Sustainable Resources and Production in New Zealand

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

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1. Summary

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

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

2. Introduction

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

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

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

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

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

3. Defining a resource

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

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

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

The RMA does not cover all resources however, as extraction of mineral and petroleum resources are, instead, legislated by the Crown Minerals Act (1991) which does not require sustainable management of those resources. The RMA, however, does cover the

[1] Daly, H., 1997. Georgescu-Roegen vs. Solow/Stiglitz. *Ecological Economics* 22:261-266.
[2] Hardin, G., 1968. The Tragedy of the Commons. *Science* 162:1243-1245.

environmental impact of that extraction and the use of resources such as water which are used in the extraction and processing of minerals. However, from a sustainability perspective, all resources, including mineral and petroleum, must be considered.

4. Types of resources

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

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

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

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

Non-renewable resources are those which have a finite supply on this planet. Some of these resources, such as carbon, iron, silicon and aluminium, are very common and it is unlikely these resources will be depleted within the next thousand years. Other resources such as copper, nickel and zinc, are more limited in supply although there are questions as to the extent

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

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

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

of their total supply and the current major limitation is the cost of recovery for those metals (Mining, Minerals and Sustainable Development (MMSD) Project, 2002).

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

5. Effects of using resources

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

5.1 Contamination

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

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

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

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

5.2 Degradation

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

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

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

5.3 Dispersion

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

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

5.4 Consumption

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

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

5.5 Loss

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

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

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

6. Current use of resources

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

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

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

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

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

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

7. Efficient use of resources

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

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

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

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

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

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

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

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

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

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

The Natural Step [9] states that we should:

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

[8] Schwartz, P. and D. Randall, 2003. An Abrupt Climate Change Scenario and Its Implications for United States National Security. U.S. Defense Department. Available at http://www.ems.org/climate/pentagon_climate_change.html.
[9] The Natural Step, 2003. Four Simple Principles of Sustainability. http://www.naturalstep.org/learn/principles.php

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

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

7.1 Use minimisation

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

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

7.2 Durability

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

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

7.3 Recycling

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

7.4 Servicising

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

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

8. Engineering Considerations

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

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

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

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

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

9. Sustainable design of technologies and products Checklist

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