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SUSTAINABILITY AND ENGINEERING IN NEW ZEALAND

IPENZ
Engineers New Zealand

CONTENTS

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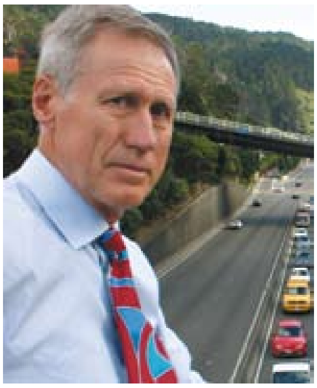

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Gerry is a consulting professional engineer, and from 2003 to 2004 was President of IPENZ. During his Presidential year he initiated a Task Committee that focused on getting sustainability back on engineers' agendas in a practical sense. This report is an outcome of that committee. He also founded the independent group Engineers for Social Responsibility in 1983 which has now become a worldwide movement among professional engineers who care about the direction technology is taking.

Since 1970 Gerry has worked as a consulting electrical engineer specialising in high level advice, forensic and fire investigations and expert witness services through his own firm Wise Analysis Limited. Of Ngai Tahu descent, he acted as a consultant to Ngai Tahu in 1997, helping to prepare their Treaty of Waitangi claim ready for acceptance and settlement by both the Government and the tribe.

He writes widely on technology issues that concern him, contributing to *e.nz magazine*, its predecessor *New Zealand Engineering* and various other newsletters and journals. Gerry is also active in the fields of arbitration, mediation, counselling and conflict resolution.

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Andrew also has extensive expertise in road classification systems, having rationalised the system for the City of Toronto in Canada and developed the national road classification system currently being implemented in New Zealand through CAS, Land Transport New Zealand's Crash Analysis System. Andrew is currently on the national committee of the IPENZ Transportation Group and the executive of the Cycling Advocates' Network (CAN).

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Ian is a consultant for Energy Information Services Limited, which is located in Wellington. He spent 20 years designing and constructing thermal and geothermal power stations before focusing more on his personal passion for energy efficiency and renewable energy systems.

A quick search of the Internet brings up references to his periods of management of renewable energy industry associations – the New Zealand Wind Energy Association and the New Zealand Photovoltaic Association – and his services to the Sustainable Energy Forum.

Ian also has a passion for technical engineering training issues, and is chairman of the Engineering Associates Registration Board. In 2004 he was made a Fellow of IPENZ for services to the Institution and renewable energy developments.

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EDITOR'S NOTE

Sustainability has major implications for society and engineers. Engineers are involved in all aspects of resource use, from resource extraction through to technology and product design, manufacture, operation and even management of wasted resources and products. 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- to 50-fold, in order to achieve sustainability and this reduction will only occur through cleaner production, recycling, servicising and, most importantly, through sustainable technology design. This will require engineers to better understand the services technologies and products provide and find new ways of providing those services.

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 business from unsustainable designs. Engineers need to recognise this professional responsibility and 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.

This document is the result of work completed by the Institution of Professional Engineers New Zealand (IPENZ) Presidential Task Committee on Sustainability during the period 2003 to 2004.

Dr Ir Ron McDowall FIPENZ
New Zealand Society for Sustainability Engineering and Science

SUSTAINABLITY AND ENGINEERING IN NEW ZEALAND

PRACTICAL GUIDELINES FOR ENGINEERS

SUSTAINABILITY, PRINCIPLES AND PRACTICES

Sustainability is often discussed as intra- and inter-generational equity – meeting present needs without compromising the needs of future generations. But what is meant by future generations?

Economists argue that, although we care about our children, grandchildren and possibly our great-grandchildren, beyond four generations we do not have a sense of concern or obligation for future welfare. On the other hand, Maori would identify five generations as the minimum period of thinking.

However, in the context of future society, even four or eight generations (100 to 200 years) is relatively short. Many societies have existed for much longer than that – some for thousands of years in Europe, the Middle East, China, India and Egypt. Some of the major cities in Europe, North Africa, the Middle East and Asia have been in existence for between 2,000 and 5,000 years. Environmental impacts caused by civilisations can also 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, such as loss of soil or biodiversity, desertification, deforestation and depletion of resources. Thus, at the very least we should be considering a period of 1,000 years and looking to the type of future we might be able to envisage at that point. As Tonn (2003) 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 will be available 1,000 years into the future. However, we can make some assumptions and use these to guide sustainable thinking. These assumptions include:

a) humans will be here

b) current cities will be here

c) food will still be grown

d) materials and energy will still be required to meet human needs

e) humans' basic needs will not have changed

According to Peet and Bossel (1999), these basic needs are:

- 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 – ability to change
- coexistence – ability to exist peacefully with other races and species
- reproduction – provision for the reproduction of new members and consideration of 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

We can then determine, using these assumptions, what we have to consider over these 1,000 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 issues for long-term consideration and planning. 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 because it is within that framework that the 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 the technologies which are essential for future survival to be identified.

Risk

Having identified these issues, we certainly cannot predict with any certainty what will happen in the future. However, we can evaluate the risks that our activities create for future generations and act to 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 and irreversible consequences.

Identifying risks requires us to understand more fully the systems we are affecting – environmental, social and even economic. Systems thinking is critical to enable the linkages between various systems to be identified and planned for. The limitations of those systems, not only for the short-term but also for the long-term, also need to be reconsidered. These are the limitations which we must live within if we are to achieve sustainability. We have already identified some critical species or ecosystem levels – the points at which species or ecosystems will crash. However, the causes and factors leading to such crashes are still not well-known and the critical thresholds for 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 1,000 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 to 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 six billion people and it is highly 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 1,000 years without the use of non-renrewable resources such as fossil fuels.

Engineers need to consider ways and means of providing basic amenities for such populations using renewable sources.

Fossil fuel energy will probably be depleted within the next 200 years; current reserves of oil, gas and coal, when increasing rates of consumption are taken into account, only provide for approximately 40 (natural gas) to 200 (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 at about 2040 and rapidly decline over the following 50 years; if liquefied coal takes its place that would then reduce the long-term supply of coal. Locally, this could have a significant impact not only on transportation, but also on industrial productivity, agriculture, fishing, construction and the supply of basic amenities.

Water resources are being rapidly depleted and polluted; it is expected that water shortages will be experienced by two-thirds of the world's population within 25 years (United Nations Environment Programme, 2002). This will not only 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 it can support, as well as risks to that supply.

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

Urbanisation is increasing rapidly; by 2007, some 50% of the global population will live in urban areas (United Nations Environment Programme, 2002). This will have benefits in terms of increased density, but 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 managers to define appropriate living areas within the city landscape and determine how the population can be accommodated and provided with food and transport while maintaining an adequate quality of life.

Resources may also be depleted over 1,000 years of extraction and dilution – careful attention needs to be paid to renewable resources to ensure that the long-term supply will be maintained. As a result of depletion, local industries could fail, particularly those in areas which are reliant on specific resources for supply, thus affecting the sustainability of local communities. Other sources will need to be found for resources required to meet infrastructure and other needs. Products whose manufacture relies on such resources need to be redesigned to eliminate such reliance.

Over-population is resulting in increasing competition for water, arable land and valuable resources such as oil and minerals. As populations increase, such conflict will only escalate, 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 that of today. The increase will be primarily in developing countries, which will place pressure on developed countries to accept immigrants. This may increase ethnic conflict as new immigrants and native inhabitants struggle to accommodate different ways of life.

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). 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. 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.

Gross material and energy flows in the production of goods are becoming significant, of the order of some natural flows, now have a 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- to 50-fold (Weaver et al, 2000). Some research is also indicating that factors of 50 to 75 may not only be desirable, but necessary.

Sustainability Principles

We consider that three key principles are the basis of sustainability. The overarching problem is the need to manage changes in the environment, many of which are increasingly human-induced and need to be addressed to avoid long-term degradation of the environment.

Principle 1: Maintaining the viability of the planet

1. Humans need to maintain the integrity of global and local biophysical systems.
2. Renewable resources must be managed within sustainable harvest rates and non-renewable resource depletion rates must equal the rate at which renewable substitutes take their place.
3. Technological options must favour choices that minimise the use of resources and reduce risks.
4. The material and energy intensity used in products, processes or systems needs to be reduced significantly – by 10 to 50 times – using recycling and minimisation techniques.
5. Waste streams during the life cycle of products, processes or systems must be minimised to the assimilative capacity of the local and global environments.
6. Any use and production of environmentally hazardous materials must be minimised and carried out prudently if necessary.

Principle 2: Providing for equity within and between generations

1. Humans, now and in the future, must have equal access to choices in life that reduce significant gaps between people in areas such as health, security, social recognition and political influence.
2. Total consumption of resources needs to be within the environment's sustainable capacity, and balanced between the affluent and those yet to fulfil their basic needs.
3. Present resource use and development must be considered over a sufficiently long timescale that future generations are not disadvantaged.
4. Those directly affected by engineering projects, products, processes or systems must be consulted and their views incorporated into the planning and decision-making processes.

Principle 3: Solving problems holistically

1. Problem solutions must be needs-based, rather than technology-driven.
2. Demand growth targets must be realistically assessed and if necessary managed, rather than simply meeting predictions.
3. A holistic, systems-based approach must be used to solve problems, rather than technology focusing on only single aspects of problems.
4. Unsustainable practices must be reduced to zero over time, and where practicable past degradation shall be addressed.
5. Problem solutions must be based on prudent risk management approaches.

Sustainability Practices

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

There are four key sustainability factors for engineers: managing changes in the environment, ensuring the equity and safety of engineering activities, holistic problem solving, and making good existing problems.

Managing changes in the environment

Engineers must thoroughly consider any project or plan that will have a significant impact on the life support functions upon which human well-being depends, many of which are irreplaceable. An example of this is the use and placement of dams on waterways, or the deployment of techniques, materials or processes with side-effects that have yet to be fully assessed – such as nanotechnology.

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; however, this is often not so, particularly for some externalities. Where alternatives exist, the more sustainable product or material should be used. For example, a recyclable container is inherently more sustainable than a single-use container, whatever the apparent cost.

Minimise the absolute use of resources and convert energy sources from fossil fuel-based to renewable energy. This requires a constant awareness of optimisation processes on a life cycle basis. For example, engineered projects should be designed to minimise the initial use of resources and to provide for maximum recycling and reuse of resources through their lifetime. This applies both to scarce resources and apparently abundant resources such as concrete and timber, all of which have embedded and largely non-renewable energy content.

Maximise the use of renewable resources but always within sustainable extraction or harvest rates and taking account of environmental damage. An example of this is the use of biomass from sustainable forests as a boiler fuel instead of oil or gas.

Minimise 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

Primarily aim engineering projects at improving the overall quality of life for humans and other life forms, but not at the long-term expense of the environment. Any increased consumption of resources and energy must be weighed against the improvement in quality of life that can be achieved.

Consider resource use over a sufficiently long timescale so that present and future generations are not disadvantaged economically, socially or environmentally, by excessive, unnecessary or wasteful consumption. This may be considerably longer than an anticipated project lifetime.

Give greater priority to projects, products and processes that decrease significant gaps in health, security, social recognition, and political influence between groups of people. Those projects that increase gaps must be carefully considered before embarking on them in whole or part.

Consult with all those affected by engineering projects where practicable and give them an equal opportunity to voice their concerns without repercussions. Consider relevant opinions and, where practical, incorporate them into the planning, decision-making and implementation process.

Where outcomes cannot be accurately foreseen, base choices as much as possible on risk reduction and the precautionary principle (where in the absence of data, new risk is avoided).

Holistic problem solving

Take an integrated systems approach or an overall holistic approach to considering all stakeholders and the effect on the environment when attempting to solve problems. Rather than focusing solely on the technology aspects, and solving one problem at the expense of another, aim for a co-ordinated overall solution.

Base problem solutions primarily on existing or new human needs, rather than on finding a use for newly-available technological means.

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 return journeys is more sustainable than single load journeys.

Making good existing problems

Where desirable, and technically and economically practicable, remedy past environmental degradation. For example, land degradation, groundwater contamination and hazardous waste sites should be considered for stabilisation at a minimum and, wherever possible, total clean-up to current or foreseeable standards.

Cease and clean up past hazardous practices in a cost-effective manner and timeframe. These include, for example, hazardous materials such as asbestos, lead, mercury and polychlorinated biphenyls (PCBs).

Reduce the use of non-sustainable practices (such as burning or using petroleum and fossil fuel products for combustion or industrial feedstock) towards zero over a relatively short timeframe (50 to 100 years).

Support social and economic accounting methods which disclose, identify and quantify previous or developing environmental problems.

SUSTAINABLE RESOURCES AND PRODUCTION

Humans use a massive amount of resources. In developed countries resource usage is now higher than any previous time in history and is still increasing. We purchase huge quantities of clothing, food, household appliances and furniture, vehicles, toys, property and houses; many of these items are used once or twice and then stored, left to decay or discarded. We throw out vast amounts of goods, including uneaten food, disposable products, unfashionable clothing, furniture, and appliances which may still be in working order. Computers, cellphones and other electronic goods are discarded while still in working order simply because new technology renders two-year-old goods obsolete. We waste huge quantities of energy and water through poor infrastructure design and lack of maintenance.

The concept of sustainability is based on equity of both current and future generations; that is people in the future should not be disadvantaged by the actions of people today. Fundamental to this discussion is the issue of resource use, particularly resources which are currently being depleted for short-term economic gain. Current political economic thinking basically ignores natural capital (materials provided by nature), considering it to be replaceable with human capital (labour) (Daly, 1997). Moreover, as Hardin (1968) points out, immediate consumption is more profitable to the consumer and provides a competitive advantage to the consumer's immediate descendants.

Types of resources

Loss, recycling and renewal of resources must be considered when assessing their sustainability. 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, their 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 Project, 2002). Although such limits may be determined within the next 500 to 1,000 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, include complex materials which are broken down, consumed or lose their useful properties during use. These resources must be replenished at the rate of consumption or they will be depleted. The crash of a number of fishing stocks throughout the world within the past 10 years 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 United States Geological Survey has recently produced estimates of total global oil resources and, using these results, the United States Energy Information Administration (2003) suggests that production will peak in 30 to 40 years, with most resources being depleted by the end of the 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. However, 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 to be renewable because 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 lower than for extracting of fossil fuels (Hall et al, 2003).

Non-renewable resources are those which have a finite supply. Some of these resources, such as carbon, iron, silicon and aluminium, are very common and it is unlikely that 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. At present the current major limitation is the recovery cost for those metals.

For resources which can be renewed within a short timeframe, it is necessary to assess the sustainability of consumption, the renewal of such resources and the risks posed by current renewal practices. For resources that are not renewable, the availability of substitutes must be considered. Current management practices must be assessed to determine the risk to future generations from the loss of that resource.

Resource use has five effects: 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 greater or lesser extents.

Contamination

Contamination is introducing a foreign, unwanted material into the desired substance or resource. This can include polluting a river stream, introducing 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 by only some groups in society or by a specific culture; others may consider that the effect is positive or that the benefits outweigh the costs.

Remediation of contamination requires removing it and preventing further contamination. For water or air contamination, the usual practice has been diluting 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 likely to increase with globalisation. Other types of contamination, particularly noise or visual contamination, result from increased technology, population and resource consumption. Societies must decide how much visual and noise contamination they are willing to accept.

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 ecosystem collapse increases; and as the gene pool within a species is reduced through loss the risk of losing the species increases.

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, loss of species or the results of overgrazing. For materials which are to be recycled, all input materials must usually meet standards to ensure 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.

Dispersion

Dispersion occurs when a material decreases 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 galvanised roofs and copper guttering 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.

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 too high for current solar technologies to be utilised as a major source. 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. Current technology is insufficient to enable many consumed materials to be replaced. However, species can be restored if they are not yet extinct or are not yet past their critical limit for breeding.

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. It is currently impossible to recover a species once loss has occurred. 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.

To determine the sustainability of a resource, the risks to that resource must be identified. A resource that is being contaminated still exists but it must be determined whether it needs to be decontaminated, whether it can be decontaminated and the associated cost. Resources that are dispersed are not destroyed and therefore sustainability must be considered in light of the energy and cost of collecting the dispersed materials, as existing stockpiles are depleted. Of course, recycling assists in this process. Renewable resources must be evaluated to determine 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.

Current use of resources

While we see the quantities of goods which are purchased and discarded, we don’t see the quantities of materials and resources which contribute to the manufacture of those goods, nor do we know the extent of the impact of extraction, manufacturing and operating processes. The extraction of resources such as minerals, metals and energy requires significant quantities of equipment, chemicals, water and energy. The process may also disrupt or destroy ecosystems by releasing waste into the environment and also displacing or removing plants, animals, soil and water.

Life cycle assessment tries to account for 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.

Overall, however, the above measures do not fully indicate the sustainability of a product – they do not take social or economic issues into account. To do so requires a systems analysis which identifies 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.

Efficient use of resources

Cleaner production, eco-efficiency and pollution prevention have been used for over 10 years to reduce the amount of resources and energy used in processes. After a resource and waste audit, the 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. More advanced steps include a 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 200 to 300% increases in efficiency.

Efficiencies and design changes will go a long way towards reducing resource consumption but it is not clear if they 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 be achieved using cleaner production technologies. This will require a new design concept, new thinking and new methods of producing and harnessing energy.

Energy is likely to be a major limiting factor because of our 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 the 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, 2003). Even in the best case scenario, there will be significant impacts due to changes in climate.

Society relies on energy, particularly fossil fuel energy, to supply food, water and all goods, to construct, heat and light buildings and other infrastructure; and, in fact, undertake most modern activities. This reliance leaves society highly vulnerable to any interruption in energy supply, as evidenced by recent breakdowns in the electricity supply in Auckland during 1998 and California in 2001. In these situations 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 greenhouse gas emissions will cause temperatures to 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 effects of greenhouse gas releases in the 1950s and 1960s. Rapid increases in releases from the 1960s to the present mean that increases in temperature are likely to occur more rapidly and we will see greater and greater effects and more and more extreme weather events. The only way 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, due to the 50-year time lag, it is not even clear that we can actually mitigate changes which are going to occur over the next 20 years.

New, renewable sources of energy which can sustain quality of life need to be developed. 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 social disruption, conflict and war caused by both climate change and loss of fossil fuels.

Durability

Generally, 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 in landfills, with components which are still functioning but difficult to recycle.

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 its accessories but has a memory much greater than that available today. This will make most desk-top computers obsolete – and the change is likely to occur within the next five years as the technology is already available.

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

Recycling

Recycling resources from products assists in extending the availability of resources. While contamination and energy consumption must be taken into account, recycling 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 therefore are difficult to disassemble into recyclable components. Whiteware, computers and other electronic goods are examples of such products. However, Xerox has designed its photocopiers so that components and materials can be recycled, thus reducing the requirement for new resources.

Servicising

Servicising has been touted as a means of reducing product use. 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 electronic goods or whiteware rather than the purchasing them and a needs-based use of vehicles rather than purchase.

Care must be taken in the design of a servicised system so that it does not encourage greater consumption of products rather than reduce 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.

Engineering considerations

The issue of sustainable resource use and product design is highly complex. It must be considered over the product life cycle and resources must be considered in light of the type of resources and how they are being affected by human use. The limits of systems and of resources are also important in making decisions about resource use and product design. A further consideration is that the risk to the environment, society and the business from using a resource must be considered over the short-, medium- and long-term. In this case, however, the long-term is not the standard five to 10 years of business strategies; it is up to 1,000 years when considering resources such as soil. Such a focus recognises the needs of many future generations, not merely 50 to 100 years in the future.

For engineers, this means a greater responsibility in product design and resource use. Complex issues regarding environmental impact, resource availability, renewability, recyclability and the potential 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 product design and manufacture, resource use and to ensure that the life cycle of products is fully taken into account in the design process. Companies also need to recognise their responsibility in ensuring that they plan for the product's end-of-life.

Engineers have to realise that current consumption is already most likely greater than 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 their effect on the environment, society and 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 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.

SUSTAINABLE BUILDINGS

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

Guy (1997) 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.

The concept of sustainability with respect to buildings is still poorly defined. Much of the focus is on energy use in buildings. In the United Kingdom, approximately 66% of the total energy consumption goes towards buildings and building construction (Vale and Vale, 1991). In the United States, buildings use one-third of all energy and two-thirds of electricity (United States Environmental Protection Agency, 2003). The energy consumed in operating the building overshadows that of construction – 90% is consumed in operation over the lifespan of the building (Winther and Hestnes, 1999). As a consequence, much research has focused on means to reduce energy consumption for house and water heating (Eaton and Amato, 1998).

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 the 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, 2003, Treloar et al, 2001).

Concentrating on the use of energy alone has raised concerns that a number of environmental factors are not considered. Uher (1999) points out that buildings contribute significantly to the environmental burden, quoting Levin (1997) for the following contribution levels to the overall environmental burden of a building: use of raw materials (30%), energy (42%), water

(25%) and land (12%); and pollution emission: 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 after considering energy and other environmental factors, the primary question still arises – what do we mean by a sustainable building? Does focusing on energy alone ensure that a building will be sustainable? This section will discuss the concept of sustainable buildings, tools for measuring sustainability and the application of those tools to buildings.

Table 1: *Five competing discourses of green buildings (Guy, 1997)*

	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	maximum efficiency	express nature	living building	create identity
Urban scale	decentralised	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, building management system	organic, recycled	selective, non-toxic	appropriate
Evaluation	holistic	cost-benefit	truth to nature	productivity	social cohesion

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. Achieving technologies which minimise the risk to the environment requires a 20- to 50-fold reduction in resource consumption and inefficiency (Weaver et al, 2000).

This will be particularly significant to the construction industry which is a major consumer of resources. Estimates of resource use vary but the United States Environmental Protection Agency (2003) estimates that a standard wood-frame house uses one acre of forest and produces three to seven tonnes of waste during construction. Lippiatt (1999) 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 United Kingdom alone, it was estimated that six tonnes of building materials are used annually for every member of the population (Cooper and Curwell, 1997).

Much of the waste and consumption occurs during the extraction and processing of raw materials. 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; harvesting and processing timber requires energy. Timber is often grown in plantations which replace old growth forest and significantly reduce biodiversity. Transportation of materials 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 processing by-product and contain heavy metals; cyanide wastes are a by-product of aluminium smelting. Timber processing includes treatment against rot and pests and usually requires hazardous materials.

Transporting and reprocessing recycled materials often consumes significantly fewer resources than extracting and processing raw materials. This is particularly true for metals such as copper, iron and aluminium which can be reprocessed to a product with the same quality as that produced by raw material processing. Both concrete and timber can be recycled or reused but the quality of the final product is often reduced. Concrete can be crushed and reused as aggregate for some purposes, particularly paving (Khati and Boyle, 1998) and mortar (Corinaldesi et al, 2002). Good grade timber can be used for making furniture but reusing beams as supporting timber is not always suitable because it is difficult to determine whether a used timber beam has stress cracks or other weak points. Plastic can be recycled into a number of construction products, including tiles, lumber, heating and wire insulation, and carpet.

Huang and Hsu (2003) 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 could easily have been recycled, thus reducing the material and energy costs of importing $51x10^6$ tonnes of asphalt. Thormark (2002) 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, in some cases, replaced. In particular, exterior coatings, guttering, piping, walls, and flooring will require repair or replacement on a five to 15 year basis. Effective maintenance can also have a significant impact on reducing the need for replacement. Maintenance decisions are not made by the builder or designer – 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 its lifespan. Although buildings can easily be designed to last well over 100 years, and many traditional buildings are designed for more than 200 years (Morel et al, 2001), many designers and researchers only plan for 50 years and, in the case of office buildings, an even shorter timespan. 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 a factor of up to four.

Durability of a building depends on a variety of factors – the design, construction methods, materials, its purpose, its aesthetics and the owner. The owner is the primary determinant of the building lifespan and it 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 because their durability and suitability for construction has not been proven over the long-term.

Major renovations which change the design of a building are also likely to occur within its lifespan. With office buildings, interior layouts are frequently modified to suit the corporate function – about a third of construction activities in Europe involve office refurbishment (Caccavelli and Genre, 2000). 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. 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 and 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 designing and constructing buildings.

Energy

A significant amount of energy is consumed during 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 three and could reduce impacts from transportation by more than a factor of six. The local materials studied by Morel et al (2001) included rammed earth, stone and timber and were compared to the use of imported concrete which requires significant energy for processing. Treloar et al (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 four, depending on the weight of the lumber and the steel beams.

Table 2: *Material extraction and production emergy intensity of building materials (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 with recycled glass	3.06
Glass	2.16
Steel	4.13
Plastic (PVC)	5.85
Aluminum	12.53

Achieving significant reductions in energy consumption assists significantly in reducing resource consumption and improving efficiency – 90% of energy consumption is over the operational lifespan of the building and energy is the major resource consumed in buildings. 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 and composting toilets 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 (1998) pointed out that savings of up to 80% 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 at no additional construction cost. 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 avoidance 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 (2001) 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 to 42% of the embodied energy could be recovered by recycling 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. 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 of time they are in the building; occupation and monthly income; perception of energy; and preference for location within the building (Lucas et al, 2001). The use of low-energy appliances and conservation measures can significantly reduce energy requirements.

Having considered the energy requirements for material extraction, processing and recycling, and for building operation and maintenance, the sustainability of the energy source also needs to be considered. Gagnon at al (2002) 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 also rated well, primarily because the issue of waste management was not taken into account. Solar and biomass were the next best options, with all fossil fuels ranking significantly lower due to poor payback, emissions, health effects and future performance. However, the World Commission on Dams (2000) noted that:

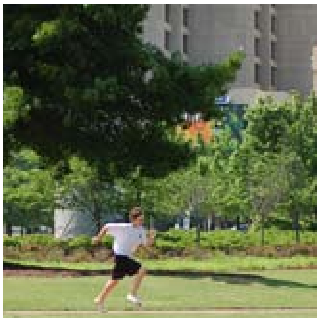
Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable… In too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced,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

Gagnon at al (2002) did not take 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 terms of energy consumption, 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, constructing 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 do not increase the load on the existing power supply grid and therefore do not require additional generation and plant to be constructed. Use of the existing grid primarily as a backup would provide buildings with a reliable power source unless the grid was not well maintained.

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 affect 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 (2002) found that energy requirements per m^3 of water for water and wastewater plants in Taipei were six times that of the pumping requirements within a six-floor apartment. Hendrickson and Horvath (2000) found that highway, bridge and other horizontal construction costs were 0.6% of the 1992 United States 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, and railroads 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, 1999). The sprawled-out character of many urban sites in the United States, 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 the United States is expanding outwards with increasing costs for infrastructure and loss of arable land, while the inner cities are being neglected and losing population.

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 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 groundwater pollution; clearing of land 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 made by 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 to local planning and decision-making if they are to seriously consider constructing sustainable buildings.

Social and cultural aspects of buildings

Within the concept of sustainability, both social and cultural aspects must be considered. Jackson (2003) identified the influence of the 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." Visual and physical access to greenery was identified as a principal element for health which must be incorporated into relatively high-density neighbourhood designs. These designs include public 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 cars.

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.

Saleh (2001) 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. Architecture and urbanism had been traditionally viewed as more than an agglomeration of buildings and streets. Residents valued the features of modern village extensions and landscape elements which enhanced their interaction with the physical environment but there were elements of the vernacular villages and landscape that people regretted losing, such as "qasabahs", weekly markets and cultivation of terraces. Saleh (2000) 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."

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 such as climate, weather extremes, environmental conditions and local building materials. Some traditional designs use woods which are resistant to local insect infestations rather than more commonly imported softwoods such as pine. Local 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.

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 (see Table 3), with local councils:

- defining acceptable areas for development such as inner cities and marginal lands
- defining urban population strategies to manage density and overall city population
- providing effective infrastructure for long-term management with an emphasis on maintaining existing systems rather than increasing them
- defining 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
- facilitating the use, reuse and recycling of local materials rather than imported materials
- working with local building material suppliers to provide quality timber to the local market

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

Activity	Potential reduction
Planning	
Increasing urban density	50–90% in energy and impacts
Development on marginal lands	40–50% improvement in crop production; reduction in erosion
Integrated urban and architectural design	Improvement in building value
Incorporation of green and open space	Improvement in building value and human health
Human powered transportation	90% in 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% in energy
Local source of materials	50–80% in energy and impacts
Use of low emergy materials	50–80% in energy
Recycling/reusing materials	40% in energy; 10–50% in impacts and materials
Water tanks, composting toilets	80–90% in external water and energy
Operation	
Low energy, low water appliances	20–50% in energy and water
Use of human powered transportation	90% in energy; improvement in health
Minimising water and energy use	10–20% in 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 by: 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 to the system and recognise the need for refurbishment and maintenance rather than rebuilding or construction, use low energy appliances and conservation 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.

Tools to achieve sustainability

The CIB Working Commission (Bourdeau et al, 1998) identified a number of recommendations towards achieving sustainable construction:

- building owners and clients should have a very important role in disseminating sustainable construction since they represent the demand of the building sector
- initiatives should involve planning, industry and constructors through adapted regulations, standards or fiscal measures and incentives
- education and training should be used to make sustainable development concepts well known and accepted by all people
- a common language should be developed
- designers should adopt a more integrated approach to design
- manufacturers of building products should assess life cycle considerations as the basis of product development
- building users should see environmental issues as one aspect of productivity
- building maintenance organisations should see environmental consciousness as a factor of competitiveness
- adapted tools to help in decision-making should be developed
- the building process itself should be improved

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

Life cycle assessment (LCA) is being used to further identify the life cycle impacts of buildings. Peuportier (2001) found it difficult to use LCA to determine which building materials should be used but found it useful in determining the technologies which were suitable. Further research is needed at local levels to identify the best options for materials, technologies, construction methods and designs which are suited to local climates, and 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 LCAs for their products, making it easier for builders and consumers to make choices. Overall, the major current issue 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 10 years, a greater understanding of local limitations and requirements will enable councils to manage their areas as systems, rather than in the piece-meal manner of 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 better enable engineers, architects and others involved with buildings to make decisions for the design and construction of sustainable buildings.

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 of 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 timescales. 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 the rate at which they may be harvested may become restricted. These resources are the basis for a sustainable energy future for humanity.

However, a significant and courageous effort by political and community leaders will be required to change 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 10 warmest years in recorded weather history have occurred since 1987. The world is experiencing the impacts that global warming models predicted. The physical evidence includes retreating glaciers, melting permafrost in Alaska, and many more severe weather events, such as the Manawatu floods in 2004. Even the Pentagon has issued a warning that global warming, if it takes place abruptly, could result in a catastrophic breakdown in international security. It suggests that wars over access to food, water, and energy would be likely to break out between states.

Even if climate change happens 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 stabilise greenhouse gas concentrations, enhance global energy security and eradicate energy poverty. We urgently need the technical expertise, political will and international co-operation required to make sustainable energy a reality. Engineers need to lead the discussion and action on this issue.

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 New Zealand 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 is achieved in an efficient, fair, reliable and sustainable manner.

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

a) environmental sustainability

b) a continuing improvement in our energy efficiency

c) a progressive transition to renewable sources of energy

d) the lowest possible costs and prices to consumers

e) prices that reflect the full costs of supply, including environmental costs

f) reliable and secure supplies of essential energy services

g) fairness in pricing, so that the least advantaged in the community have access to energy services at reasonable prices

In 2001, the Energy Efficiency and Conservation Authority (EECA) published a *National Energy Efficiency and Conservation Strategy* (NEECS) for moving New Zealand toward a more sustainable energy future. This strategy established two targets as mechanisms to measure progress and confirm that New Zealand was heading in the right direction. The first target was a 20% improvement in energy efficiency and the second target was to increase the contribution of renewable energy by 30 Petajoules. These targets had only government "ownership" and will need to be replaced with targets and mechanisms with widespread ownership 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.

Government has also ratified the Kyoto Protocol and is committed to reducing New Zealand's greenhouse gas emissions to below 1990 levels. However, performance in achieving this target is poor. To help reflect the full environmental costs, government is implementing programmes to help change the direction on our energy future. The government intends introducing 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, Ministry of Economic Development projections for New Zealand's energy future 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 Ministry of Economic Development model, are shown in Figure 1 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.

Figure 1: *Total Primary Energy Supply Projections*

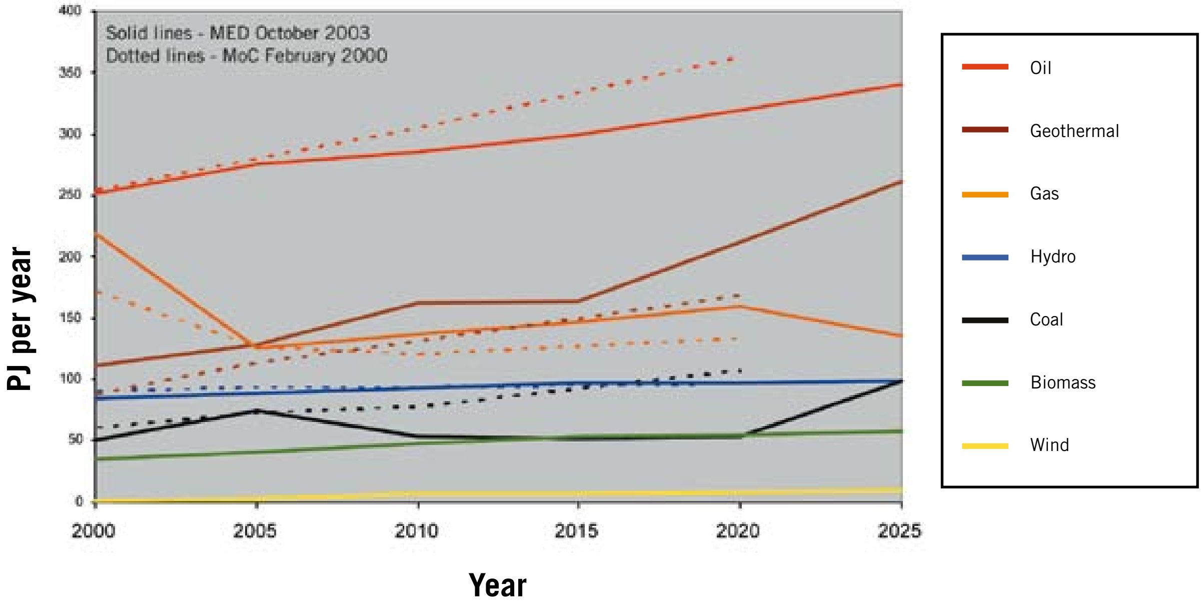
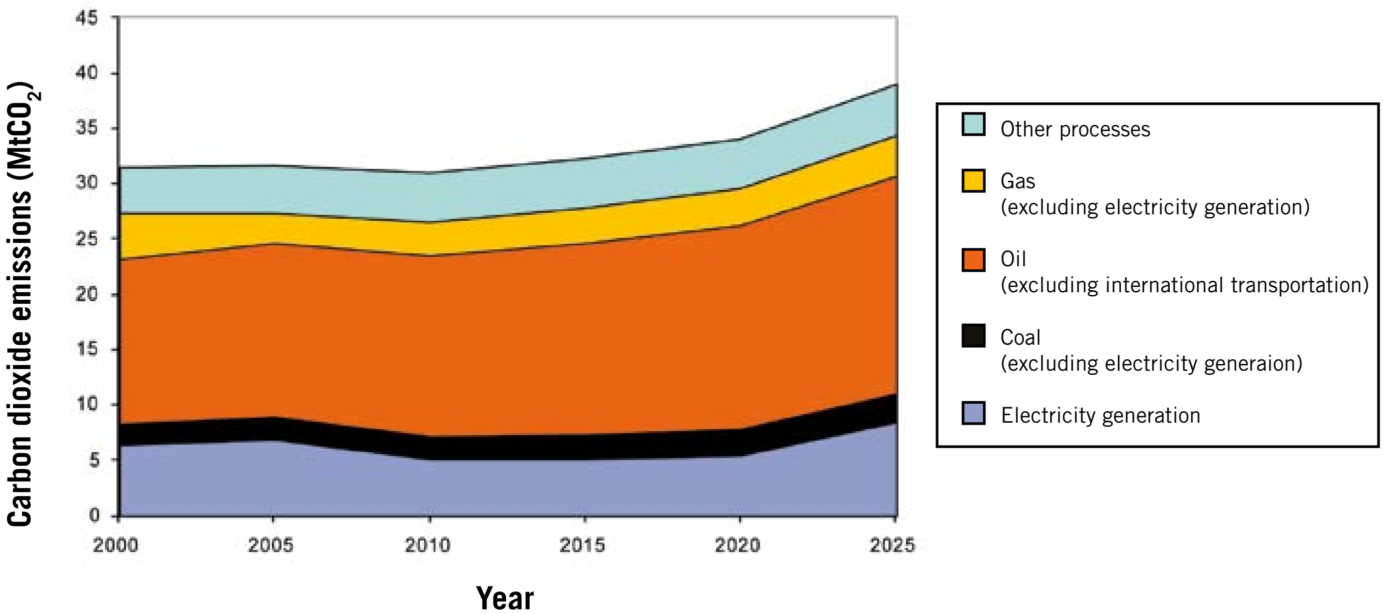


Figure 1 shows a steady continuous rise in oil demand, primarily due to increasing demands of the transport sector. The natural gas primary energy resource line reflects the early depletion of the Maui gas field followed by a steady increase in gas use as Pohokura, Kupe and new gas discoveries are exploited. Beyond 2020, the Ministry of Economic Development 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 Ministry of Economic Development assumptions on the costs of new generation. The increase in wind generation is projected to be about 10% per annum 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 Ministry of Economic Development 2003 reference scenario would result in CO_2 emissions of 39 million tonnes by 2025, as shown in Figure 2 below.

Figure 2: *Carbon Dioxide Emission by Fuel Type*



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 Ministry of Economic Development 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 the Ministry of Economic Development's (2003) *New Zealand Energy Outlook to 2025* to a more sustainable energy future, New Zealand will require widespread adoption of a changed way of thinking about energy. Commentator Steve Goldthorpe (2003) stated that 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 must be defined. The energy markets need to become the servants of the energy industry, not its master.

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 to minimise the impact of end-use demand on energy supply include:

- 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 the use of energy where possible (it is 10 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 (for example, 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 (for example, 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 (for example, combined heat and power schemes)
- consider combinations of energy sources (such as 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)
- value energy in proportion to its usefulness

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

SUSTAINABLE TRANSPORTATION

Currently, transportation generates about 40% of our CO_2 emissions, or 15% of all greenhouse gas (GHG) emissions. These are the fastest growing source of GHG emissions in New Zealand. Air pollution from the motor vehicle fleet is also increasingly unsustainable. The goal of achieving sustainable transport is therefore appropriate for New Zealand and its engineering community. This will have implications for both the way we travel and the shape of our communities.

An increased focus on managing demand for motor vehicle transportation is necessary, as opposed to traditional approaches to predict future trip demand based on historical growth trends and attempts to provide road capacity. This is in line with overseas trends as most western countries and their engineering communities have begun developing sustainable transportation policies and initiatives, including Australia, Canada and many countries in Western Europe.

In the near future, a variety of techniques will be needed to manage traffic demand, including:

- land use planning to deter urban sprawl
- road tolling techniques, including congestion pricing
- parking supply management and pricing
- fuel pricing
- high occupancy vehicle lanes
- more support for walking and cycling

These changes, some of which have already occurred, will encourage New Zealanders to make necessary changes in lifestyle and travel behaviour.

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). There are a number of ways in which engineers and the engineering community can help to achieve this goal.

More support will be needed for walking and cycling.

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.

New Zealand aspects of sustainable transportation

GHG 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 GHG emissions. Road motor vehicles produce over 11 million tonnes of CO_2 annually, about 40% of our CO_2 emissions and 15% of our GHG emissions.

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 period 1990 to 2001. 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 and Transit New Zealand are to allocate resources and operate the state highway system to achieve an "integrated, safe, responsive and sustainable land transport system".

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 at making 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 (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 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 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 GHG emissions. The New Zealand Climate Change Office 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 if available in your area.***

According to *Getting there – on foot, by cycle* (2005), quoting the New Zealand Travel Survey (1997/1998):

- 30% of trips undertaken by mechanised transport (private motor vehicles, public transport, and bicycles) are for distances of under two kilometres
- 60% of trips are less than five kilometres in length

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

We cannot build our way out of congestion

Overseas perspectives

In Western Australia, the government is developing a sustainability code of practice for government agencies and their employees (Government of Western Australia, 2004). 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 is a partnership of local authorities and other organisations working together to promote sustainable transport. "Car share" schemes are increasingly common in the United Kingdom 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 10 people own a car, whereas in New Zealand, 10 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. In 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, *Natural Capitalism* (Hawken, Lovins and Lovins, 1999) devotes a chapter to transportation, 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 United States, 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 United 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.

The Association of Professional Engineers and Geoscientists of British Columbia (2004) has developed a primer on sustainability 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 in length) and is recommended as background reading for New Zealand engineers and others interested in sustainable transportation.

The Centre for Sustainable Transportation (2002) 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.

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.

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.

Both carrots and sticks are needed to change travel behaviours – support for walking, cycling and public transport, and disincentives for single-occupant motor vehicles.

Members of IPENZ and 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 achieving a more sustainable transportation future.

SUSTAINABLE WATER

Many countries are facing serious environmental and socio-political problems concerning their water resources. Issues 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 low population and geographical, population, geological and climatic advantages compared with many other regions in the world, we are lucky enough not to have to directly address such issues yet. However, if these issues need to be given serious consideration in the future, they will expose New Zealand's poor water resource management and threaten the sustainability of our future water resources.

The need for sustainable water resources management was identified more than a decade ago at the Rio Earth Summit. 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. When we consider that true sustainability involves designing for the long-term (that is, 1,000+ years as mooted by Tonn, 2004 and Boyle, 2004), we start to realise that the concerns 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 already faces threats to our stormwater, wastewater and groundwater resources as infrastructure has become increasingly outdated, overused and polluting.

The purpose of this section 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. By doing so, it will present ideas and guidance on the future role of engineers in shaping a more sustainable (or "less unsustainable" according to James, 1999) water industry.

Sustainability thinking for water resource engineers

The water resources development paradigm of recent years has largely been driven by growth. This model caused adverse effects on our environment with respect to degradation of ecosystems, removal of human settlements and cultural sites, disruption of sedimentation processes and contamination of water sources. It has now become stalled as social values and political and economic conditions have changed.

Engineers have traditionally described the water industry as comprising three separate components and their respective infrastructure: stormwater, wastewater and water supply. A sustainable water management approach requires that these separate water resources be managed as one integrated system.

Water engineers need to be able to apply process thinking (and/or systems thinking) to 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 appreciates that the whole is greater than the sum of its parts; objects and their relationships contribute to a process; and that 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 comparable to 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 independently of each other.

In 2002, Integrated Water Resources Management (IWRM) developed to reflect a process-thinking approach out of the realisation that the traditional water resources paradigm had been characterised by (International Water Association, 2002):

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

Engineers must also consider when and where sustainable water services can be achieved and what water infrastructure is required in the local, regional and national contexts. Consideration needs to be given to whether it is possible to develop sustainable water services on a specific site, sub-catchment or an entire catchment, given that the surrounding local or regional contexts are likely to be unsustainable. While it is possible to implement "more sustainable" or "more ecologically-friendly" technologies and approaches at specific sites or within catchments, until an entire region's water infrastructure is modified to reflect sustainable 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 need to recognise that the continued operation of these existing systems is threatened, especially by growth in demand. Sustainability does not necessarily mean replacing the existing systems completely, but will require adaptation, incorporating new approaches and technologies. Integrating the currently fragmented water infrastructure will take many years and may require considerable adaptations. In the interim, water resource engineers can endeavour to practice sustainability principles as discussed below.

Sustainability of New Zealand water resources

A working definition of sustainable water use is provided by Gleick (2000) 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 Parliamentary Commissioner for the Environment in 2002, identifies sustainable urban water systems as having several key characteristics which cover the following measures:

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

The Parliamentary Commissioner for the Environment (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 involving consultation with the whole community of interest including residential uses, industry, tangata whenua, agencies, agriculture and recreational users
- residents are guaranteed access to a minimum supply of potable water to maintain basic health

Beyond Ageing Pipes focuses 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 which are constrained by a legacy of existing infrastructure. However, many of the principles and issues outlined in *Beyond Ageing Pipes* are applicable to both suburban and rural districts.

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 (2000) believes that applying sustainable principles to water resource management and design will help to bridge the gaps between such diverse and competing interests.

Central government

New Zealand's water sector has no central government "home". The Parliamentary Commissioner for the Environment (2002) recognises that the legislative framework for the management of water services is outdated and conflicting. There is no overarching Act which represents this sector, unlike the Building Act and Land Transport Management Act representing the building and transport sectors respectively. Water engineers' work is therefore governed by central government policy and legislation that is fragmented.

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. Consequently, the majority of water engineers either work within local government authorities, for the local authorities or have to report to them (for example, via resource consents).

Sustainable water management rhetoric can be found in many New Zealand local government policies, strategies, objectives and plans, which suggests there are vast opportunities for engineers to action the intents and visions of such documents. Examples include:

- *Proposed Auckland Regional Plan: Air, Water, Land*: "to provide for the integrated and sustainable management of natural and physical resources"
- North Shore City strategic plan: "to implement sustainable, integrated water supply, stormwater and wastewater services that are in harmony with the natural water cycle"

The fundamental question is how do we implement these good intentions, especially when there are many different agencies controlling the different water services? In many cases, individual engineers, planners and asset managers at the local government level are already changing the way water projects are prioritised and implemented. Councils should encourage engineers and the larger community 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, that is, through requests for proposals, contractual arrangements and involvement at the policy/project decision-making stage.

Water resource engineering in a sustainable society

There are issues associated with promoting and implementing alternative, "more sustainable" technologies, given that such alternatives are likely to be under-represented at site and regional levels until there are significant changes to economic, political and regulatory incentives. Weaver et al (2000) 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 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 imperative to develop such technologies. This catch 22 is one that many other industries are grappling with as they strive to implement more "less unsustainable" technologies.

Engineers that work at a site level are often constrained by economics, the desires of the client and particular physical site constraints which frequently rule out more sustainable options. In contrast, water resource engineers who operate at an infrastructure planning and asset management level can influence regional and district water infrastructure priorities.

It is noted that sustainable technologies rely on fundamental cultural, social and economic reform. Nonetheless, the heavy dependence of sustainable technologies on market reconstruction to enable technologies to become cost-competitive and socially and culturally acceptable makes them a special case (Weaver et al, 2000). As a result, the uptake of sustainable technologies is likely to be longer when compared to other types of new technology, such as internet and email technologies.

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 through incremental improvements to existing technologies but will require a concerted and focused effort on the part of government, business and societal groups to tackle the issue strategically and systematically (Weaver et al, 2000).

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 in providing practical steps towards more sustainable water resource practices.

While many water resource engineers are familiar with assessments including economic and environmental aspects, the inclusion of cultural and social criteria is a new concept. The cultural aspect is especially important in New Zealand given the high value Maori place on water resources.

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 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 encouraged land re-entry options as an alternative to discharging to water bodies.

The social aspect of sustainable water is more than merely including social criteria in the sustainability decision-making matrix. It means a social process of decision-making, not just public consultation but true participation by an active and informed public. The state of our water bodies is often very visible, such as oil and scum floating on the surface or discolouration from excess sediment, and hence very much in the public eye. For the engineer, this means dealing with the all-inclusive nature of sustainability and educating the public in clear and simple language that the public can understand.

The choice of different water technologies often leads to confrontation, polarisation and indecision by stakeholders. This issue is often one of scale and personal preference. Advances in new technologies are often at opposite ends of the scale of treatment, for example:

- new higher quality, individual wastewater treatment systems (replacement of the traditional septic tank) versus the "economies of scale" and new sophisticated, centralised treatment plants
- at-sources stormwater treatment methods versus a mature wetland at the bottom of the catchment

The challenge here is the choice of assessment criteria when comparing one technology versus another.

Another issue relates to the short-term and long-term actions that can be taken using an integrated three-waters approach (stormwater, wastewater and water supply). Weaver et al (2000) found that when analysing five different water technologies, the greatest impact was created with a combination of innovations, advancing tailor-made solutions based on sets of integrated measures. Weaver et al (2000) 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 example, in many cases the installation of rainwater tanks in the urban environment is only economically viable when including both stormwater and water supply benefits.

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
- decision-making that uses sustainability assessment and life cycle analysis tools

Accepting that the current piped systems (or 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 (1999) 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 (1999) predicts that by linking networks with Geographical Information Systems data and accurate rainfall sensors, real-time information could be put "online" to provide water resources information and issues to the general public, thereby countering the "out of sight, out of mind" attitude.

Other potential technological advances which will improve the sustainability of our water resources include:

- greater material choice, such as smaller pipe sizes
- improved construction techniques, such as 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
- new and improved maintenance techniques, such as using robots to access small diameter pipes

Already in the New Zealand industry, software water management models are becoming the dominant decision-making tools for water infrastructure development, management and optimisation. Developing models for integrated situations (that is, stormwater, wastewater and water supply networks and systems), in accordance with Integrated Water Resources Management good practice, will require models with superior technical accuracy and the capability to represent the complexities of these real situations. Further models that have the capacity to correctly build and model alternative systems, for instance 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 sustainable water checklist draw heavily from *The Hanover Principles: Design for Sustainability* by William McDonough Architects (1992).

SUSTAINABLE SOLID WASTE MANAGEMENT

The increasing pressures of consumerism, the 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 are one of the most overt indicators of an unsustainable society. There is no definition of waste in New Zealand legislation; however the Ministry for the Environment (2002) defines waste as "any 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.

Sustainability and solid waste

The New Zealand Waste Strategy (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: environment, social and economic:

- lowering the social costs and risks of waste
- reducing the damage to the environment from waste generation and disposal
- increasing economic benefit by more efficient use of materials

Hawkens et al (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
- investing in natural capital – reversing environmental destruction through investment in sustaining and restoring natural capital

Both 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, creating more efficient use of materials and energy.

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, 2003). Since then it has received a widespread following in New Zealand led by the funding and advocacy group New Zealand Zero Waste Trust. 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 New Zealand" has been used for public campaigns. In this way, the zero should not be viewed as the only indicator by which success is measured, but 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 "manage" 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 (Zero Waste Trust, 2003).

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-loop 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. They have been adopted by industry for obvious environmental reasons (improved resource, material and energy efficiencies, and 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.

Sustainable solid waste practices

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 New Zealand. 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* (2004) 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 lifespans (Ministry for the Environment, 2002). 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 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. 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, and 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 in 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.

At an international level, Gertsakis and Lewis (2003) 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 programmes 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.

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?

Gertsakis and Lewis (2003) 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 (2003) illustrates how using a "sustainability" decision-making framework can result in different solutions for a given waste recovery problem (Table 4).

Weaver et al (2000) highlight, however, that sustainable technologies, unlike many other new technologies, depend 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. Uptake of sustainable technologies (such as 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 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 (2003) 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.

Table 4: *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 can we find other ways to keep clothes clean (eg considering new fabrics)? (Avoidance)
Can we design components and the overall appliance to extend product life? (Reduce)	Can we develop a completely new technology for cleaning clothes that has a much lower environmental impact (eg 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 the 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 for disassembly and recyclability to recover materials? (Recycle)	Can we establish product stewardship programs that establish closed-loop programmes 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 of energy, water and detergent consumption? (Avoidance and Reduce)

Beyond recycling

It is critical for engineers to remember that recycling can only be considered one component of the solution. It does not address the issue of product design and can allow manufacturers to get away with unchecked resource consumption. Waste volumes in the United States are still rising despite more recycling than ever.

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 product's life rather than at the end. For example, a gold ring weighing 10 grams has generated approximately three tonnes of waste on a life cycle basis (cited in Gertsakis and Lewis (2003)). This is an example of the ecological footprint of a product on which decision-making regarding resource-efficiency can be based.

Jacobsen and Kristoffersen (2002) provide examples of the positive impacts that producer responsibility initiatives in Europe have had on reducing the impact of packaging on overall waste quantities. In 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 six. Producer responsibility does not 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 and vacuum cleaners that are designed for durability will need to be designed alongside reformed industries and markets which can accommodate 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 its 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, 2000).

Future priorities

Waste work within the Ministry for the Environment is now spread across three major policy groups with the overall responsibility for the implementation of the New Zealand Waste Strategy sitting within the Sustainable Industry Group. The priority areas of work for the Ministry for the Environment in coming years are (MacLeod, 2004):

- Special wastes – priority is being given to the recovery of used oil and tyres and the development of an extended producer responsibility policy for New Zealand.
- Monitoring and evaluation of progress – as started with the recent review document (Ministry for the Environment, 2003).
- Organic wastes – the recent review identified some of the challenges involved with meeting the New Zealand strategy target for organic waste (that is, conflict with landfill gas generation, contamination in compost and biosolids products, and market creation). The Ministry for the Environment plans 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 New Zealand 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 – a new programme designed to reduce waste generated by government agencies and imbed “environment” into everyday activities.
- Unwanted Agrichemicals – a national programme for the collection of unwanted agrichemicals which supports current regional, council-led agrichemical collections.

New Zealand standards, guidelines, best practices

The lack of specific New Zealand 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 the Ministry for the Environment’s *Guide to the Management of Cleanfills* (2002) or the Centre for Advanced Engineering’s *Landfill Guidelines* (2000), there are few examples of best practices for waste minimisation initiatives.

Construction and demolition waste management and minimisation best practice guidelines are currently in development but 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.

Central government recognises that reducing New Zealand’s solid waste generation is a cornerstone for sustainable development (Ministry for the Environment, 2002). 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. 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 sustainable solid waste checklist.

SUSTAINABLE ENGINEERING AND TECHNOLOGY CHECKLIST

CHECKLISTS

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 timescale 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 and political influence between groups of people as much as possible?
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 or 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 manner and timeframe?
14. Does the project, product or process contribute towards reducing non-sustainable practices to zero over a relatively short timeframe?
15. Can social and economic accounting methods be used at the planning stages to disclose, identify and quantify previous or developing environmental problems?

CHECKLISTS

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, ie based on needs rather than wants, and not driven by technology?
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 will be (such as solar and wind power – locally abundant renewable resources)?
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 CHECKLIST

1. Have you considered the embodied energy or emergy for materials proposed for the building 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 minimise 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 (eg 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 to 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?

CHECKLISTS

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. Have you established guidelines and methods of evaluation for determining the external effects and life cycle costs and risks for energy systems, taking into account the environmental, health and other damage caused by energy-related activities, and made 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. Have you encouraged the substitution of non-renewable energy resources with 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 the co-operation 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. Can you support the regulation of access to electricity networks to increase community interest in the decentralisation of power supply?

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 “predict and provide”?
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 (eg 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 (eg 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 programmes 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 for some meetings instead of face-to-face meetings requiring extensive land or air travel?

CHECKLISTS

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 that we need to change how we work accordingly?

Specific tasks for water resource engineers:

4. Have you carefully accounted for water use throughout the entire design process?
5. Have you protected water sources (including groundwater) from contamination and given careful consideration to efficiency techniques at every step?
6. Have you potable water consumption only for life-sustaining functions?
7. Have you considered water from aquifers, rainwater, surface run-off water, greywater, and any water use for sewage transport or processing systems within a cyclical concept?
8. Have you returned wastewater to the earth in a beneficial manner and considered organic treatment systems?
9. Do your designs minimise impermeable ground cover?
10. Do your designs consider rainwater and surface run-off water as a possible water resource for use in infrastructure systems and processes?
11. Have you treated greywater and applied it to practical or natural purposes suitable to its characteristics?
12. Have you minimised contamination and put any water used in any process-related activity back into circulation?
13. If used for sewage treatment or transportation, have you restored water to appropriate water quality standards prior to distribution or reuse?

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 (eg specified tenders use recycled content, reusable materials or reduce waste generated by the project as much as possible)?
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; 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 (eg using life cycle analysis tools to guide decision-making processes on best use of materials and energy)?
8. Have you considered all the various initiatives that could assist with waste minimisation (eg 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 (eg application of biosolids to land for soil conditioning or use of wastewater as heating)?
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?

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