomous	integrated	reveal networks	diminish intensity	locally managed
Technology	local, renewable	hi-tech, BMS*	organic, recycled	selective/ nontoxic	appropriate
Evaluation	holistic	cost-benefit	truth to nature	productivity	social cohesion

* BMS - building management system

The concept of sustainability with respect to buildings is still poorly defined. Much of the focus is on the use of energy in buildings. In the UK, approximately 66% of the total energy consumption goes towards buildings and building construction (Vale et al., 1994). In the US, buildings use one third of all the energy and two thirds of the electricity (US EPA, 2003). The energy consumed in operation of the building overshadows that of the construction – 90% is consumed in operation over the lifespan of the building (Winther and Hestnes, [3]). As a consequence, much research has focused on means to reduce energy consumption for house and water heating (Winther and Hestnes, 1999; Eaton and Amato [4]).

The measure of embodied energy or emergy within a building is also used as a major indicator of environmental impact. This measure considers all the energy used in production of building materials and construction of the building, as well as energy needed for disposal or recycling of materials. Since the consumption of energy is also related to the production of greenhouse gases, particulates, acid gases, volatile organic carbons and other air pollutants, this measure also provides an indication of the pollutants released through energy consumption. Embodied energy is often used as the major indicator for sustainability of buildings (Brown and Buranakarn [5] ; Treloar, Owen and Fay, [6]).

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[3] Winther, B.N. and A.G. Hestnes, 1999. Solar versus green: the analysis of a Norwegian row house. *Solar Energy* 66(6): 387–393.

[4] Eaton, K.J. and A. Amato, 1998. A Comparative life cycle assess of steel and concrete framed office buildings. J. Construct. Steel Res. 46(1-3): 286-287.

[5] Brown, M.T. and V. Buranakarn, 2003. Emergy indices and ratios for sustainable material cycles and recycle options *Resources, Conservation and Recycling* 38 (2003) 1 – 22.

[6] Treloar, G J., C. Owen and R. Fay, 2001. Environmental assessment of rammed earth construction systems *Structural Survey* 19(2):99-105.

The use of energy alone has raised concerns that a number of environmental factors are not considered. Urher (1999) points out that the buildings contribute significantly to the environmental burden, quoting Levin [7] for the following contribution levels: use of raw materials (30%), energy (42%), water (25%) and land (12%), and pollution emission such as atmospheric emissions (40%), water effluents (20%), solid waste (25%) and other releases (13%). The impact on the environment results from pollutants, energy consumption, water consumption, land degradation/consumption, resource consumption, waste production and loss of biodiversity incurred throughout the life cycle of buildings, from raw material extraction, processing, construction, building operation and demolition.

Even with consideration of all the energy and other environmental factors, the primary question still arises – what do we mean by a sustainable building? Does focusing on the energy alone ensure that a building will be sustainable? This paper will discuss the concept of sustainable buildings, tools for measuring sustainability and the application of those tools to buildings.

3. Direct consumption of resources

With the overall context of inter-generational equity, there is agreement that risk to the environment (encompassing ecosystems and resources), society and the economy must be minimised over both the short and the long term. To achieve technologies which minimise the risk to the environment requires reductions of a factor between 20 and 50 in resource consumption and efficiency (Jansen and Weaver, 2000).

This will be particularly significant to the construction industry which is a major consumer of resources. Estimates of resource use vary but the US EPA (2003) estimates that a standard wood-frame house uses one acre of forest and produces 3-7 tonnes of waste during construction. Lippiatt [8] states that buildings consume 40% of the gravel, stone and sand, 25% of the timber, 40% of the energy and 16% of the water used globally per year. In the UK alone, it was estimated that about 6 tonnes of building materials is used annually for every member of the population (Cooper and Curwell, [9]).

Much of the waste and consumption occurs during the extraction and processing of the raw material. Mining requires water and energy, consumes land and produces significant quantities of acid and heavy metal contaminated gas, liquid and solid wastes. Timber requires significant tracts of land and amounts of fertiliser and harvesting and processing it requires energy. It is also often grown in plantations which replace old growth forest and significantly reduces biodiversity. Transportation of the material also requires energy and the fossil fuels used for transportation, extraction and harvesting produce greenhouse gases and a range of air pollutants. Processing of metals and minerals often results in major gas emissions; the concrete industry is a major producer of CO_2 while aluminium smelting produces perfluorocarbons, which are very powerful greenhouse gases. Hazardous wastes are often a byproduct, containing heavy metals and, from aluminium smelting, cyanide wastes. Processing of timber includes treatment against rot and pests and usually requires hazardous materials.

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[7] Levin, H. (1997). Systematic evaluation and assessment of building environmental performance (ASEABEP). *Proc. Second International Conference on Buildings and the Environment, CSTB and CI*B, 2, Paris, June, 3–10 *as cited in,* Uher, T.E., 1999. *Absolute indicators of sustainable construction*. Rics Research Foundation, Royal Institution of Chartered Surveyors, available at http://www.rics.org.uk/ (May, 2003)..

[8] Lippiatt, B.C., 1999. Selecting cost-effective green building products: BEES approach. *Journal of Construction Engineering and Management Nov./Dec.1999: 448-455.*

[9] Cooper, I. and Curwell, S. (1997). BEQUEST – Building Environmental Quality Evaluation for Sustainability through Time. *Proc. Second International Conference on Buildings and the Environment, CSTB and CI*B, 2, Paris, June, 515–523.

Recycled materials, while requiring transportation and reprocessing, often consume significantly fewer resources than extraction and processing of raw materials. This is particularly true for metals such as copper, iron and aluminium which can be reprocessed to a quality of that from raw material processing. Both concrete and timber can be recycled or reused but quality of the final product is often reduced. Concrete can be crushed and reused as aggregate for some purposes, particularly paving (Khati and Boyle, 1999) and mortar (Corinaldesi, Giuggiolini and Moriconi, [10]) while good grade timber can be used for making furniture. Since it is difficult to determine whether a used timber beam has stress cracks or other weak points, reusing them as supporting timber is not always suitable. Plastic can be recycled into a number of construction products, including tiles, lumber, heating and wire insulation and carpet.

Huang and Hsu [11] found that over $10x10^6$ tonnes of construction material were extracted for use per year in Taiwan while over $40x10^6$ tonnes of construction waste were disposed of without recycling. The waste included significant amounts of asphalt which had to be imported but could easily have been recycled, thus reducing the material and energy costs of importing $51x10^6$ tonnes of asphalt. Thormark [12] pointed out that 'recycled concrete, clay brick and lightweight concrete can meet the total need for gravel in new houses and in refurbishment.'

Over the lifespan of a building, the materials will have to be maintained and, for some, replaced. Exterior coatings, guttering, piping, walls, and flooring in particular will require repair or replacement on a 5-15 year basis. Effective maintenance can also have a significant impact on reducing requirements for replacement. The decisions here are not made by the builder or designer regardless of the original design; the owner determines what materials are going to be used for repair and how the building is maintained.

The overall investment of resources into a building needs to be considered over the lifespan of the building. Although buildings can easily be designed to last well over 100 years and many traditional buildings are designed for more than 200 years (Morel, Mesbah, Oggero and Walker, [13]), many designers and researchers only plan for 50 years and, in the case of office buildings, even less. Using materials which will be durable and require minimal maintenance reduces the requirement for repairing or replacing the materials or even replacing the building, thus reducing the potential environmental impact. Simply designing and maintaining a building for 400 years rather than 50 will reduce its environmental impact from material resources by up to a factor of 4.

Durability of the building depends on a variety of factors – the design, construction methods, materials, purpose of the buildings, its aesthetics and the owner. The owner is the primary determinant on the lifespan of a building and that may also be affected by current and local fashions in architecture, lifestyles and economics. In addition, new materials which are being developed for exterior cladding, roofing and to replace preserved timber are difficult to assess as their durability and suitability for construction has not been proven over the long term.

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[10] Corinaldesi, V., M. Giuggiolini and G. Moriconi, 2002. Use of rubble from building demolition in mortars, *Waste Management, 22(8): 893-899.*

[11] Huang, S. and W. Hsu, 2003. Materials flow analysis and emergy evaluation of Taipei's urban construction, *Landscape and Urban Planning 63(2): 61-74.*

[12] Thormark, C., 2002. A low energy building in a life cycle—its embodied energy, energy need for operation and recycling potential. *Building and Environment 37(4): 429-435.*

[13] Morel, J.C., A. Mesbah, M.Oggero and P.Walker, 2001. Building houses with local materials: means to drastically reduce the environmental impact of construction. *Building and Environment 36 (2001):1119 –1126.*

Major renovations which change the design of the building will also likely occur. With office buildings, interior layouts are frequently modified to suit the corporate function and about a third of construction activities in Europe involve office refurbishment (Caccavelli and Genre [14]). Although these renovations can be used to improve energy and water consumption and interior air quality as well as refurbishment of worn materials, they are often primarily cosmetic changes to suit the company operations. Such renovations can contribute significantly to the solid waste stream and consume resources.

Regardless, both designers and builders have some influence on building durability. Good design, flexible spaces, quality materials, refraining from fashion statements which could become outmoded, all contribute to the durability of a building. However, the design and construction of many buildings today is undertaken by developers who have little interest in the long term durability of the building and are most concerned with maximising profit over the short term. Unless developers are required to consider long term durability and quality of the buildings they produce, this short term focus will continue to be the driving factor in design and construction of most buildings.

4. Energy

Significant energy is consumed during the extraction, processing and transportation of materials as well as during the construction. Morel et al. (2001) found that use of local materials during construction could reduce energy costs by more than a factor of 3 and could reduce impacts from transportation by more than a factor of 6. The local materials studied by Morel et al. included rammed earth, stone, timber and were compared to use of imported concrete which requires significant energy for processing. Treloar, Owen and Fay (2001) found that rammed earth, using a concrete binder, had an energy load equivalent to that of a brick veneer construction due to the energy required in processing the cement.

Brown and Buranakarn (2003) compared the emergy (total life cycle energy required to provide a service or make a product) of major building materials (Table 2). Aluminium had the highest emergy requirement, with wood lumber being the lowest. By using wood rather than steel beams in a building, the emergy requirement would be reduced by more than a factor of 4, depending on the weight of the lumber and the steel beams.

Table 2. Material extraction and production emergy intensity of building materials
(from Brown and Buranakarn, 2003).

Material	Emergy (solar energy j/ g)
Wood lumber	0.88
Concrete	1.54
Cement	1.97
Clay brick	2.32
Ceramic tile w/ recycled glass	3.06
Glass	2.16
Steel	4.13
Plastic (PVC)	5.85
Aluminum	12.53

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[14] Caccavelli, D. and J. Genre, 2000. Diagnosis of the degradation state of building and cost evaluation of induced refurbishment works, *Energy and Buildings, 31(2): 159-165.*

Since 90% of the energy consumption is over the operational lifespan of the building and energy is the major resource consumed in buildings, achieving significant reductions in energy consumption assist significantly in reducing the resource consumption and improving efficiency. Although a house can be designed to be totally self sufficient for energy and water, much depends on location, climate, availability and potability of local water sources as well as on the attitude of the user. The designer/builder can incorporate some energy saving devices and designs such as solar water heaters, passive heating, composting toilets, etc. which are suitable for local conditions. Again, however, such devices and designs will only be incorporated if a profit can be realised; many developers resist including energy saving measures unless they are required by local councils or are considered essential by buyers in the local community. However, Zydeveld [15] pointed out that up to 80% savings in heating energy and improvements in indoor air quality and thermal comfort could be made in the Netherlands with the inclusion of passive solar design with no additional construction cost and with an additional 10% cost in construction, savings of 90% could be achieved. Four major design principles enabled architects and builders to incorporate passive solar design into their buildings – solar orientation; maximisation of solar gain through low surface loss and high internal volume; high mass within the insulation and avoiding of shading.

The increase in use of materials in a low energy building can, however, mean that there is an increased consumption of materials and energy overall; Thormark [16] found that up to 45% of the total energy use is in embodied energy in a low energy building and that such buildings could have a greater total energy use than that of a building with a higher operating energy consumption. However, 37-42% of the embodied energy could be recovered by recycling of materials.

The building owner and occupants determine which appliances are to be used for the house and the energy efficiency of those appliances as well as how the building will be operated – ambient house temperature, type and number of appliances, conservation measures applied during operation etc. Many of the factors which dictate energy consumption are specific to the occupants and their daily activities: age and composition of occupants (people, pets), amount they are in the building, occupation and monthly income, perception of energy, preference for location within the building etc. (Lucas et al [17]). The use of low energy appliances and conservation measures can reduce energy requirements significantly.

Having considered the energy requirements for material extraction, processing, and recycling and for building operation and maintenance, the sustainability of the energy source needs to be considered. Gagnon, Bélanger and Uchiyama [18] compared the life cycle environmental impacts of renewable, hydro, fossil fuel and nuclear energy sources and found that hydro electricity and wind power were the best sources although the latter required a backup source. Nuclear power was also well rated, primarily as the issue of waste management was not taken into account. Solar and biomass were the next best options with all fossil fuels ranking

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[15] Zydeveld, C., 1998. From simple design principles to 4000 passive solar homes; Factor 4 in energy savings at no cost. *Renewable Energy* 15: 240-242.

[16] Thormark,C., 2001. Conservation of energy and natural resources by recycling building waste. *Resources, Conservation and Recycling 33(2): 113-130.*

[17] Lucas, B., E. Hidalgo, W. Gomez and R. Rosés, 2001. Behavioral factors study of residential users which influence the energy consumption. *Renewable Energy 24 (2001): 521–527.*

[18] Gagnon, L., C. Bélanger and Y. Uchiyama, 2002. Life-cycle assessment of electricity generation options: The status of research in year 2001, *Energy Policy, 30(14): 1267-1278.*

significantly lower due to poor payback, emissions, health effects and future performance. The World Commission on Dams, [19] however, noted that:

> 'Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable…. In too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment.'

Gagnon, Bélanger and Uchiyama did not take the social concerns into account and minimised the land required by hydro power by considering only the direct impacts. Moreover, there was little comparison of the type of land required; hydro power often affects highly productive areas while solar power can use unproductive desert areas and wind power does not take land out of production.

In considering energy consumption then, the use of existing hydro energy combined with wind power to supply electricity is the most efficient. The major concerns are the use of land, the impact of hydro dams and the limited potential to construct dams for future requirements. As a consequence, rather than focusing on constructing more major dams, efforts should be focused on maintaining existing dams, construction of low impact in-river hydro systems, incorporating alternative sources of renewable energy such as wind and tidal power and improving the performance of solar energy collection.

By including energy generation on site, buildings are then not increasing the load on the existing power supply grid and therefore not requiring that additional generation and plant be constructed. Use of the existing grid primarily as a back up would provide buildings with a reliable power source unless the grid was not well maintained.

5. Indirect impacts of buildings

In addition to the direct life cycle impacts of buildings, there are a number of indirect impacts to the environment and to society. These include infrastructure requirements such as water, electricity, roads and telephone lines, services such as stores, restaurants, schools and hospitals and the changes in land use which result in loss of critical ecosystems and biodiversity and effect watershed integrity. Many of these are considered to be planning issues but the pressure for extended development of land around urban centres by developers often results in economic decisions being made which do not fully consider the indirect impacts of such development.

This is changing as the concept of sustainable urban planning is being accepted more widely by urban councils. However, in New Zealand, such planning is still in its infancy and many developments are being allowed to progress without sufficient planning. The traffic situation in Auckland is a good example of poor consideration of roading requirements for suburban developments.

The indirect costs of any building development are often not measured and are likely to be equal to that of the original building. Cheng [20] found that energy requirements per m^3 of water for water and wastewater plants in Taipei was six times that of the pumping requirements within

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[19] The World Commission on Dams, 2000. *Dams and development: A new framework for decision-making.* Earthscan Publications Ltd, London and Sterling, VA November 2000.

[20] Cheng, C., 2002. Study of the inter-relationship between water use and energy conservation for a building, *Energy and Buildings 34(3): 261-266.*

a six floor apartment. Hendrickson, and Horvath [21] found that highway, bridge, and other horizontal construction costs were 0.6% of the 1992 U.S. gross domestic product (GDP), industrial facilities and commercial and office buildings were 1.5% of GDP, residential one-unit buildings were 1.9% of GDP and other construction such as towers, water, sewer and irrigation systems, railroads, etc. were 2.4% of GDP. Overall, the direct cost of buildings was 3.4% of GDP while the indirect costs were 3.1%. Although this is not a measure of environmental or social impact, it does provide a relative indication of the material and energy requirements for direct and indirect construction of buildings.

The location of a building or development will also impact on the energy and material requirements over the building lifespan. Transportation requirements for shopping, employment or education, energy requirements for water and wastewater services and loss of energy over power lines are all affected by the distance of the building from services (Hartkopf and Loftness, [22]). The sprawled out character of many urban sites in the US, Canada, Australia and New Zealand result in higher consumption of energy and materials; in addition, the tendency towards longer commuting distances even in Europe is also increasing energy consumption and requiring upgrades in infrastructure services. Hartkopf and Loftness (1999) point out that while cities in the US are expanding outwards, the inner cities are being neglected and losing population while the costs for infrastructure and the loss of arable land are increasing.

Another major factor is the increasing use of land for urban and industrial development. Frequently, the land used is arable, thus removing prime agricultural land from production. Agricultural and grazing requirements are then met through clearing of marginal lands, resulting in loss of ecosystems and biodiversity. Urher (1999) states that urban and coastal development in Australia has resulted in land degradation and erosion, surface and ground water pollution, as well as land clearing required for new developments and the acquisition of more agricultural and grazing land further inland where the rain pattern is irregular and the quality of soil inferior.

The selection of building sites is not usually up to the architect or builder – the decision is that of the local council and the developer or landowner. Yet, when considering the sustainability of buildings, the location must be considered as it obviously has a major impact on the environment. Both architects and builders need to provide input into local planning and decision making if they are to seriously consider building sustainable buildings.

6. Social and cultural aspects of buildings

Within the concept of sustainability, both social and cultural aspects must also be considered. Jackson [23] identified the influence of design of buildings and grounds, neighbourhoods, and towns/regions on aspects of physical and mental health, and social and cultural vibrancy. She emphasised the requirement for 'cross-disciplinary collaboration in urban planning and design, and the participation of residents in shaping their living environment.' Greenery and access to it visually and physically were identified as principal keys to health, elements which must be incorporated into relatively high-density neighbourhood designs. These designs include public

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[21] Hendrickson, C. and A. Horvath, 2000. Resource use and environmental emissions of U.S. construction sectors. *Journal of Construction Engineering and Management*, 126(1).

[22] Hartkopf, V. and Vivian Loftness, 1999. Global relevance of total building performance. *Automation in Construction 8 (1999):377–393.*

[23] Jackson, L., 2003. The relationship of urban design to human health and condition, *Landscape and Urban Planning, In Press, Corrected Proof, Available online 24 December 2002*

buildings, open space, mixed land use, and pedestrian walkways to increase physical exercise and enhance civic life. Existing urban infrastructure must contain neighbourhoods to provide larger cultural and business opportunities and reduce reliance on the automobile.

Cultural design is also important and frequently ignored, particularly when architects, developers and builders import concepts into an area. Florides et al. (2001) assessed the consumption of energy by traditional Cyprus houses, imported Western designed houses and insulated houses. They found the traditional house design to be more efficient in its energy use and equivalent to an insulated house in comfort while the imported design performed poorly in the Cyprus climate. Moreover, traditional buildings were often constructed from local materials, giving them an aesthetic harmony with the local environment.

Selah examined the evolution of planning and design in Saudi Arabia and found that with a move towards modernisation there was a loss of how cultural and social aspects were implied in vernacular architectural and urban forms – that architectural and urbanism had been traditionally viewed as more than an agglomeration of buildings and streets (Saleh, [24]). Residents valued features of modern village extensions and landscape elements enhanced the interaction with the physical environment but there were elements of the vernacular villages and landscape that people regretted losing, such as `qasabahs', weekly markets, cultivation of terraces, etc. (Saleh, [25]). He also points out, in an evaluation of the architecture of Arriyadh, that 'in a city without character, it is almost impossible to talk about value, and any kind of creative or critical manifestation is destined to be absorbed in the void of relativism.' (Saleh, [26]).

Both the architect and the builder need to recognise the quality of traditional urban and building designs and their function within the local society, culture and living conditions (climate, weather extremes, environmental conditions, local building materials etc.). Some traditional designs use woods which are resistant to local insect infestations rather than more commonly imported softwoods such as pine. The use of such materials should be used to encourage the sustainable management of local resources, including the growth of traditional, local timber, rather than exotic pine plantations. Moreover, urban design needs to consider overall social and cultural function and specific building design should be in harmony with such a function.

7. Sustainability of Buildings

The sustainability of buildings therefore requires more than a simple focus on energy consumption over the lifespan of the building. An integrated urban management system is essential (Table 3), with local councils defining acceptable areas for development such as inner cities and marginal lands; urban population strategies to manage density and overall city population; provision of effective infrastructure for long term management with an emphasis on maintaining existing systems rather than increasing them; requirements for developers to meet urban and architectural design standards, take cultural and social concerns into account and use existing infrastructure capacity in life-cycle building design; facilitate the use, reuse and recycling of local materials rather than imported materials and work with local building material suppliers to provide quality timber to the local market.

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[24] Saleh, M., 2001. The Changing Image of Arriyadh City: The Role of Socio-cultural and Religious Traditions in Image Transformation. *Cities 18(5): 315-330.*

[25] Saleh, M., 2001. The decline vs the rise of architectural and urban forms in the vernacular villages of southwest Saudi Arabia. *Building and Environment 36(1): 89-107.*

[26] Saleh, M., 2000. The architectural form and landscape as a harmonic entity in the vernacular settlements of Southwestern Saudi Arabia. *Habitat International 24(4): 455-473.*

Table 3. Estimates of potential reductions and improvements through changes in current building management

Activity	Potential Reduction
Planning	
Increasing urban density	50-90% energy and impacts
Development on marginal lands	40-50% improvement in crop production; reduction of erosion
Integrated urban and architectural design	Improvement in building value
Incorporation of green and open space	Improvement in building value; human health
Human powered transportation	90% energy; improvement in human health
Establishment of mixed growth managed forest to supply industries	50-80% in energy and impacts
Construction	
Passive solar power	50-90% energy
Local source of materials	50 – 80% impacts and energy
Use of low emergy materials	50 – 80% energy
Recycling/reusing materials	40% energy; 10-50% impacts and materials
Water tanks, composting toilets	80-90% external water and energy
Operation	
Low energy, low water appliances	20-50% energy and water
Use of human powered transportation	90% energy; improvement in health
Minimising water and energy use	10-20% energy and water
Maintaining and refurbishing buildings	50-80% over 200 years

Builders, architects and developers need to work with local councils to understand and meet the local needs and limitations of the environment, incorporating passive solar heating, water tanks and composting toilets into designs; reducing or eliminating external water or energy requirements; using local and recycled materials wherever safe and possible and minimising the use of materials with low energy or impact on the environment. Building owners also need to have input into the system and recognise the need for refurbishment and maintenance rather than rebuilding or construction, use of low energy and conservation appliances and measures and accept and value local and recycled materials.

Overall, the system must function within its long term capacities. The land itself should define the limitations of urban sprawl, with priority being given to agricultural land and green space, provision of a vibrant, inner city life and a focus on human powered transportation. The materials that are needed for construction should be primarily derived from wastes from demolished buildings and local, recyclable or renewable materials. Use of water and energy must be limited to locally available sources and infrastructures, without damaging surrounding ecosystems and, if possible, regenerating those which have been negatively affected.

8. Tools to achieve sustainability

The CIB Working Commission (Bourdeau, Huovila, Lanting and Gilham,[27]) identified a number of recommendations towards achieving sustainable construction:

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[27] Bourdeau, L., P. Huovila, R. Lanting and A. Gilham, 1998. *Sustainable development and the future of construction*. CIB report publication 25, CIB Working Commission W82, 1998. available at http://bativille.cstb.fr/CIB_Reports_pdf/Synthesis.pdf (May, 2003).

- 'Building owners and clients should have a very important role in disseminating sustainable construction since they represent the demand of the building sector;
- ·Initiatives which involve planning, industry and constructors through adapted regulations, standards or fiscal measures and incentives;
- Education and training which should be largely used to have sustainable development concepts well known and accepted by all people;
- Developing a common language;
- Designers adopting a more integrated approach to design;
- Manufacturers of building products assessing the life cycle considerations as the basis of product development;
- Building users should see the environmental issues as one aspect of productivity;
- Building maintenance organisations should see environmental consciousness as a factor of competitiveness;
- The development of adapted tools to help in decision making;
- The improvement of the building process itself.'

Many of the tools needed to assist planners, builders and consumers in achieving sustainable buildings are now being developed. GIS systems are proving valuable as planning tools to define, map and manage local regions, including sensitive ecosystems, land uses, soil types, urban densities, watersheds, infrastructure etc. They can also be used to map potential future scenarios, derived from modelling changes to ecosystems, land use, water consumption etc. and thus providing planners with an understanding of the local limitations to growth and, therefore, to planning.

Life cycle assessment is being used to further identify the life cycle impacts of buildings. Peuportier [28] found it to be difficult to use life cycle assessment (LCA) to determine which building materials should be used but LCA was useful in determining the technologies which were suitable. Further research is needed on local levels to identify the best options for materials, technologies, construction methods and designs which are suited to local climates, materials and infrastructure limitations.

New building materials and technologies are being developed but their life cycle impact on the environment is often unclear. Some manufacturers are providing assessments of the LCA of their products, making it easier for builders and consumers to make choices. Overall, the major issue currently is energy, particularly for transportation; research is ongoing to reduce transportation energy requirements and the reliance on fossil fuels.

At this point, few, if any, sustainable buildings have been constructed outside of the developing world. Most buildings require a variety of materials, technologies and appliances that use fossil fuels for extraction, production or transportation. In some cases, local planning rules prevent residents from using rain water for drinking purposes, thus requiring all buildings to use local infrastructure and therefore increasing energy and material requirements. Such rules actively discourage achieving sustainability.

There is a slow movement, however, towards the concept of sustainable buildings, particularly in Europe. Over the next ten years, a greater understanding of local limitations and requirements will enable councils to manage their areas as systems, rather than in the piece-

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[28] Peuportier, B., 2001. Life cycle assessment applied to the comparative evaluation of single family houses in the French context. *Energy and Buildings 33 (2001):443-450.*

meal manner usually found in councils today. Hopefully, this will mean that local suppliers will recognise the need for recycling materials and councils will provide support for use of such materials. Local regulations will ensure that the use of water, energy, land and materials is within the capacity of the area. This will enable engineers, architects and others involved with buildings to better make decisions for design and construction of sustainable buildings.

The following checklist is designed to ensure that sustainability aspects are taken into account at the design stage.

9. Sustainable Buildings Checklist

1. Have you considered the embodied energy or emergy for materials proposed for the building is as a major indicator of environmental impact? ☐

2. Are you using life cycle assessment techniques to identify the best options for materials, technologies, construction methods and designs which are suited to local climates, materials and infrastructure limitations? ☐

3. Have you assessed the impact on the environment from pollutants, energy consumption, water consumption, land degradation/consumption, resource consumption, waste production and loss of biodiversity incurred throughout the life cycle of the building, from raw material extraction, processing, construction, building operation and demolition? ☐

4. Have you considered alternative methods of achieving the same result, which will minimised these impacts and be more sustainable? ☐

5. Is it possible to use any recycled materials such as paving, timber or metals? ☐

6. Have you considered the maintenance feasibility and ongoing costs over the lifespan of the building? ☐

7. Have you chosen a suitable design life for the building and assessed durability factors – the design, construction methods, materials, purpose of the buildings, its aesthetics and the owner, over the selected life? ☐

8. Have you considered the degree of self-sufficiency of the building with regard to energy and other services such as water and waste? ☐

9. Have you designed the building to current or anticipated standards for energy efficiency, including any appliances that use energy? ☐

10. Have you considered the indirect impacts to the environment and to society of the building? e.g. infrastructure requirements, local services, land use changes that affect ecosystems, biodiversity and watershed integrity? ☐

11. Have you considered the location and occupant density of the building with regard to sustainable transport options, now and in the future? ☐

12. Can you provide input into local planning and decision making to encourage the serious consideration of sustainable building design? ☐

13. Does the urban design consider overall social and cultural function and is the specific building design in harmony with such a function? ☐

14. Are you using local materials in preference to those imported or transported long distances? ☐

Sustainable Energy in New Zealand

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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1. Summary

Energy plays a crucial role in the economic and social development of all people and New Zealanders are more dependent on energy than many people in the world. Visionary energy policies are essential to facilitate sustainable, affordable economic and social development.

Engineers need to be in the forefront of efforts to mitigate and prevent adverse local and global impacts from energy generation, transmission and use on human health and all living things in the environment. The climate change implications of increased atmospheric concentrations of greenhouse gases are of particular significance to all people in the world. This paper does not include specific information on transport energy as that is the topic of another paper in this series.

The objective of this paper is to present an action framework to assist engineers to:

1. Promote sustainable energy initiatives that will help ensure the survival of living species and support positive economic and social developments;
2. Encourage and prioritise the rational use of energy, energy efficiency and renewable, clean, safe and sustainable energy technologies;
3. Encourage relevant research, development and commercialisation of innovative technologies, information exchange, training, consultancy, monitoring, planning and by bringing adequate financial resources to sustainable energy issues;
4. Support action that ensures sustainable energy services are available in quantities that are sufficient for all human beings to satisfy their survival and development needs.

2. International Perspectives on Sustainable Energy & Climate Change

In 1999, a report "Ethics of Energy" by a sub-committee of the UNESCO World Commission on the Ethics of Scientific Knowledge & Technology[1] defined sustainable development as:

"Sustainable development, meaning the use of our planetary resources for the well-being of all its present and future inhabitants, has become the concept which must guide both individual and collective action at every level and national and international policies."

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[1] World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) Sub-Commission on "The Ethics of Energy" (2000), UNESCO Headquarters, *Report,* 2-3 November 2000.

The report's conclusion was that access to adequate sources of energy is no longer a matter of maximising supplies for more and more people, it is also a matter of social, environmental and future equity. Discoveries of new supplies of traditional commercial energy resources – mainly fossil fuels – have peaked, and future fossil fuel supplies will become scarce and more expensive. There is now a widely accepted awareness of the atmospheric, climatic and environmental consequences from the burning of fossil fuels.

Renewable energy resources are those that can be utilised at a rate which allows for their replenishment, through natural processes, within reasonable time-scales. Fortunately, the underlying sources of most renewable energy are the sun, the action of gravity, the earth's rotational forces and internal temperature. The growth of plant material, or biomass – from photosynthesis of sunlight – is another renewable source. These resources are not in short supply, although there may be a restriction of the rate at which they may be harvested. These resources are the basis for a sustainable energy future for humanity on the Earth.

However a significant and courageous effort by political and community leaders will be required to redirect our direction toward a sustainable energy future. New Zealand, like the rest of world, will need to adopt new ways of thinking about energy for this shift in direction to occur.

Studies over the past decade have confirmed that the climate warming trend is continuing. The ten warmest years in recorded weather history have taken place since 1987. The world is experiencing what the global warming models predict. The physical evidence includes retreating glaciers, melting permafrost in Alaska, and many more severe weather events. Even the Pentagon has issued a warning that global warming, if it takes place abruptly, could result in a catastrophic breakdown in international security. They suggest that wars over access to food, water, and energy would be likely to break out between states.

Even if climate change impacts happen more gradually, recent studies have argued that as many as one million plant and animal species could be rendered extinct due to the effects of global warming by 2050. A recent report by the world's largest reinsurance company, Swiss Re, predicted that in 10 years the economic cost of disasters like floods, frosts, and famines caused by global warming could reach $150 billion annually. Accelerating the development of a portfolio of new technologies could stabilize greenhouse gas concentrations, enhance global energy security, and eradicate energy poverty.

We urgently need the technical expertise, political will and international cooperation to make sustainable energy a reality. Engineers need to be leading the discussion and action on this issue.

3. The New Zealand Context

Around 29% of commercial consumer energy used in New Zealand is supplied from renewable energy sources, but the efficiency of use of energy in New Zealand is poor.

In 2000, the Government published an overall energy policy framework that committed NZ to achieving a sustainable and efficient energy future. This policy commitment also included an objective of ensuring that the delivery of energy services to all classes of consumer was done in an efficient, fair, reliable, and sustainable manner. [2]

This overall policy framework declares that energy services must aim to achieve:

- environmental sustainability,
- a continuing improvement in our energy efficiency, and
- a progressive transition to renewable sources of energy,
- costs and prices to consumers to be as low as possible,
- prices to reflect the full costs of supply including environmental costs,
- reliable and secure supplies of essential energy services, and
- fairness in pricing, so that the least advantaged in the community have access to energy services at reasonable prices.

In 2001 the Government's Energy Efficiency and Conservation Authority (EECA) published a National Energy Efficiency & Conservation Strategy (NEECS) for moving New Zealand toward a more sustainable energy future. [3] This strategy established two targets as a mechanism to measure progress and confirm that New Zealand was heading in the right directions. The first target was for a 20% improvement in energy efficiency and the second target was to increase the contribution of renewable energy by 30 Petajoules. These targets will need to further tightened if the overall goal is to be achieved.

The Government's Climate Change Goal is *"..that New Zealand should have made significant greenhouse gas reductions on business as usual and be set towards a permanent downward path for total gross emissions by 2012."* [4]

Government has also ratified the Kyoto Protocol and is committed to reducing New Zealand's greenhouse gas emissions back to below 1990 levels. To help reflect the full environmental costs, Government is implementing programmes to help change the direction on our energy future. The imposition of a carbon tax from 2007, and the distribution of carbon credits to developers of new renewable energy has already started. Whilst these Government policy positions are a good beginning, there will need to be concerted action by everyone, particularly engineers, if the country is to move significantly toward the overall goal of a sustainable energy future.

Unfortunately projections about the current energy future for New Zealand - from the Ministry of Economic Development (MED) [5] - show an ever-increasing demand for more fossil fuels. The current reliance on global energy markets to meet the demand for energy in New Zealand is inherently unsustainable.

Future primary energy requirements for New Zealand - from the MED model - are shown below. The solid lines show the Reference Scenario from the 2003 Energy Outlook report. The dotted lines show the corresponding projections from the 2000 Energy Outlook report.

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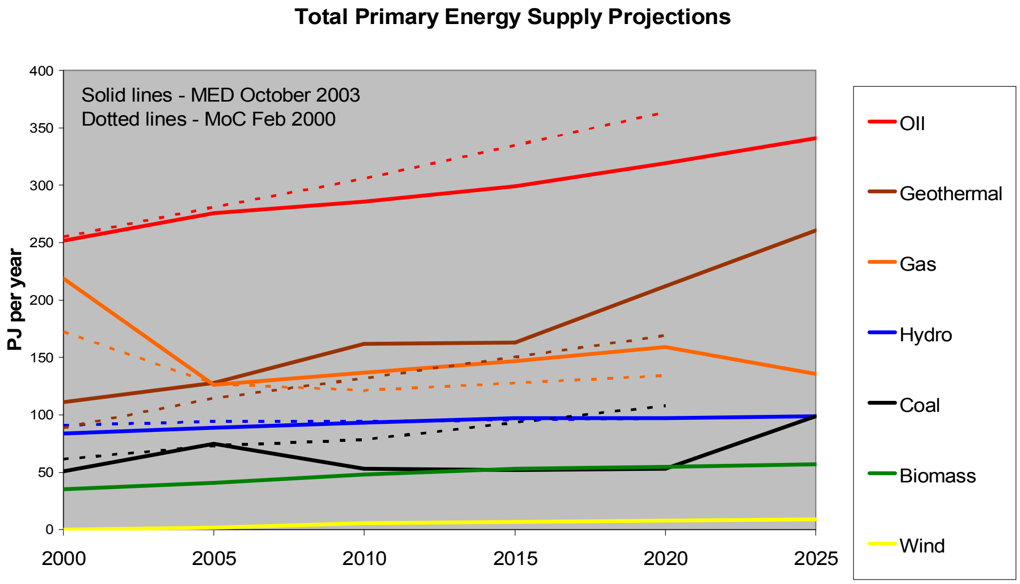
[2] New Zealand Energy Policy Framework, http://www.med.govt.nz/ers/electric/package2000/epf.html

[3] National Energy Efficiency & Conservation Strategy, http://www.eeca.govt.nz/default2.asp

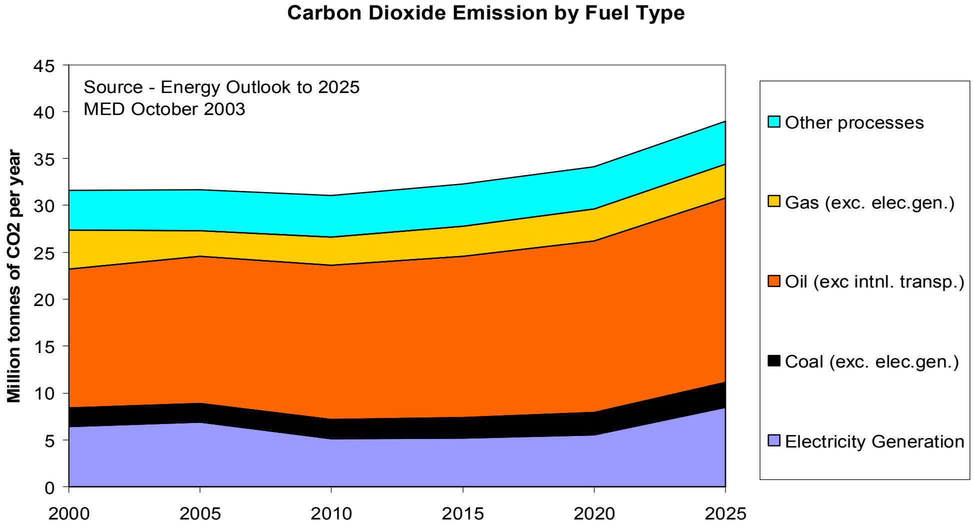
[4] Climate Change Policy in New Zealand, http://www.climatechange.govt.nz/policy-initiatives/

[5] New Zealand Energy Outlook to 2025, Ministry for Economic Development; Nov 2003, http://www.med.govt.nz/ers/en_stats/outlook/index.html



This MED graph shows a steady continuous rise in oil demand (primarily due to increasing demands of the transport sector). The natural gas primary energy resource line reflects the early depletion of the Maui gas field followed by a steady increase in gas use as Pohokura, Kupe and new gas discoveries are exploited. Beyond 2020 the MED economic model projection assumes an increase in gas price towards that of imported LNG and its replacement by coal as a fuel for electricity generation.

There are no stated assumptions in the 2003 Energy Outlook about the uptake of renewable energy. Their output is projected by economic analysis using MED assumptions on the costs of new generation. The increase in wind generation is projected to be about 10% pa over the outlook period. This outlook does not specifically address the impact of policy changes or the introduction of new and emerging energy technologies, although the effect of the carbon charge in 2007 is included.
These fossil fuel use projections in the MED 2003 Reference Scenario would result in CO_2 emissions of 39 million tonnes by 2025, as shown in the graph below.



The upward trend in CO_2 emissions, is dominated by the use of oil in the transport sector. This figure shows that CO_2 emissions in 2010 are a minimum with steady increases thereafter. The MED economic assessment model takes account of the impact of a carbon charge on the basis of $15 per tonne of CO_2. However, no assumptions are made about other measures that might be required to address climate change beyond the First Kyoto Protocol Commitment Period.

To change direction from the pathway set out in MED's 'Energy Outlook to 2025' to a more sustainable energy future, New Zealand will require widespread adoption of a changed way of thinking about energy. A recent commentator, Steve Goldthorpe [6] stated "Instead of being considered only as a tradable commodity, energy supply and its infrastructure need to be considered a privilege available to our generation that must be handed down in good shape to future generations. A practical energy strategy to take New Zealand forward to a sustainable energy future needs to be developed and then the policies and prices needed to facilitate the change to that regime need to be defined. The energy markets need to become the servants of the energy industry not its master."

4. An Energy End-use Focus

To achieve a sustainable energy future, New Zealand needs to find ways to control the demand for energy in a way that energy pricing alone demonstrably cannot deliver.

Suggested principles for minimisation of the impact of end-use demand on energy supply: -

- Match the application to its primary energy source (Take a holistic view of the path from end use to energy supply);
- Understand where energy is used via energy audits (Defining the problem is the first step towards solving it);
- Avoid use of energy where possible (It is ten times better to avoid a journey than to make that journey in a vehicle that is 10% more efficient);
- Locate renewable electricity generation as close as possible to the end-use of energy services (Dispersed energy resources are well suited to distributed generation);
- Where the end use requires low-grade energy for heating or drying then a low temperature energy source should be used (e.g. Solar water heating, recycling waste water heat to a cold water inlet, passive solar space heating);
- Only convert energy from one form to another where that conversion improves the usefulness of the output energy (e.g. direct use of gas for heating is preferable to the use of electricity generated from gas);
- With fossil fuel combustion use high temperature energy for a high temperature duty and residual low temperature part for a low temperature duty (e.g. combined heat and power schemes);

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[6] "2025 - Then What? - Can NZ achieve a Sustainable Energy Future?" Steve Goldthorpe – Energy Analyst, Presentation to the Sustainable Energy Forum Conference, UNITEC - Auckland - 15th November 2003.

- Consider combinations of energy sources (e.g. a low grade energy source for water heating, topped up by a high quality energy source);
- Provide high quality reliable electricity and power conditioning locally (isolate critical services for the general purpose electricity grid);
- Minimise the number of energy conversion steps (each time energy is converted from one form to another some of it is lost and losses compound together); and
- Value energy in proportion to its usefulness.

Implementing these ideas will help New Zealand move along the way to a sustainable energy future.

5. Implications for IPENZ Members and Engineers in General

IPENZ President's Sustainability Group recommends that the Sustainable Energy concepts and ideas, presented in this paper, are adopted by engineers for works and projects in which they are involved, and that IPENZ promotes these principles at every appropriate opportunity.

There a number of ways in which engineers and the engineering community can move New Zealand towards sustainability. The following checklist provides some guidance.

Sustainable Energy Actions Checklist

1. Have you supported the establishment of targets, programmes and other actions to reduce energy-related atmospheric emissions? ☐
2. Have you encouraged and used energy performance standards and labelling for energy using equipment and systems, based on international best practice? ☐
3. Establish of guidelines and methods of evaluation for determining the external effects and lifecycle costs and risks for energy systems, taking into account the environmental, health and other damage caused by energy-related activities. Make decisions based on these methods. ☐
4. Have you developed programmes for improvements in energy efficiency, safety controls, waste management and emissions reductions in the production, storage, transportation and consumption of all types of energy, and implemented them? ☐
5. Encourage the substitution of non-renewable energy resources by environmentally benign sustainable energy sources? ☐
6. Have you promoted the development of new financial instruments and investment mechanisms, including full life-cycle costing assessments, to encourage private and public sectors to invest in sustainable energy developments? ☐
7. Have you supported and promoted cooperation and exchange of technology, expertise, education, training programmes, information and statistics on the best sustainable energy technologies? ☐
8. Can you encourage performance monitoring as a vital element to achieve long term success? ☐
9. Can you support the re-introduction of “community service obligations” for utilities to ensure financing for enhanced research, development and demonstration of renewable energy technologies? ☐
10. Can you support sustainability linked tax incentives and subsidies to foster renewable energy utilisation? ☐
11. Support regulation of access to electricity networks to increase community interest in the decentralisation of power supply? ☐

Sustainable Transportation in New Zealand

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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Revised May 2004

1. Summary

Sustainable transportation is an appropriate goal for New Zealand and its engineering community. Sustainability means meeting today's needs without compromising the needs of future generations. This will have implications for the way we travel and the shape of our communities in New Zealand.

An increased focus on managing demand for motor vehicle transportation will be necessary, as opposed to traditional approaches to predict future trip demand based on historical growth trends and to then attempt to provide road capacity. As has been increasingly appreciated overseas, it will be futile in New Zealand to attempt to build our way out of congestion. Traffic expands to fill the available road capacity. In the not-too-distant future, a variety of techniques will be needed to manage traffic demand, including stronger land use planning to deter urban sprawl, congestion pricing and other road tolling techniques, parking supply management and pricing, fuel pricing and high occupancy vehicle lanes. These changes, some of which have already occurred, will encourage us to make the necessary changes in lifestyle and travel behaviour.

Currently, transportation generates about 40% of our carbon dioxide (CO_2) emissions, or 15% of all greenhouse gas (GHG) emissions. Transportation emissions are also the fastest growing source of GHG emissions in New Zealand. Air pollution from the motor vehicle fleet is also increasingly unsustainable.

A number of recent policy initiatives confirm that it is the government's intention that we as a nation become more sustainable in transportation. These initiatives include the New Zealand Transport Strategy (2002), the signing of the Kyoto Protocol (2002) and the Land Transport Management Act (2003).

Most western countries and their engineering communities have begun developing sustainable transportation policies and initiatives, including Australia, Canada and many countries in western Europe.

There are a number of ways in which engineers and the engineering community can move New Zealand towards sustainability in transportation. A checklist is included at the end of this paper as an aid for transportation practitioners and engineers in general towards achieving this goal.

2. Definitions of Sustainable Transportation

Sustainable development has been defined by the **Brundtland Commission**[1] as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Accordingly, sustainable transportation can be thought of as transportation systems that meet the needs of the present without compromising the ability of future generations to meet their own transport needs.

The Organisation for Economic Co-operation and Development (OECD) in a 2002 report entitled **OECD Guidelines towards Environmentally Sustainable Transport** noted that[2]:

> "A sustainable transport system is one that throughout its full life-cycle operation:
>
> 1. allows generally accepted objectives for health and environmental quality to be met, for example, those concerning air pollutants and noise proposed by the World Health Organization (WHO);
> 2. is consistent with ecosystem integrity, for example, it does not contribute to exceedence of critical loads and levels as defined by WHO for acidification, eutrophication and ground level ozone; and
> 3. does not result in worsening of adverse global phenomena such as climate change and stratospheric ozone depletion"

The **Centre for Sustainable Transportation**[3] (in Canada) defines sustainable transportation more widely as:

> "A sustainable transportation system is one that:
>
> - allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
> - is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
> - limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise."

This definition differs from the OECD definition in that it recognises the social, cultural, economic and environmental aspects of sustainability inherent in the Brundtland Commission definition. The OECD definition relates to a rather narrower concept, environmental sustainability.

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[1] The World Commission on Environment and Development (Brundtland Commission) 1987

[2] http://www1.oecd.org/publications/e-book/9702191E.PDF

[3] http://www.cstctd.org/CSTadobefiles/Definition%20Vision%20English%20Oct%202002.pdf

3. New Zealand Aspects of Sustainable Transportation

Greenhouse gas emissions from transportation are just one aspect of sustainability, but they provide a useful indicator of New Zealand's sustainability (or otherwise) in transport. Motor vehicle use is New Zealand's fastest growing and to date least controllable major source of greenhouse gas (GHG) emissions. Road motor vehicles produce over 11 million tonnes of carbon dioxide (CO_2) annually, about 40% of our carbon dioxide emissions and 15% of our GHG emissions[4].

After enteric fermentation (methane emissions from domestic livestock), land transport is the largest source of GHG emissions in New Zealand. It is also the fastest growing, accounting for 18% of the growth of GHG emissions over the 1990 – 2001 period. Thus nationally, road transport should be a significant focus in New Zealand's efforts to become more sustainable.

Aviation, by comparison, contributes only 1% of GHG emissions and 1.5% of the growth. Nevertheless, air travel still produces many times more GHG emissions per person kilometre of travel than cars, and is thus much less sustainable than car travel on a per person kilometre basis.

In November 2003 the **Land Transport Management Act** (LTMA) was passed. It attempts to provide a more balanced approach to land transport projects, and places increased emphasis on multi-modal transportation systems and solutions.

New objectives for Transfund New Zealand (Transfund) and Transit New Zealand (Transit) are to allocate resources, and operate the state highway system, to achieve an "integrated, safe, responsive and **sustainable** land transport system".

To further enhance a long-term and strategic focus, Transfund and organisations approved to get funding from Transfund, including Transit, will be required to prepare ten-year financial forecasts. The LTMA enables the Minister to give Transfund and Transit annual instructions relating to the government's priorities for land transport funding.

The LTMA allows regional councils to fund, and both own and operate, public transport infrastructure and services unless prohibited by Order-in-Council. Future work will look to make it easier for public road controlling authorities to work together. The LTMA also modifies the purpose of Regional Land Transport Strategies, which set out an integrated approach to managing land transport in each region, to be consistent with achieving a land transport system that is integrated, safe, responsive and sustainable.

The **New Zealand Transport Strategy**[5] (December 2002) also moves New Zealand in the direction of sustainability in transportation. This strategy outlines the government's vision for transport: that New Zealand has an affordable, integrated, safe, responsive, and sustainable transport system. The strategy also notes that:

> "Economic development, social cohesion and environmental improvements must be progressed in parallel. Transport decisions will need to reflect the wider government commitment to sustainability.
>
> "To ensure that transport is underpinned by the principles of sustainability and integration, transport policy will need to focus on improving the transport system in ways that enhance economic, social

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[4] New Zealand Climate Change Office (2003) **Climate Change – National Inventory Report New Zealand**, Wellington, pp 3-4. http://www.climatechange.govt.nz/resources/reports/nir-apr03/nir-apr03.pdf

[5] http://www.beehive.govt.nz/nzts/home.cfm

> and environmental well-being, and that promote resilience and flexibility. It will also need to take account of the needs of future generations, and be guided by medium- and long-term costs and benefits."

The **Ministry of Transport's Statement of Intent**[6] 2003 – 2004 (May 2003) states:

> "Sustainable Transport is the Ministry's vision. As the government's principal transport advisor, we will continue to identify solutions with longer-term benefits. Decisions will be based not only on monetary costs and benefits, but will also take into account the social, regional, economic, health and environmental impacts of all projects."

New Zealand ratified the **Kyoto Protocol** on 19 December 2002, confirming its commitment to managing greenhouse gas emissions. The New Zealand Climate Change Office[7] identifies the following issues under the Transport theme:

> "The number of vehicles in New Zealand is increasing rapidly. Since 1960 the number of registered vehicles has more than trebled. About 40% of our carbon dioxide emissions come from transport – mostly private cars – and transport is one of the biggest growth areas of New Zealand's greenhouse gas emissions. These emissions are causing Earth to warm at an unprecedented rate and the climate to change.
>
> "The New Zealand Transport Strategy defines the Government's vision of an affordable, integrated, safe, responsive, and sustainable transport system by 2010. One of its aims is to ensure environmental sustainability – policies will encourage usage of more energy efficient modes of transport and contribute to reducing greenhouse gas emissions from the transport sector.
>
> "We have come to rely on cars as a quick and convenient way of getting from place to place, but we need to reduce the number of cars on the road. Ways to do this include:
>
> - Use public transport and walk or cycle more often.
> - Car pool when possible.
> - Do you really need that second car? Consider upgrading your bicycle instead.
> - Set concrete goals at home and at work for reducing your travel.
> - Choose a place to live where you can drive less.
> - Consider telecommuting and video conferencing as options to reduce the need to travel.
> - Make use of a Walking School Bus[8] if available in your area."

According to **Getting there – on foot, by cycle**[9], quoting the New Zealand Travel Survey (1997/98):

> - "Thirty percent of trips undertaken by mechanised transport (private motor vehicles, public transport, and bicycles) are for distances of under two kilometres.
> - Sixty percent of trips are under five kilometres in length."

There is clearly scope for some of these trips to be undertaken by more sustainable modes of transportation.

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[6] http://www.transport.govt.nz/publications/soi_0304/index.shtml

[7] http://www.climatechange.govt.nz/

[8] http://www.eeca.govt.nz/default2.asp?target=content%2FTransport%2Ftransport_wsb.htm

[9] The draft New Zealand Walking and Cycling Strategy (October 2003): http://www.transport.govt.nz/business/land/getting-there/index.shtml

4. Overseas Perspectives

In **Western Australia**, the government is developing a sustainability code of practice for government agencies and their employees. Amongst other things, it recognises the significance of transportation in the sustainability debate:

> "Agencies shall ensure that … the number of vehicles are minimised, vehicle use is reduced, fuel efficiency is maximised and travel alternatives are promoted."

There has been considerable sustainable transportation policy development work done in the **United Kingdom** including work on "travel plans" for schools and businesses, for example. The National TravelWise® Association (NTWA)[10] is "a partnership of local authorities and other organisations working together to promote sustainable transport". "Car share" schemes are increasingly common in the UK and Europe, where cars are communally owned and rented by the hour or day as necessary by members of the group. In this way, typically ten people own a car. (In New Zealand, ten people on average own five cars.)

In London, a congestion charging programme was introduced in February 2003 in a major initiative to combat traffic congestion. The scheme, which is widely regarded as being highly successful, charges motorists £5 per day to enter or park on a street in the central part of London. The area covered by the scheme is 22 square kilometres. For comparison, Auckland City (part of the greater Auckland metropolitan area) has an area of 60 square kilometres and a population of about 400,000 people (making it New Zealand's fourth most populous city).

From the **United States of America**, "Natural Capitalism" (written by Paul Hawken, Amory Lovins and Hunter Lovins and published by the Rocky Mountain Institute in 1999) devotes a chapter to transportation[11], noting that:

> "A fleet of 200 mpg, roomy, clean, safe, recyclable, renewably fueled cars might keep drivers from running out of oil, climate, or clean air, but they'd instead run out of roads, land, and patience—the new constraints *du jour.* Many of the social costs of driving have less to do with fuel use than with congestion, traffic delays, accidents, roadway damage, land use, and other side effects of driving itself. Those social costs approach a trillion dollars a year—about an eighth of America's gross domestic product. Because that figure is not reflected in drivers' direct costs, the expenses are in effect subsidized by everyone."

In the USA, many agencies are using the "parking cash out" system. Employers that offer free or subsidised parking to employees can implement parking cash out. Under a parking cash out programme, an employer gives employees the choice of keeping a parking space at work, or accepting a cash payment and giving up the parking space.

High occupancy vehicle (HOV) lanes (where lanes on motorways or arterial roads are reserved for use by buses and cars with three or more people) are also in widespread use in the States and Canada. Variants of this such as high occupancy toll (HOT) lanes (where not only are the lanes reserved for these vehicles but users also pay for the use of the lane) are also in use.

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[10] http://www.travelwise.org.uk/index.shtml

[11] http://www.natcap.org/images/other/NCchapter2.pdf

The Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) has developed a Primer on Sustainability[12] to raise knowledge of sustainability amongst its members. One section of this is devoted to sustainable transportation. It is a very comprehensive piece of work (over 40 pages) and is recommended as background reading for New Zealand engineers and others interested in sustainable transportation.

The Centre for Sustainable Transportation has developed a Vision for Sustainable Transportation in 2035 as follows:

> *"Focus on access*: In a society in which transportation is sustainable, people have at least as much access to goods, services, and social opportunities as they have today, particularly people who are economically disadvantaged or who face unusual physical challenges. But the ways in which this access is achieved may be quite different.
>
> *"Non-motorized transportation*: Much more of the access depends on widespread use of nonmotorized means of transport for persons, particularly in urban areas. This is possible because living and working arrangements have become much more compact. Walking, bicycling, rollerblading, and other non-motorized modes have become much more acceptable and agreeable.
>
> *"Motorized transportation by current means*: Some access depends on motorized transportation systems that are similar to those of the early 2000's but use very much less energy and pollute much less. There is more public transport, because it is encouraged by the layout and design of urban regions and because owning and using a car costs much more.
>
> *"Motorized transportation by potential means*: Some access depends on the use of quite different technologies from those in common use today. They might include fuel cells using renewable resources such as hydrogen produced with solar energy, intelligent transportation systems, automated highways, maglev rail services, and airship technologies. Together they provide cleaner, more conserving, and safer movement of people and goods.
>
> *"Movement of goods*. The movement of goods utilizes modes of transport appropriate to the size and distance of shipment and to the minimization of resulting emissions. Shippers and carriers include environmental as well as financial goals in selecting the timing and mode of shipping.
>
> *"Less need for movement of people and goods*: Whatever the mode, journeys made by motorized transport are shorter on average than in early 2000's, for the movement of both people and goods in part because urban areas are more compact and have a good mix of uses. More access is achieved through telecommunications, with less movement of people or goods.
>
> *"Little or no impact on the environment and on human health*: The net result is dramatically lower local and global impacts of transportation on the environment. The impacts are so low they no longer provide reason for concern about people's health or any part of the natural environment, in the present or the future. In particular, emissions of carbon dioxide and other greenhouse gases from transportation are less than one fifth of the total of such emissions in the 1990s.
>
> *"Methods of attaining and sustaining the vision:* As well as changes in urban areas that facilitate collective transportation, bicycling, and walking, there has been and continues to be rigorous application of the full costs of transportation, supported by appropriate incentives and also by enforcement of standards for vehicles, fuels, and infrastructure.

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[12] http://www.sustainability.ca/index.cfm?Mid=481

> “*Non-urban areas*: While the opportunities for achieving sustainable transportation in rural areas may be different and perhaps more limited when compared to urban areas, Canadians living in rural areas can make a positive contribution towards transportation sustainability.
>
> “*Date of attainment*: Achieving the level of sustainability in transportation described above is believed to be achievable by about 2035. This does not preclude the possibility that much or all of transportation could be sustainable at an earlier date. In any case, setting and meeting performance milestones in the short and mid-term will be essential parts of the attainment of sustainable transportation in the longer term.”

5. Implications for IPENZ Members and Engineers in General

The policy framework is now in place for sustainable transportation to be implemented in New Zealand. Engineers have many opportunities to be involved in this process. They also have professional responsibilities to do so, as noted, for example, in the IPENZ Code of Ethics:

> “Members shall be committed to the need for sustainable management of the planet's resources and seek to minimise adverse environmental impacts of their engineering works or applications of technology for both present and future generations.”

Members of IPENZ and of its Transportation Group, and others engaged in transportation generally, are encouraged to learn what they can about sustainable transportation and apply it in their day-to-day actions at work and in other aspects of their lives. Much information is already available both from New Zealand and internationally. The engineering and transportation professions should lead the way and be seen to lead the way towards a more sustainable transportation future.

There a number of ways in which engineers and the engineering community can move New Zealand towards transport sustainability. The following checklist draws heavily on the work of the APEGBC, for which acknowledgement and appreciation are given.

6. Sustainable Transportation Checklist

1. Have you taken all reasonable steps within the scope of the project to reduce or manage demand for motor vehicle use, rather than "predicting and providing"? ☐
2. Can you support official commitment to alternative modes of transportation and mixed use development at the leadership or policy level? ☐
3. Can you use the success of other municipalities or public agencies to educate or inform a council or agency about sustainable transportation? ☐
4. Can you use your knowledge of sustainable transportation to educate and suggest alternatives (e.g. traffic calming and walking school buses near schools are safety issues as well as sustainable transportation issues)? ☐
5. Can you use your knowledge of transportation's link with land use to support service to alternative modes? ☐
6. Can you quantify and apply the real costs of car dependency to your project? ☐
7. Can you monitor key performance indicators for transportation sustainability? ☐
8. Can you purchase local materials instead of importing from other parts of New Zealand or overseas? ☐
9. Can you co-ordinate shipping or freight (e.g. bringing in trucks with solid waste and leaving with gravel)? ☐
10. Can you amend subdivision, engineering or zoning regulations to support alternative modes of development that are more sustainable for transportation? ☐
11. Can you set targets for minimising parking and impermeable surfaces in new developments? ☐
12. Can you support or initiate internal trip-reduction programs in the workplace? ☐
13. Can you lead by example by walking, cycling or taking public transport for some trips? ☐
14. Can you use telephone conference calls instead of face to face meetings requiring extensive land or air travel for some meetings? ☐

Sustainable Water in New Zealand

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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March 2004

> *"[Sustainable development] must inevitably involve multi-objective tradeoffs in a multi-disciplinary and multi-participatory decision-making process. I believe no single discipline, and certainly no single profession or interest group, has the wisdom to make these tradeoffs themselves. They can only be determined through a political process involving all interested and impacted stakeholders".* (Loucks, 2000). [1]

1. Summary

Sustainable development is a recognised goal for New Zealand. The engineering community have a significant role to play to help our nation achieve it. Careful management of our water resources will be critical in order to ensure the continued existence of our communities and our natural environment.

Water resource engineers have a crucial role to play in the sustainable management of water. Policy initiatives at central and especially local government levels confirm the need for more sustainable water systems and infrastructure. There a number of challenges and tasks that engineers and the engineering community must face and undertake in order to move New Zealand towards a more sustainable water sector. A checklist is included at the end of this paper to aid towards achieving this goal.

This paper is a working draft and comments for improvements are welcomed.

2. Introduction

Many countries are facing serious environmental and socio-political issues concerning their water resources. Examples include inter-country boundary conflicts, overpopulation, severely arid environments, and the need to invest in alternative water sources such as desalination, fog-collection or freshwater / iceberg relocation. Due largely to New Zealand's geographical, population, geological and climatic advantages compared to many other regions in the world, we are lucky enough not to have to directly address such issues, yet. If, in the future however, some of these issues need to be given serious consideration, it will reflect very poorly on New Zealand's water resource management and the sustainability of our water resources.

The need for sustainable water resources management was identified more than a decade ago at the Rio Earth Summit. It was here where the provision of integrated urban infrastructure services (including water supply, drainage and sanitation) was included as a key programme area in Agenda 21 to promote sustainable human settlement development (United Nations, 1992). When we consider that true sustainability involves designing for the long-term (that is, 1000+ years, as

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[1] Loucks, D.P. (2000). Sustainable Water Resources Management. *International Water Resources Association*. 25:(1), 3-10.

mooted by Tonn [2] and Boyle [3], we start to realise that concerns as listed above may become potential threats to New Zealand, especially in light of climate change issues and national growth. Beyond water supply issues, New Zealand has already been facing threats to our stormwater, wastewater and groundwater resources and infrastructure as these become increasingly outdated, overused and polluting.

The purpose of this discussion paper is not to explain in detail the reasons why sustainable water resources management is required in the New Zealand water industry but to accept, sustainability, as the political-social-environmental ethic by which future water resources management will be based and by doing so, present ideas and guidance as to the future role of engineers in shaping a more sustainable (or "less unsustainable" – James [4]) water industry.

3. Sustainability Thinking for Water Resource Engineers

The water resources development paradigm of recent years which has largely been driven by an ethic of growth, is now, in light of the impacts this growth has produced (e.g. degradation of ecosystems, removal of human settlements and cultural sites, disruption of sedimentation processes, contamination of water sources), stalled as social values and political and economic conditions have changed.

Engineers have traditionally described the water industry as being made up of three components and their respective infrastructure (i.e. "water services"): stormwater, wastewater and water supply. The current thinking in regards to sustainable management of water however is to manage water resources as one integrated system rather than separating these components from one another.

Given this new thinking, water engineers need to therefore be able to apply *process thinking* into their work. This means going beyond pure scientific thought, which tends to look at relationships between individual parts of a system and/or the individual parts themselves. Process thinking recognises that the whole is greater than the sum of its parts, and is about identifying how objects and their relationships contribute to a process, and how systems, objects and their relationships change to sustain the process over time. Process thinking is therefore temporally related and well suited as a thought paradigm for sustainability. Process thinking is also especially appropriate when comparing with what water engineers are ultimately trying to manage – the hydrological cycle which is a dynamic process not just a system made up of separate components that operate independent of each other.

New thinking in water resources management have recognised this link and developed the paradigm of Integrated Water Resources Management (IWRM) (International Water Association, 2002). This new thinking has developed out of the realisation that the current water paradigm is characterised by:

- A linear system of water use where water is sourced, used, polluted and disposed of; and
- A fragmented system of management where a single resource is managed as three separate elements (e.g. water supply, wastewater and stormwater)

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[2] Tonn, B.E. (2004). Integrated 1000-year planning. *Futures*. 36, 91-108.

[3] Boyle, C. (2004). Sustainability for Engineers. Paper prepared for IPENZ Task Committee on Sustainability, IPENZ.

[4] James, W. (1999). On smart, benign drinking water, wastewater, and stormwater infrastructure for a less unsustainable future – a personal vision. Paper presented at the Great Cities/Illinois-Indiana Sea Grant Urban Water Resources Conference, September 16-17, Chicago.

Engineers must also consider what sustainability in water infrastructure means within the local, regional and national contexts. One question that arises when considering water resources management and sustainability is, "when and where can sustainability be achieved?". Is it possible to develop sustainable water services on a specific site, sub-catchment or an entire catchment given that currently the surrounding local or regional contexts are likely to be unsustainable (i.e. upstream catchments contributing to stormwater flows at site; discharges from site connecting to 'less sustainable' systems)? It is certainly possible to implement "more sustainable" or "more ecologically-friendly" technologies and approaches at these sites or in catchments but until an entire region's water infrastructure is modified to reflect sustainability principles and address hydrological process issues, the ultimate aim of sustainable water resources will be impossible to realise.

While our current centralised and separated water services provide essential services for our survival, engineers needs to recognise that the continued operation of these existing systems is facing significant threats, not least of which is growth in demand. Sustainability does not necessarily mean replacing the existing systems completely, but will require adaptation, incorporating new approaches and technologies.

But what can water resource engineers do to practice sustainability principles in the meantime given that integrating a currently fragmented water infrastructure will take many years and considerable radical adaptation?

4. Sustainability of New Zealand Water Resources

A working definition of sustainable water use is provided by Gleick [5] as:

> *"..the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it ."*

"Beyond Ageing Pipes", a report prepared by the New Zealand Parliamentary Commissioner for the Environment (PCE) in 2002 [6], identifies sustainable urban water systems as having several key characteristics which cover the following measures:

- **Increase the efficiency** of water use, thereby reducing the need for new dams, pipelines and treatment plants;
- **Reduce wastewater** by decreasing total potable water supply, reusing greywater and recycling biosolids from wastewater treatment plants; and
- **Reduce stormwater** through better site design, with reduction in proportion of impervious surfaces, onsite collection use, and retention of natural streams and waterways.

PCE (2002) describes additional features of sustainable urban water systems which are:

- **sufficient water flows** allocated to natural and modified water systems in order to maintain ecosystem health;
- **water management and planning** involves consultation with the whole community of interest including residential uses, industry, tangata whenua, agencies, agriculture and recreational users; and

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[5] Gleick, P.H. (2000). The changing water paradigm. A look at twenty-first century water resources development. *International Water Resources Association.* 25 (1) 127 – 138.

[6] Parliamentary Commissioner for the Environment. (2002). Beyond Ageing Pipes: Urban Water Systems for the 21st Century. Wellington: Office of the Parliamentary Commissioner for the Environment.

- residents are guaranteed access to a minimum supply of potable water to maintain basic health.

The focus of the PCE report is on *urban* water systems with the understanding that smaller rural communities and townships (or 'greenfields') are potentially better placed to make the transition to sustainable urban water systems than larger urban areas that are constrained by a legacy of existing infrastructure. This is largely based on the assumption that these smaller communities will have sufficient finance, in-house knowledge, technology and motivation to achieve the desired sustainable systems which in most situations will not be the case. Many of the principles and issues outlined in the PCE report are therefore also applicable to suburban and rural communities also.

5. Influencing legislation and guiding documents

Water supply and use in our communities presents many diverse and competing interests. While water is a common good and community resource, it is also used as a private good or economic commodity; it is not only a recreational resource but also is a basic necessity of life; it is filled with cultural values, *mauri*, and plays an essential part in the social fabric of our communities. Gleick [7]believes that applying sustainable principles to water resource management and design will help to bridge the gaps between such diverse and competing interests.

The purpose of this section is to summarise the various documents and agencies that influence, restrict and/or encourage water industry engineers to incorporate sustainability principles into their work. The range of influencing documents has been listed under the following headings: Central Government; Local Government; Standards New Zealand; and Professional Associations and Educational Institutions.

5.1 Central Government

The water sector in New Zealand has no central government 'home'. PCE [8] recognises that the legislative framework for the management of water services is outdated and conflicting. There is no overarching Act which represents this sector, as there is for example, the building sector or transport section (e.g. Building Act or the Land Transport Act). Water engineers' work is therefore governed by central government policy and legislation that is largely fragmented, as illustrated by the various Acts regulating the water industry listed below.

- Resource Management Act 1991 – recognises and promotes the goal of sustainable management of natural and physical resources; requires that developments avoid, remedy, mitigate impacts on the environment; establishes a framework for resource consents for air, land, water discharges.

- Local Government Act 2002 – encourages sustainable development and requires Councils to "promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future" (Part 2, 10 (b)); territorial authorities are required to produce Long Term Council Community Plan (LTCCP) which have a long-term view (i.e. 10yrs).

- Rating Powers Act 1988 (replaced by Local Government Act 2002) – had no provision for local authorities to charge for wastewater by volume/contaminant loading except in respect of

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[7] Gleick, P.H. (2000). *ibid.*

[8] Parliamentary Commissioner for the Environment. (2002). *ibid.*

trade waste; no provision for local authorities to charge for stormwater by area of impervious area or for capital costs for new developments.

- **Local Government Act 1974 –** gives territorial authorities the right to control water supplies; no provision for local authorities to prepare a strategic water services plan (like a waste management plan).

- **The Health Act 1956 –** territorial authority to provide sanitary water source but lacks clarity regarding a framework for water delivery.

A number of central government Ministries and /or the Parliamentary Offices have also produced the following documents which are relevant to the water industry:

- **The Water Programme of Action** (Ministry for the Environment, November 2003)
  - "The programme initially consists of a number of projects within three separate strands covering water allocation, water quality and water bodies of national importance."

- **A Cultural Health Index for Streams and Waterways - Indicators for recognising and expressing Maori values** [9] (Ministry for the Environment, June 2003, MfE Number 475). A trial methodology to calculate the Cultural Health Index (CHI) incorporating the three aspects of traditional association, the mahinga kai (food gathering) measure and a cultural stream health measure.

- **Sustainable Development for New Zealand: Programme of Action** (Department of Prime Minister and Cabinet, January 2003).
  - One of the four key areas of action is 'Fresh Water'. Specific key programme elements include: *"Identifying better and more strategic ways of conserving and allocating freshwater from the resources available; Maximising the sustainable, efficient and effective use of freshwater".*

- **Beyond Ageing Pipes: Urban Water Systems for the 21st Century** (Parliamentary Commissioner for the Environment, April 2002).
  - One of the recommendations from this report was for *"all territorial authorities and water services providers to prepare an overarching water services strategic plan as a framework for the sustainable and integrated management of urban water systems".*

- **Sustainable Wastewater Management: A handbook for smaller communities.** (MfE, 2003).

- **Guidelines for the Safe Application of Biosolids to Land.** (DRAFT) (NZWWA, MfE, MoH, MoF, 2003)

- **Making Every Drop Count: The National Agenda for Sustainable Water Management – Action Plan** (Ministry for the Environment (MfE), 2000).

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[9] Ministry for the Environment. (2003). *A Cultural Health Index for Streams and Waterways. Indicators for recognising and expressing Maori values.* Report prepared for the Ministry for the Environment by Tipa. G., and Teirney, L., MfE Number 475, June 2003, Wellington, NZ.

5.2 Local Government

A large proportion of the work that New Zealand water engineers undertake relates to the water services that local government own, operate and / or manage. Therefore the majority of water engineers work within local government, for them or have to report to them (e.g. via resource consents).

Given the many examples of sustainable development rhetoric in local government policies, strategies, objectives and plans it would suggest there are vast opportunities for engineers to action the intents and visions of these documents. The fundamental question is, how, especially when there are many different agencies controlling the different water services? In many cases, it is the work of individual engineers, planners and asset managers at the local government level who are already enacting changes to the way water projects are prioritised and implemented. One avenue is certainly also for councils to remind and encourage engineers at every opportunity (and vice versa) to incorporate sustainable principles into their infrastructure designs, contracts and maintenance requirements, while producing budgetary and consultative allowances for these considerations (i.e. through requests for proposals, contractual arrangements, involvement at the policy/project decision-making stage). Examples of local government documents which promote and/or influence sustainability principles in water resources management include:

- Regional Policy Statements and Plans:
    - e.g. Auckland Regional Policy Statement (1999), *"…to promote the sustainable use of natural and physical resources; to manage the use of water to enable people and communities to provide for their present and future social, economic and cultural wellbeing…."*;
    - e.g. Proposed Auckland Air, Water, Land Plan (2001): *"to provide for the integrated and sustainable management of natural and physical resources";*

- District Council Plans and Strategies:
    - e.g. Waitakere City Comprehensive Urban Stormwater Management Strategy and Plan: *"To achieve a multi-disciplinary approach to address all aspects of stormwater management";*
    - e.g. North Shore City Strategic Plan: *"To implement sustainable, integrated water supply, stormwater and wastewater services that are in harmony with the natural water cycle.";*

- Infrastructure Design Standards / Codes of Practice:
    - e.g. North Shore City Council Infrastructure Design Standards (2003) - provides the engineering design requirements for all land development and new infrastructure projects within North Shore City; including stormwater, wastewater, water supply, as well as roads, geotechnical, parks, playgrounds. Latest version has included 'more sustainable' design options for stormwater management and wastewater designs (e.g. design requirements for raintanks, swales, raingardens etc and specific design features such as, reducing the number of manholes in wastewater systems to reduce stormwater infiltration volumes);
    - e.g. Waitakere City Stormwater Management Code of Practice (2002) – *"focused on implementing stormwater management solutions that mitigate against adverse effects on development";*

- Technical Publications:
    - e.g. Auckland Regional Council TP10 Stormwater Treatment Devices: Design Guideline Manual;

  - e.g. Auckland Regional Council TP124: Low Impact Design Manual (Stormwater Management); and
  - e.g. Waitakere City Council's Guidelines for Best Practice: Water Management.

5.3 Standards NZ

There are numerous codes, standards and guidelines that Standards New Zealand has produced relating to the field of water management. Some standards can present barriers to implementing more sustainable water infrastructure solutions by restricting the use of certain materials and/or setting strict design criteria, while others include reference to or allowances for more sustainable designs:

- NZS 9201 Model General Bylaws – these influence Local Authority By-Laws which in turn influence engineers' design work. Examples are:
  - NZS 9201.23 1999 – Trade Waste ;
  - AS/NZS 4271.1 2000 – Utilities;
  - NZS 9201.7 1994 – Water Supply;
  - NZS 9201.22 1999 – Wastewater Drainage; for example *"in order to meet the principles of sustainable management as promoted by the Resource Management act 1991 (RMA)…recommends a customer fits the devices contained in Table 1.1 on all new installations" (e.g. dual flush toilet cistern, low flow shower head, urinal flushing control);*
- NZHB 44:2001 – Subdivsions for People and the Environment;
- ISO 14000 – Environmental Management Systems; and
- ISO 9000 – Quality Management Systems.

5.4 Professional Associations and Educational Institutions

The various professional and non-governmental organisations that engineers belong to (including the organisation they work in) represent another area-of-influence for the promotion of sustainability principles. Examples of such groups include:

- New Zealand Water and Wastes Association (NZWWA) – a non-profit technical and educational organisation which aims to "*be the pre-eminent organisation in New Zealand for promoting and enabling the sustainable management and development of the water environment."* www.nzwwa.org.nz
- At a business, organisation or council level e.g. development of company-policy relating to sustainability principles; consider joining a 'sustainability-linked' organisation, for example the Sustainable Business Network, www.sustainable.org.nz
- Institute of Professional Engineers in New Zealand (IPENZ) – Code of Ethics; discussion papers on sustainability issues. www.ipenz.org
- New Zealand Society for Sustainability Engineering and Science (NZSSES) - a Technical Interest Group of IPENZ www.nzsses.org.nz
- Centre for Advanced Engineering - a not-for-profit organisation which aims to enhance engineering knowledge within New Zealand by technology transfer and the application of NZ and overseas research to engineering-related issues of national importance. www.caenz.com

In addition, the following list provides some website links to articles, projects, organisations etc that discuss sustainability in water resources management:

- International Water Association (IWA) - http://www.iwahq.org.uk/documents/sus/V_2_1.pdf [10]
- The Engineer´s Response to Sustainable Development (WFEO) - www.ecouncil.ac.cr/rio/focus/report/english/wfeo.htm
- Western Australia State Water Strategy - www.ourwaterfuture.com.au/community/statewaterstrategy.asp
- Murdoch University: Institute for Sustainability and Technology Policy – www.istp.murdoch.edu.au
- Sustainable Water: Uncertainty, Risk and Vulnerability in Europe - www.ncl.ac.uk/swurve/case4.html
- Association of Engineers and Geoscientist British Columbia (APEGBC) – www.sustainablity.ca
- The Dublin Statement on Water and Sustainable Development - www.wmo.ch/web/homs/documents/english/icwedece.html
- Integrated Water Cycle Management and Water Sensitive Urban Development (University of Newcastle) - http://rambler.newcastle.edu.au/~cegak/Coombes/CoombesKuczera.pdf
- USEPA Municipal Technologies - www.epa.gov/owm/mtb/mtbfact.htm

6. Water Resource Engineering in a Sustainable Society

6.1 Issues to consider regarding alternative technologies and approaches

This section discusses the issues associated with promoting and implementing alternative, "more sustainable" technologies, given that such alternatives are likely to be underrepresented at site and regional levels until there are significant changes to economic, political and regulatory incentives. Weaver et al [11] highlight the phenomenon of new technology being locked out of the marketplace by old technology and old technology being locked in. Not having sustainable technologies being here 'on the shelf' is a barrier to the general restructuring of incentives, while not having the incentives and framework conditions to make sustainable technologies viable means there is little business imperatives to develop such technologies. This "Catch 22" is one that many other industries are grappling with as they strive to implement more sustainable, or "less unsustainable" technologies.

Engineers who work at a site level are often constrained by economics, the desire of the client and particular physical constraints of the site which mean more sustainable options are frequently ruled out. On the other hand however there are water resource engineers who operate at a planning, infrastructure and asset management level, who are capable of having a much wider influence on the promotion of regional and district water infrastructure priorities.

It is also noted that sustainable technologies, unlike many other new technologies, rely on fundamental cultural, social and economic reform. All markets are socially constructed and markets are subject to potential reconstruction by societies and their representatives to achieve societal objectives. Nonetheless, the heavy dependence of sustainable technologies on market reconstruction to enable technologies to become cost-competitive makes for a special case (Weaver et al). Uptake of sustainable technologies is therefore also likely to take longer compared to other types of technology (such as the uptake of internet and email) because of this reliance on market reconstruction.

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[10] International Water Association (IWA). (2002). Industry as a partner for sustainable development: Water Management. United Kingdom: Beacon Press for the International Water Association and the United Nations Environmental Programme (UNEP).

[11] Weaver, P., Jansen, L., Grootvelf, G.V., Spiegel, E.V., and Vergragt, P. (2000). *Sustainable Technology Development.* Greenleaf Publishing, Sheffield, UK.

Replacements for technologies that are to be phased out or scaled down on the grounds of being 'unsustainable' must be capable of addressing multiple needs by fulfilling multiple functions. Such technologies will not come about however through incremental improvements of existing technologies, nor will they come about without a conscious, concerted and focused effort on the part of government, business and societal groups to tackle the issue strategically and systematically (Weaver et al [12]).

It is also important for water resource engineers to challenge the assumption that an alternative approach or technology is more sustainable just because it appears to be more environmentally-friendly or aesthetically-pleasing. Sustainable solutions and designs need to be more than just minimising adverse effects on the hydrological cycle or surrounding ecology and environment – sustainability is about a new way of thinking that includes all aspects of cultural, social, economic and environmental issues. Engineers are in a position to play a leading role in creating examples of what sustainable water infrastructure can look like and therefore providing practical steps towards more sustainable water resource practices.

While many water resource engineers are familiar with assessments including economics and environmental aspects, the inclusion of cultural and social criteria is a new concept. The cultural aspect is especially important for water infrastructure in New Zealand as the Maori perspective is different in its treatment of the interactions between people and nature. The Ministry for the Environment have developed a trial set of guidelines for calculating the Cultural Health Index (CHI) for streams and waterways [13]. The index includes three components:

- Traditional Association – Is there a traditional association between runanga (local Maori) and the site? Would Maori come to the site in the future?
- Mahinga kai features – How many mahinga kai (food and other resources) species are present? Are the species that were gathered in the past still here? Are the species accessible for gathering? Would Maori come to the site in the future?
- Cultural Stream Health - includes five indicators of catchment land use, use of riparian margin, use of river, river flow and water quality.

In addition, one of the major factors in the acceptability of different wastewater options is in the method of disposal of the treated water and solids. Discharge of wastewater effluent to streams, rivers, estuaries, harbours and the ocean has traditionally been used by most New Zealand cities that have been developed in close proximity to such waters. However, cultural issues associated with Maori spiritual values, together with the recognition that water re-entry systems often do not provide sound environmental performance, have shifted the emphasis away from water re-entry to land re-entry.

The social aspect of sustainable water includes more than merely including social criteria into the sustainability decision-making matrix. It includes a social process of decision-making. That is, more than just public consultation, but true participation by an active and informed public. The state of our water bodies are often very visible (e.g. oil and scum floating on the surface, discolouration from excess sediment) and hence very much in the public eye. For the engineer, this means educating the public in clear and simple language that the public can understand. This is especially difficult when grappling with the all-inclusive nature of sustainability.

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[12] Weaver, P., Jansen, L., Grootvelf, G.V., Spiegel, E.V., and Vergragt, P. (2000). *ibid.*

[13] Ministry for the Environment. (2003). *ibid*

The choice of different water technologies often leads to confrontation, polarization and indecision of stakeholders. This issue is often one of scale and personal preference. For instance, advances in new technologies are often at opposite ends of the scale of treatment. The challenge here is the choice of assessment criteria when comparing one technology versus another. In the area of the three-waters (stormwater, wastewater and water supply), examples of new technological advances at opposite ends of the scale are:

i) Wastewater – new, higher quality, individual treatment systems (replacement of the traditional septic tank) versus the "economies of scale" and new sophisticated centralised treatment plants;
ii) Stormwater – the benefits of at-source treatment methods versus a mature wetland at the bottom of the catchment;
iii) Water supply – the development of more strict drinking water standards versus the use of rainwater as non-potable (or potable) water use within the household.

Another issue relates to the short-term and long-term actions that can be taken in regards to integrated three-waters approach (including stormwater, wastewater and water supply). For instance, Weaver et al [14] found that when analysing five different water technologies, the greatest impact was found with a combination of innovations, a tailor-made solution based on sets of integrated measures. Weaver et al also found that most of these improved measures could be implemented today, as they depended less on technological innovation and more on organisational innovation. For instance, in many cases, the installation of rainwater tanks in the urban environment is only economically viable when including both stormwater and water supply benefits. However, for long-term sustainability, Weaver et al concluded that fine-tuning today's systems is not sufficient. Achieving major improvements in sustainability depends on defining a new strategic approach and on restructuring the water system using new criteria and insights.

6.2 Future priorities

Water resource engineers should first give attention to 'beginning of the pipe' solutions relating to the following areas:

- Water demand management and forecasting;
- Water resources management in relation to ecosystem needs;
- Efficient water use;
- At-source water collection, use, and treatment; and
- Decision-making that uses sustainability assessment and life-cycle analysis tools.

Accepting that the current piped systems (and the pipe paradigm) are here to stay for a few decades to come, there are opportunities to improve the performance and life of these systems using smart technology and new techniques. James [15] expects that future urban drainage systems will be retrofitted with real time control designed to support a pollution prevention strategy. Real time control could be used to reduce the number and duration of overflow events, reduce basement flooding, reduce downstream environmental impacts and monitor and enforce water quality. James predicts that by linking networks with Geographical-Information-Systems (GIS) data and accurate rainfall sensors, real-time information could be put "online" to enable water resources information and issues available to the general public and to counter the "out of sight out of mind" attitudes.

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[14] Weaver, P., Jansen, L., Grootvelf, G.V., Spiegel, E.V., and Vergragt, P. (2000). *ibid.*

[15] James, W. (1999). *ibid*

Greater material choice, smaller pipe sizes, improved construction techniques (e.g. shallow-buried, improved erosion and sediment controls), effective establishment and use of distributed storage, more efficient use of raw water, greywater, stormwater and potable water, greater use of renewable energy for pressurising flows where necessary, and new and improved maintenance techniques (e.g. using robots to access small diameter pipes) are all potential technological advances of the future which will improve the sustainability of our water resources.

Already in the New Zealand industry, software water management models are becoming the dominant decision-making tools for water infrastructure development, management and optimization. Developing models for integrated situations (i.e. stormwater, wastewater and water supply networks and systems), in accordance with Integrated Water Management good practice, will require models with superior technical correctness and capabilities to represent the complexities of these real situations. Further models that have the capacities to accurately build and model alternative systems (i.e. infrastructure beyond concrete pipes) will assist with future decision-making regarding ‘more sustainable’ options.

There are many ways in which water resource engineers and the engineering community can help move New Zealand towards sustainability. Parts of the following checklist draw heavily from the Hanover Principles by William McDonough Architects, [16] for which acknowledgement is given.

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[16] William McDonough Architects and Michael Braungart. (1992). *The Hanover Principles: Design for Sustainability.* New York: William McDonough Architects.

7. Sustainable Water Checklist

General Responsibilities for Water Resource Engineers:

1. Do you understand the concept of sustainability, the holistic-thinking it requires and what it means in the field of water resource management? ☐

2. Do you actively seek out more efficient and sustainable technologies, and, more importantly, find ways to make them competitive with conventional approaches? ☐

3. Do you realise that sustainability must be addressed at multiple levels and by many disciplines, and we need to change how we work accordingly? ☐

4. Do you keep up to date with the changing aspects of sustainability by reading widely and being aware of trends and current arguments for and against increasing efforts to make the world sustainable, particularly in the field of water resource engineering? ☐

Specific Tasks for Water Resource Engineers:

1. Have you carefully accounted for water use throughout the entire design process? ☐

2. Have you ensured that water sources (including groundwater) are protected from contamination and given careful consideration to efficiency techniques at every step? ☐
3. Can potable water only being used for life-sustaining functions? ☐

4. Is water from aquifers, rainwater, surface run-off water, greywater, and any water use for sewage transport or processing systems all being considered within a cyclical concept? ☐

5. Have you ensured that wastewater is returned to the earth in a beneficial manner, and in particular considered organic treatment systems? ☐

6. In your designs have you minimised impermeable ground cover? ☐

7. Have you considered rainwater and surface run-off water as a possible water resource for use in infrastructure systems and processes? ☐

8. Can ‘greywater’ be treated and applied to practical or natural purposes suitable to its characteristics? ☐

9. Can water use in any process-related activity be put back into circulation, and contamination minimized? ☐

10. Has water used for sewage treatment or transportation been restored to appropriate water quality standards prior to distribution or reuse? ☐

Sustainable Solid Waste Management in New Zealand

One of a number of discussion papers produced by the IPENZ Presidential Task Committee on Sustainability during 2003 and 2004.

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> *"A mark of how civilised a population is: what they start worrying about when their ordinary needs are met. An advanced civilisation might start being concerned about spiritual or philosophical questions. We go shopping"*
>
> Anholt [1]

> …..*"Fundamental changes in the way societies produce and consume are indispensable for achieving global sustainable development"*
>
> World Summit on Sustainable Development (2002)[2]

1 Summary

Sustainable development is a recognised goal for New Zealand and will rely heavily on the engineering community to help our nation achieve it. The generation of waste at rates above what our environment can sustain and our natural resources can replenish is a critical factor indicating an unsustainable society.

Solid waste engineers have a crucial role to play in restructuring how materials flow in our societies to avoid waste generation and minimise toxicity. Policy initiatives at central and local government levels confirm that we need to work towards a more sustainable solid waste infrastructure. There a number of challenges and tasks that engineers and the engineering community must face and undertake in order to move New Zealand towards this goal. These issues include tackling consumerism, promoting and implementing sustainable technologies, working within the various interwoven governmental, industry and community sectors that influence resource efficiency and waste generation, and finding solutions that go beyond recycling and waste disposal. A checklist is included at the end of this paper to aid towards achieving this goal. This paper is a working draft and comments for improvements are welcomed.

2 Introduction

The increasing pressures of consumerism, availability of "cheap" resources and disposal methods, and the forces of globalisation have contributed to the massive solid waste volumes generated in New Zealand over the last few decades. These wastes are placing increasing pressure on the various waste sinks in our environment that are currently used to accommodate them. The increasing quantities of waste generated in New Zealand is one of the most overt indicators of an unsustainable society. There

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[1] Anholt, S. *Branding New Zealand*. Interview with Linda Clark, National Radio, New Zealand. 13 June 2003.

[2] United Nations. (2002). Plan of Implementation of the World Summit on Sustainable Development. www.un.org.

is no definition of waste in NZ's legislation, however the Ministry for the Environment's New Zealand Waste Strategy [3] defines waste as "a*ny material, solid, liquid or gas, that is unwanted and or unvalued, and discarded or discharged by its owner".* This definition recognises that in fact "waste" is not necessarily a useless material but rather a resource unused.

Waste represents the loss of both material and energy resources and in efficient materials processing systems, "waste" is a sign of design failure. The solid waste industry in a future sustainable society will therefore represent a completely different industry from what we know today.

The purpose of this discussion paper is not to explain in detail why sustainable solid waste management is required in New Zealand but to accept sustainability as the political-social-environmental ethic by which future solid waste management will be based and by doing so, present ideas and guidance as to the future role of engineers in shaping a more sustainable, or "less unsustainable", society. It is noted that this paper presents information relating to solid municipal waste and does not attempt to discuss hazardous waste or associated contaminated sites.

3 Sustainability and Solid Waste

A framework for action towards sustainable development was first prepared over a decade ago at the United Nations Rio Earth Summit. Agenda 21 was the main outcome of the Summit and in Chapter 21 of this document a preventative waste management approach was first officially advocated on an international scale, one which focuses on changes in lifestyles, and in production and consumption patterns, as the best chance for reverting waste generation trends and promoting sustainable development.

The New Zealand Waste Strategy [4] (MfE, 2002) states that the reduction of waste is a cornerstone of the government's commitment to sustainable development and it has three main goals each relating to the three recognised spheres of sustainability (i.e. environment, social and economic):

- **Lowering** the social costs and risks of waste;
- **Reducing** the damage to the environment from waste generation and disposal; and
- **Increasing** economic benefit by more efficient use of materials.

Hawkens et al [5] (1999) in their book, Natural Capitalism, argue that the earth's natural capital (resources such as time, oil, water and clean air) are diminishing at an alarming rate and there is a need for a new industrial revolution which values human and natural capital as well as conventional economic values. They propose four strategies for natural capitalism:

- **Radical resource productivity** – using resources more efficiently;
- **Biomimicry** – eliminating waste though closed cycles and eliminating toxicity;
- **Service and Flow Economy** – a shift from an economy based on products to one based on services; and
- **Investing in Natural Capital** – reversing environmental destruction through investment in sustaining and restoring natural capital.

[2,3] Ministry for the Environment (MfE). (2002). *The New Zealand Waste Strategy.* Ministry for the Environment, Wellington, NZ.

[5] Hawkens, P., Lovins, A.B., and Lovins, H.L. (1999). *Natural Capitalism: Creating the Next Industrial Revolution.* Little Brown and Company, USA.

All three of these documents advocate for more efficient production practices that eliminate or minimise waste generation. One of the fundamental goals of a sustainable society is to move toward a pattern of closed-loop material use so that materials, once extracted from the earth, are continually reused, remanufactured, or recycled providing for the more efficient use of materials and energy (refer Figure 1).

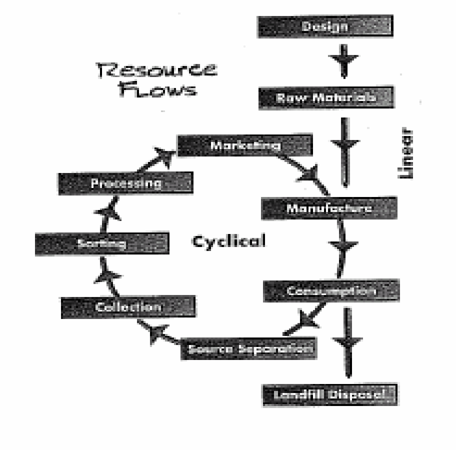

Figure 1 Material Flows in a Sustainable System (Zero Waste Trust 2002 brochure)

3.1 Zero Waste

It is unclear where the term Zero Waste was first conceived, but it is thought that in the early 1990s the idea was first incorporated into Canberra's "No Waste by 2010" policy (Zero Waste Trust [6]). Since then it has received a widespread following in New Zealand led by the funding and advocacy group New Zealand Zero Waste Trust (www.zerowaste.co.nz). Currently over half of New Zealand's City and District councils have adopted the Zero Waste vision into their waste management policies and / or plans.

The term, Zero Waste, is best considered as a vision rather than an ultimate target in a similar way as "Zero Accidents" is used on construction sites, or "SmokeFree NZ" has been used for public campaigns. In this way, the zero should not be viewed as the only indicator by which success is measured rather as a goal to focus creativity and resources on a journey of continuous improvement to change the way we think about and deal with waste. The Zero Waste vision aims to eliminate waste rather than just "managing" it.

Zero Waste thinking encompasses waste elimination at source through product design and producer responsibility, and waste reduction strategies further down the supply chain such as cleaner production, product dismantling, recycling, reuse and composting. Terminology used in Zero Waste literature refers to material flows instead of waste streams, and wasted resources instead of waste[5].

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[6] Zero Waste NZ Trust. (2003). *Getting There! The Road to Zero Waste.* Report prepared for Zero Waste Trust by Envision NZ.

4 Changing Role of the Solid Waste Engineer

Solid waste engineers have traditionally been involved in activities relating to waste disposal practices, such as improving the sanitary and public health aspects of collection and disposal options, creating environmentally-sound waste management infrastructure designs, and more recently developing waste minimisation systems and strategies for initiatives such as composting and recycling. What will be required by “solid waste engineers” in a sustainable future will be quite different, given that sustainable systems aim to eliminate waste wherever possible via product design, resource efficiency, closed-looped systems and resource recovery.

The role of the solid waste engineer in the future will need to reduce its focus on removing or minimising the harmful and adverse effects of solid waste by designing safer and improved sanitary collection and disposal practices and increase its focus on designing cyclic collection, recycling and reuse systems which transfer materials from one location to another efficiently and safely. At the same time, other engineers involved in product design and materials processing will take on greater roles to improve the design of goods and products that have complete life-cycles and use materials more efficiently.

Solid waste engineers have already been developing new thinking in the area of solid waste management, due to the promotion of integrated waste management and the waste hierarchy principles (reduce, reuse, recycle, recovery and disposal), which started over two decades ago. Waste minimisation actions linked to the waste hierarchy principles have become part of policy in recent years, and adopted by industry for obvious environmental reasons (i.e. improved resource, material and energy efficiencies, reduced environmental impacts from disposal) but also for practical economic factors relating to extending the lives of operating landfills and saving costs during material production via cleaner production techniques. The promotion of the waste hierarchy and the implementation of waste minimisation initiatives have transferred the onus of waste generation on to the community as a whole in addition to council and industry, which has created a whole new social component to waste management. This now means that engineers and council staff now control and manage waste in ways that must give consideration to the priorities and participation of local communities. Even though the waste hierarchy is now recognised by government, industry, educators, environmental groups and the community, the majority of energy and resources is still devoted to the lower tier of the hierarchy - waste disposal.

It is argued that the solutions solid waste engineers have traditionally helped to create for New Zealand’s waste quantities have, in fact, fuelled the real issue of waste generation, while at the same time providing a necessary public health and environmental service. By designing and constructing landfills as our primary disposal option, the landfill becomes a council or private asset that requires more refuse to sustain its very existence and viability. This in turn removes focus from the up-stream issues of resource conservation, cleaner production, efficient product design and durability, and in many cases has marginalised community recycling and reuse initiatives.

Although there have been some clear shifts in the way waste is perceived by those within and outside the sector, there is still a long way to go when considering what the real implications of sustainability on the NZ waste sector will be.

5 Sustainable Solid Waste Practices

5.1 Issues and barriers

5.1.1 Consumer society

A number of fundamental challenges lie ahead for the solid waste industry. Our increased solid waste production in recent years is largely the result of stronger consumer trends in NZ. New Zealand's economic system has become based around maintaining and sustaining high levels of materialistic consumption and this consumption is fast becoming linked to our identities, aspirations and leisure activities. A recent document produced by the Parliamentary Commissioner for the Environment entitled *See Change: Learning and Education for Sustainability* [7], suggests that if people can learn to be consumers, they can also learn to resolve unsustainable practices and develop more sustainable ways of living. This social change is critical to order to manage the demand for waste disposal and recycling systems by eliminating the need for them.

New Zealand is a large importer of manufactured goods with extensive associated packaging and often short useable life spans [8]. While this reflects the consumer society we live in, it is also creating heavy demand for local recycling or final disposal options. Efforts to achieve sustainable urban waste management must tackle the difficult question of commodities and packaging arrived from distant sources, used and discarded locally, and processed and returned to distant manufactures and agricultural users. Engineers will not be able to tackle these issues alone and it must involve multi-disciplinary action.

5.1.2 Sharing Responsibilities

Reducing waste and changing the way materials are used and flow throughout society will need to be led by both central government as well as industry and community leaders using a range of market-based and educational instruments. Zero waste targets, dematerialisation, eco-efficiency, life cycle thinking and analysis, ecological foot-printing, sustainable consumption, design for the environment are all tools and approaches that are exciting, leading edge and potentially transforming: however in isolation their impact is limited and undeveloped. Engineers can adopt such practices into their work but it will require the support of associated sectors and communities for these efforts to be realised and meaningful.

A local council solid waste engineer currently has very little responsibility over production decisions and associated waste generation and therefore limited capacity to achieve source reduction. Industry has a large part to play in implementing more sustainable materials use and reducing the quantity of waste that councils' do not directly control. The many various stakeholders in each industry (including the consumer) make alternative, more sustainable production choices difficult to implement quickly (e.g. food safety and product marketing issues relating to packaging choices).

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[7] Parliamentary Commissioner for the Environment (PCE). (2004). *See Change Learning and education for sustainability*. PCE, Wellington.

[8] Ministry for the Environment (MfE). (2002). *Policy instruments for Waste Minimisation and Management in New Zealand: A background document to implementation of the NZ Waste Strategy*. MfE, Wellington.

At an international level, Gertsakis and Lewis [9] report that research, debate and policy development is striving to deal with the shift from waste management to resource efficiency. This shift clearly presents a major test to the fundamental nature of how society functions. A significant issue is how the concept of sustainability can be developed into programs and systems that are effective across sectors, disciplines, communities and professions. Strategic thinking and creative action ought to become a mainstream approach across all sectors

5.1.3 Sustainable technologies

One of the more significant challenges in realising a sustainable future is the interim process and how it can facilitate the desired outcome. Can incremental changes make the differences we require for a more sustainable society or do we need to make more significant "path-breaking" changes? Weaver et al [10] highlights the phenomenon of new technology being locked out of the marketplace by old technology and old technology being locked in. Not having sustainable technologies being here 'on the shelf' is a barrier to the general restructuring of incentives, while not having the incentives and framework conditions to make sustainable technologies viable means there is little business imperatives to develop such technologies. This Catch 22 is one that many other industries are grappling with as they strive to implement more sustainable, or "less unsustainable" technologies.

Gertsakis and Lewis [11] argue that sustainability thinking in regards to waste needs to go beyond waste hierarchy principles which tend to focus on incremental changes and look towards radical, innovative alternatives that consider eco-efficiency principles at all levels. A useful example taken from Gertsakis and Lewis illustrates how using a 'sustainability' decision-making framework can result in producing different solutions for a given waste recovery problem (

Table 1).

Weaver et al highlight however that sustainable technologies, unlike many other new technologies, rely on fundamental cultural, social and economic reform. All markets are socially constructed and markets are subject to potential reconstruction by societies and their representatives to achieve societal objectives. The heavy dependence of sustainable technologies on market reconstruction to enable technologies to become cost-competitive makes for a special case. Uptake of sustainable technologies (e.g. a new service to replace a product, or a new process to deal with recycling composite materials) is likely to take longer compared to the uptake of other types of technology (e.g. internet and email) because of this reliance on market reconstruction. This would suggest we need to prioritise work on sustainable technologies immediately as the uptake of new alternative technologies will take time, but as Gertsakis and Lewis[12] warn there is a risk of over-investing in recycling solutions which may be applying yesterday's solutions to a future desperate for progressive ideas, actions and leadership.

[9,11,12] Gertsakis, J. and Lewis, H. (2003). *Sustainability and the Waste Management Hierarchy.* Discussion paper prepared for EcoRecycle Victoria. EcoRecycle Victoria.

[10] Weaver, P., Jansen, L., Grootvelf, G.V., Spiegel, E.V., and Vergragt, P. (2000). *Sustainable Technology Development*. Greenleaf Publishing, Sheffield, UK.

Table 1 Example of Waste Hierarchy Thinking versus Sustainability Thinking

What alternatives are there to conventional recovery / disposal options for clothes washing machines?	
A conventional approach using the waste hierarchy principles would consider the following:	*A sustainability framework for decision-making would focus on innovation and eco-efficiency:*
Can we eliminate unnecessary components or reduce the weight of components? (Reduce)	Do we need washing machines or find other ways to keep clothes clean e.g. considering new fabrics? (Avoidance)
Can we design components and overall appliance to extend product life? (Reduce)	Can we develop a completely new technology for cleaning clothes that has a much lower environmental impact (e.g. microware cleaning?) (Reduce)
Can we design for remanufacture so components can be reused ? (Reuse)	Can we shift the product to a service? (Reduce)
Can we design product for recycling and/or use recycled materials in the product? (Recycle)	Can we design machines for more effective remanufacturing and establish lease and take-back systems similar to those in place for office equipment? (Reuse)
Can we design of disassembly and recyclability to recover materials? (Recycle)	Can we establish product stewardship programs that establish closed loop programs and eliminate waste from washing machines? (Recycle)
Can we establish take-back, disassembly and recycling programs for obsolete appliances? (Recycle)	Can we eliminate or minimise related environmental impacts re energy, water and detergent consumption? (Avoidance and Reduce)

5.1.4 Beyond recycling

It is critical for engineers to remember that recycling can only be considered one component of the solution. It does not address issues of product design and can allow manufacturers to get away with unchecked resource consumption. There is currently more recycling than ever in the United States yet waste volumes are still raising (http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm).

Using life-cycle analysis to assess overall material and energy flows during a product's creation and life-cycle is an important tool to use when considering various production options. The actual waste generated at the point of reuse or disposal is a fraction of the materials used to process and transport the product through its life cycle. The greatest gains are therefore made during the products life rather than at the end. For example, a gold ring weighing 10 grams has generated approximately 3 tonnes of waste on a life cycle basis (cited in Gertsakis and Lewis). This is an example of the ecological footprint of a product which decision-making regarding resource-efficiency can be based.

Jacobsen and Kristoffersen [13] provide examples of the positive impacts producer responsibility initiatives in Europe have had on reducing the impact of packaging on overall waste quantities. In

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[13] Jacobsen, H. and M. Kristoffersen. (2002). Case studies on waste minimisation practices in Europe. Copenhagen, European Environment Agency.

Sweden, particular waste fractions experience recycling rates of up to 90%. In Germany, the amount of packaging used has decreased by 15% while the recycling rate has increased by a factor of 6. Producer responsibility does not however only involve improving recycling rates and recycling opportunities but more importantly involves the design of more durable goods, or the establishment of product leasing or servicing arrangements.

Designing products with longer lives so that excessive energy and material loss are avoided is considered an important part of sustainable development. Products such as fridges, computers, washing machines, vacuum cleaners etc that are designed for durability will however need to be designed alongside reformed industries and markets which can accommodate for the inevitable changes in fashion, materials and technologies that will occur during the life of the product. By leasing products or providing a service instead of selling the products, manufacturers retain ownership of the product throughout the product life cycle and therefore have the incentive to maximise and recapture the end-of-life value of their product, in turn reducing the need for virgin materials (Fishbein et al [14]).

6 Influencing legislation and guiding documents

The purpose of this section is to summarise examples of New Zealand documents and agencies that influence, restrict and/or encourage solid waste engineers to incorporate sustainability principles into their work. The range of influencing documents has been listed under the following headings: Central Government; Local Government; Standards, Guidelines, Best Practices; and Professional Associations.

6.1 Central Government

The solid waste sector in New Zealand has no central government “home” unlike other industry sectors such as the building sector or transport section (e.g. Building Act or the Land Transport Act). There is no definition of “waste” in our legislation that makes for an even more disconnected legal framework. The management of solids waste and its effect on the environment (socially and economically) are partially addressed by a range of legislation including:

- Resource Management Act 1991 – recognises and promotes the goal of sustainable management of natural and physical resources; requires that developments avoid, remedy, mitigate impacts on the environment; establishes a framework for resource consents for air, land, water discharges. The focus of the RMA can therefore only be about the environmental effects of waste rather than regulating how waste activities are carried out. Specifically, regional councils are given responsibility to manage the effects of discharges from waste disposal activities.

- Local Government Act 2002 – encourages sustainable development and requires Councils to "promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future" (Part 2, 10 (b)); territorial authorities are required to produce Long Term Council Community Plan (LTCCP) which have a long-term view (i.e. 10yrs).

- Local Government Amendment Act 1996 – requires local authorities to produce waste management plans that focus on the waste hierarchy (i.e. reduce, reuse, recycling, recovery and

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[14] Fishbein, B.K., McGarry, L.S., Dillion, P.S. (2000). *Leasing: A Step Towards Producer Responsibility.* Inform Inc., New York.

residual) however it does not provide clear roles and responsibilities for central, regional and local levels in regards to waste minimisation and the roles of the private sector in waste management.

- **Hazardous Substances and New Organisms Act 1996 –** controls hazardous substances but not hazardous waste.

- **Health Act 1956 –** promotes and conserves public health and secures the abatement of any nuisance or removal of any condition likely to be injurious or offensive to health. Council statutory obligations for the collection and disposal of refuse arise from the Health Act.

6.1.1 Ministry for the Environment (MfE)

Managing solid waste involves managing the many associated environmental issues and therefore the Ministry for the Environment (MfE) has played the main central government role in regards to the development of policies and strategies to deal with it. The MfE recognises that the concept of sustainable development and disciplines such as life cycle and materials flow analysis, ecological foot-printing, and environmental resource economics have gained in credibility and are now actively being incorporating into waste policy internationally.[15]

Some of the strategy documents, technical reports, and best practice guides relating to solid waste minimisation, management and landfill design/management that the MfE have produced are listed below:

<u>Waste Minimisation</u>

- **Review of Targets in the New Zealand Waste Strategy** (MfE, November, 2003) – reviews progress with the NZ Waste Strategy document released in 2002. Among the various findings, the review found good progress had been made by councils in adopting various waste reduction targets as proposed by the strategy although some targets were recognised as currently being very difficult or impossible to achieve by some local authorities given current technology and information available (e.g. organic waste). Recommended that none of the waste minimisation targets be altered. Next review is to be undertaken in 2008.
- **The New Zealand Waste Strategy: Towards Zero Waste and a Sustainable New Zealand** (MfE, 2002).
  - A joint waste minimisation initiative between the Ministry for the Environment and Local Government New Zealand. The strategy document sets waste minimisation, hazardous wastes and waste disposal targets (albeit voluntary targets) for example, by 2008 the quantity (in weight) of construction and demolition sent to landfill will be reduced by 50% (of 2005 figures).
  - The strategy has been acclaimed for the example it gives for the vision, consultative process, and sound principles it is based on, but lacks regulatory "teeth".
- **Development of a Regional Waste Recovery / Processing Sector** (MfE, October, 2003).
- **Policy Instruments for Waste Minimisation and Management in New Zealand** (MfE, September, 2002)
- **Guidelines for the Safe Application of Biosolids to Land** (DRAFT) (NZWWA, MfE, MoH, MoF, 2003)

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[15] Ministry for the Environment (MfE). (2002). *Policy instruments for Waste Minimisation and Management in New Zealand: A background document to implementation of the NZ Waste Strategy*. MfE, Wellington.

- Business and Employment Opportunities from Waste Minimisation (MfE, 2002)
- Packaging Accord 1996 –the MfE and the then Packaging Industry Advisory Council signed this accord in 1996 which lasted 5 years and is to be renewed this year. The objective being *"to minimise adverse environmental effects arising from packaging waste by the adoption of efficient and effective practices to reduce waste.*". The Council's main role is to collect data on paper, plastic, aluminium, steel and glass materials for consumption, collection and disposal and to support waste management and minimisation options for packaging. The next accord will have a greater focus on Extender Producer Responsibility although it is a voluntary accord which will not enforce any requirements on any waste packaging producer.

Disposal

- Waste Acceptance Criteria for Class A Landfills (MfE, September, 2003)
- A Guide to the Management of Cleanfills (MfE, 2002)
- A Guide to the Management of Closed and Closing Landfills in New Zealand (MfE, 2001).
- Landfill Full Cost Accounting Guide for New Zealand (MfE, 2002).

Future Priorities

Waste work within the Ministry is now spread across three major policy groups with the overall responsibility for the implementation of the NZ Waste Strategy sitting within the *Sustainable Industry Group*. The priority areas of work for the MfE in 2004 and coming years are the following (MacLeod [16]):

- Special wastes – priority is being given to recovery of used oil and tyres and development of an Extended Producer Responsibility policy for New Zealand.
- Monitoring and evaluation of progress – as started with the recent review document (MfE, 2003)
- Organic wastes – the recent review identified some of the challenges involved with meeting the NZ Strategy target for organic waste (i.e. conflict with landfill gas generation, contamination in compost and biosolids products, market creation). MfE plan to address these issues with local government and industry.
- Landfills – progress towards closing or upgrading sub-standard landfills and further work on landfill acceptance criteria and for landfill gas collection.
- Packaged Goods Accord 2004 – continued work with the NZ Packaging Council to establish a new accord (replacing the 1994 accord) which will form a voluntary agreement with specific action plans to reduce environmental effects of packaging and quantities going to landfills.
- Govt3 – new programme designed to reduce waste generated by government agencies and imbed "environment" into everyday activities.
- Unwanted Agrichemicals – developing a national programme for the collection of unwanted agrichemicals which supports current Regional council-led agrichemical collections.

6.2 Local Government

A large proportion of the work that solid waste engineers undertake in New Zealand relates to the solid waste services that local government own, operate and / or manage. Therefore the majority of solid engineers work within local government, for them or have to report to them (e.g. via resource consents). Examples of local government documents which promote and/or influence sustainability principles in the solid waste industry include:

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[16] MacLeod, M. (2004). Priorities for 2004 waste work in the Ministry for the Environment. *Waste Awareness*. Journal of WasteMINZ. January, February.

- Regional Policy Statements and Plans:
    - e.g. Auckland Regional Policy Statement (1999), *"…minimise the quantity of waste….to promote the sustainable use of natural and physical resources;*
- District Council Plans and Strategies:
    - e.g. Rodney District Council Zero Waste Plan: *"vision is to protect Rodney's special environment by working to reduce waste with the aim of Zero Waste to landfill by 2020";*
    - Tauranga /Western Bay of Plenty Waste Management Plan: *"Sustainable waste management that protects the environment…promoting waste minimisation to achieve zero waste target by 2015".*

6.3 NZ Standards, Guidelines, Best Practices

The lack of specific NZ standards, guidelines and/or best practice documents in the areas of resource efficiency and recycled products presents an obvious gap and potential barrier to the implementation of sustainable technologies and improved waste management and waste minimisation. While there have been some comprehensive documents produced detailing best practice guidelines for waste disposal activities such as MfE's Guide to the Management of Cleanfills (2002) or CAE's Landfill Guidelines (2000), there are few examples of best practices for waste minimisation initiatives.

Construction and demolition waste management / minimisation best practice guidelines are currently in development, and various standards (or process best-practice guidelines) for recycled or compost products do not exist in New Zealand. Such documents should help to assist with the creation of markets, credibility of products and sound production efficiency practices in the areas of material efficiency, waste minimisation and waste disposal practices.

6.4 Professional Associations and Educational Institutions

The various professional and non-governmental organisations that engineers belong to and work with (including the organisation they work in) represent another area-of-influence for the promotion of sustainability principles in engineers' work. Examples of such groups include:

- Waste Management Institute of NZ (WasteMINZ) – is a non-profit organisation that aims to promote sustainable waste management practices, provide a forum for presentation and dissemination of information and to act as a facilitator for the waste management industry in New Zealand. In 2002 WasteMINZ developed the 'Life After Waste Programme' which seeks to involve all sectors, organisations, initiatives and individuals to change actions and "close the loop" on waste. http://www.wasteminz.org.nz
- Zero Waste NZ Trust – as discussed in Section 2.1, the organisation is currently promoting the following five key recommendations:
    1) A National Target Date for Zero Waste by 2020
    2) Introduction of a Landfill Levy
    3) Landfill Bans
    4) Industry Stewardship Programmes to ensure that the principle of Extended Producer Responsibility (EPR) is fully implemented.
    5) A National Zero Waste Agency.

- **BusinessCare** – is a not-for-profit trust which promotes, supports and encourages the implementation of sustainable management and cleaner production practices by local businesses nationwide. http://www.businesscare.org.nz/
- At a business, organisation or council level e.g. development of company-policy relating to sustainability principles; consider joining a 'sustainability-linked' organisation, for example the Sustainable Business Network, www.sustainable.org.nz
- **Institute of Professional Engineers in New Zealand (IPENZ)** – the Code of Ethics; Sustainability Task Committee work. www.ipenz.org
- **New Zealand Society for Sustainability Engineering and Science (NZSSES)** - a Technical Interest Group of IPENZ www.nzsses.org.nz
- **Centre for Advanced Engineering** - a not-for-profit organisation which aims to enhance engineering knowledge within New Zealand by technology transfer and the application of NZ and overseas research to engineering-related issues of national importance. www.caenz.com

6.5 Recommended Tasks for Solid Waste Engineers and Engineers in General

Central government recognises that reducing NZ's solid waste generation is a cornerstone for sustainable development [17] . Solid waste engineers have many opportunities to be involved in this process and in the future will need to modify their working roles to focus on designing cyclical materials flow instead of just end-of-pipe solutions. Engineers also have professional responsibilities to do so, as noted, for example, in the IPENZ Code of Ethics:

> *"Members shall be committed to the need for sustainable management of the planet's resources and seek to minimise adverse environmental impacts of their engineering works or applications of technology for both present and future generations."*

Members of IPENZ, their engineering colleagues, and others engaged in materials efficiency, solid waste management and minimisation, are encouraged to learn what they can about sustainability and apply it in their day-to-day actions at work and in other aspects of their lives. Much information is already available both from New Zealand and internationally. The engineering profession should be seen to lead the way towards a more sustainable future. There are many ways in which solid waste engineers and the engineering community can help move New Zealand towards a more sustainable society - some suggestions are given in the checklist below.

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[17] Ministry for the Environment (MfE). (2002). *ibid*

7 Sustainable Solid Waste Checklist

1. Have you taken all reasonable steps within the scope of the project (and/or work environment) to eliminate, reduce or manage demand for materials use to avoid the production of waste? ☐

2. Have you included materials efficiency and waste minimisation requirements into Requests for Proposals from contractors (e.g. specify tenders use recycled-content, reusable materials or reduce waste generated by project as much as feasible? ☐

3. Have you written solid waste contracts that incentivise waste reduction and introduce differential pricing to promote waste reduction? ☐

4. Can you evaluate proposals or potential jobs with some consideration given to materials efficiency and waste production? ☐

5. Can you establish a preference for materials and products that are made from renewable, sustainably acquired materials, have recycled content, are durable, low maintenance, non-toxic or low toxic, recyclable, and low polluting in manufacture, shipping, and installation? ☐

6. Can you amend policies, rules and regulations to support alternative methods of production, or more sustainable technologies? ☐

7. Can you use your knowledge of sustainability to educate and suggest alternatives for product production, materials use and waste management options (e.g. using life-cycle analysis tools to guide decision-making process on best use of materials and energy)? ☐

8. Have you considered all the various initiatives that could assist with waste minimisation? e.g. taking direct action like recycling or composting; education and consultation; legislative changes; research and development; and monitoring and feedback. ☐

9. Can you quantify and apply the real costs of materials use and waste generation and disposal to your project? ☐

10. Can you use the discharge from one process as a resource for another (e.g. application of biosolids to land for soil conditioning)? ☐

11. Have you provided specifications and dimensions that minimise waste? ☐

12. Can you establish targets for waste toxicity reduction and monitor them? ☐

13. Can you design your product or asset for disassembly of materials and systems? ☐