Sustainable Products

Using Nature's cyclic | solar | safe *Protocol for Design, Manufacturing and Procurement*

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1. Summary

This report presents a radical but simple framework for environmental sustainability. cyclic | solar | safe is an easy to understand protocol for understanding products and how they can become more environmentally sustainable. It is fast and easy to use, whether you are designing a product or considering buying it.

Most environmental problems are caused by unintentional side-effects of the manufacture, use and disposal of products. While there have been some considerable improvements in the environmental performance of the "usual suspects" like recycled paper and concentrated detergents, we must expand our horizons radically and start to look at everything, from hi-fis and golfclubs to doorhandles and lipstick.

Environmental problems can be described using a computing metaphor: the global operating system is sending us a lot of error messages – we need to reconfigure our software to be compatible with nature or else it will crash. This change needs to be very low level – in the protocols that industrial systems use; their inputs and outputs, changing their BIOS (Basic Internal Operating System) to become a "Biocompatible Input-Output System".

The "grown" and the "mined" are the two main interlocking systems on earth, and they need to be modified if they are to continue to live together. For a few hundred years they have been fighting unnecessarily – the human mineral system has been physically ousting and chemically disrupting the growing system. Yet mankind needs both to survive.

Sustainable products are products which are fully compatible with nature throughout their entire lifecycle.
For example, the materials they are made from form part of a continuous cycle, and the energy used to make them does not release persistent poisons into the air or water. Some sustainable products become part of the living ecosystem, such as plant fibres which are grown and then turned into board for packaging. At the end of the package's life, the material is composted and returned to the soil once again. Such a product would be deemed to be mostly within the "ecosphere" – the living ecosystem. Other types of sustainable product are more part of the "technosphere", but follow similar protocols. For example, aluminium sourced from recycling collection, now known as "urban mines" or "above-ground mines", makes an excellent lightweight car body. The aluminium is melted down using energy from biomass or small scale hydroelectricity, and is collected and re-used at the end of the car's life.

The author has translated these rules of nature into the five design requirements for sustainable products. The first three mimick the protocols used by plant and animal ecosystems:

> **Cyclic:** The product is made from organic materials, and is recyclable or compostable, or is made from minerals that are continuously cycled in a closed loop.
>
> **Solar:** The product uses solar energy or other forms of renewable energy that are cyclic and safe, both during use and manufacture.
>
> **Safe:** The product is non-toxic in use and disposal, and its manufacture does not involve toxic releases or the disruption of ecosystems.

The fourth requirement is based on the need to maximise the utility of resources in a finite world:

> **Efficient:** The product in manufacture and use requires 90% less materials, energy and water than products providing equivalent utility did in 1990.

And the fifth is about maximising human happiness and potential:

> **Social:** The product' s manufacture and use supports basic human rights and natural justice.

For a given product, it is possible to score each of these requirements out of 100, and this information can be expressed in a simple logo, or it can be presented in text as an vital statistics-style index: 50 | 30 | 90 | 40.

The goal of sustainable design is simple – to make all products 100% cyclic, solar and safe.

If you are a manufacturer, this means looking at each one of your product lines and making a long-term plan to bring them all up to speed. If you are a service organisation, it means looking at all the things you buy, and making a plan to change their specification and seek out products that are nearer to being 100% environmentally sustainable. We have the technical building blocks for a 100% sustainable industrial system in all but a few key areas – most of the staple technologies of the sustainable future already exist, and only a few will require major new innovation, specifically electronics and microchip manufacture.

There is a long way to go. Only about 0.001% of industrial products and services on the market today could be described as having good environmental performance. A relative handful of firms have already come up with product innovations – there are maybe 1000 potentially sustainable products on the market – out of an estimated 100 million products on sale worldwide. Yet sustainability is

inevitable – it's just about who will be first to gain a beachhead. Already firms are making major strategic stakes in what is a trillion dollar opportunity.

The design of sustainable products is not conceptually difficult. Having analysed over 500 products, the author found that all the innovations were based on just 24 techniques:

Recycled Materials	*Stewardship Sourcing*	*Increased Utility*
Re-use	*"Bio-Everything"*	*Dematerialise*
Organic Materials and Composting	*Durability*	*Every Little Counts*
	Upgradability	*Be More Local*
Takeback and Remanufacture	*Repairability*	*Multifunctionality*
Muscle Power	*Complementary Components*	*Fine Control*
Hydrogen and Electricity		*Work with the Seasons*
Photons	*Extremely Long View*	*Biomimicry*
Substitute Materials	*Increased Efficiency*	

Once a product has been assessed using the cyclic | solar | safe Scoring System, the direction for improvement is usually obvious. From this an 80:20 plan can be drawn up. This takes the top 20 products that cause 80% of the impacts, and then makes a plan for them to be 80% sustainable by the year 2020. The beauty of an 80:20 Product Plan is that it is clear and simple, so that senior executives can understand it and so it can be communicated clearly and incorporated into an organisation's overall business strategy.

What seems radical today will be mainstream tomorrow. Becoming 100% sustainable is not only possible, it can be achieved by the year 2100. By moving away from the "how can we be less bad?" mentality to the "how can we be 100% good?" mindset, we give ourselves the capability of redesigning every product to be 100% cyclic, solar and safe.

2. The Hidden Ugliness Of An Ordinary Day

Products are the source of all environmental problems. It may seem surprising, but most environmental problems are caused by unintentional side-effects of the manufacture, use and disposal of products. Looking at products closely highlights the environmental problems they cause.

For example, over 30 tonnes of waste are produced for every one tonne of product that reaches the consumer. And then 98% of those products are thrown away within 6 months. This whole process is about 2% efficient in terms of energy. And you get through a lot of products. When you include these hidden impacts of manufacturing, we each consume our own body weight in materials EVERY TWO DAYS, or every day if you are an American.

An individual product may look harmless enough. But the environmental damage it causes happens elsewhere, out of sight and mind, "hidden" from the consumer and often from the designer as well. Major issues such as pollution, deforestation, species loss, and global warming are all by-products of the activities that provide consumers with food, transport, shelter, clothing and the endless array of consumer goods on the market today. I call this the "Hidden Ugliness" of products.

Design is the key intervention point for making radical improvements in the environmental performance of products and all their byproducts as well.

Let's have a look at some of the products you use every day:

2.1. Computer

My computer is the latest model and looks very cool, but …

… when you take a closer look, there are some ugly things beneath the surface. The device that I sit in front of all day is a complicated assembly of more than 1,000 materials, many of which are highly toxic, such as chlorinated and brominated compounds, heavy metals, acids, plastics and plastic additives.

About a quarter of my computer is plastic, mostly the casing. It's a candy-coloured translucent plastic called polycarbonate, the same stuff that music CDs are made from. Polycarbonate is quite inert and very strong, but it has the greatest environmental impact of all the plastics types, according to Dutch research. It is made from phosgene, which was used as poison gas in the first World War, and Bisphenol A.

The phosgene was made in Indiana, by reacting chlorine gas together with carbon monoxide. The Bisphenol A was also made in the US, derived from cumene

supplied by one of the big oil companies. Bisphenol A is made from phenol and acetone which are catalysed together by hydrochloric acid. It is a suspected endocrine disrupter -- a chemical which can scramble critical messages carried by hormones within the body, causing "gender-bending" or loss of fertility.

Workers at silicon chip factories in Scotland and America have unusually high levels of cancer, with even people in their twenties falling ill. Workers and communities allege that chemicals used to make chips caused cancer, birth defects, and neurological and respiratory disorders. The employees work inside low-story buildings in 'clean rooms' that are so free of dust that even hospital operating rooms are dirty by comparison. Workers wear head-to-toe suits not to protect themselves but to keep their skin flakes, breath and hair from contaminating the valuable chips.

And it's not just in the factories themselves. Each plant has emissions to air and water. Two thirds of America's most polluted sites are in Silicon Valley. Covering miles of aquifers, most of the sites are tainted with trichloroethylene (TCE), a solvent once widely used to clean chips. Regulators now suspect it might cause cancer. TCE is still used at some plants.

The main ingredients in my computer are Plastics, Silica, Steel, Glass, Aluminium, Copper, Lead, Zinc, and Tin. There are also small amounts of rare or toxic metals like Nickel, Cadmium, Chromium, Mercury, Gold and Platinum.

Even in small amounts, these exotic metals can leave a big footprint on the earth. For example, the gold in circuit boards of my PC may have come from Romania. In February 2000, cyanide-containing slurry burst through a tailings dam at the Baia Mare gold mine in northern Romania. The poison flowed into the Danube, Europe's largest waterway. The spilkilled thousands of fish and devastated other wildlife in Hungary and Yugoslavia and was one of the worst river pollution accidents in Europe.

Unfortunately, this was not just a one-off accident. Environmental damage from gold extraction is routine -- for every ounce of gold extracted in Brazil, there are 9 tonnes of wastes, including silt and mercury runoff which kills fish and other aquatic life downstream.

The environmental damage caused by metals extraction has even sparked a civil war. The copper in the wires of my computer could have come from the Panguna copper mine on Bougainville in the North Solomons, which is one of the world's largest artificial holes. During the operation of this mine, about half a billion tonnes of waste ore was discharged into the local river. All aquatic life in the Jaba River and its floodplain was destroyed as a result of this chemical and physical pollution. In 1989, their livelihood and food source ruined, the local people took up arms against the mining company and successfully booted them out, creating their own independent republic.

Computer junking is also happening at a faster rate. The lifespan of computers is only about 3 to 5 years. Despite a significant increase in computer recycling, every year about 30 million computers are dumped, incinerated, shipped as waste exports or put into temporary storage or people's attics.

Consumer electronics constitute 40% of lead found in landfills. The main concern in regard to the presence of lead in landfills is the potential for the lead to leach and contaminate drinking water supplies. Hans van Weenen, Chair of the United Nations workgroup on Sustainable Product Design, says that "electronic products should actually be considered as industrial waste. Their number is increasing and their life is decreasing. Electronic waste piles are growing, as is their pollution potential. Most of these problems have their source in the development and design of the products concerned."

There have been improvements in computer design. The industry has phased out the use of gases that damage the ozone layer. The Energy Star is a voluntary standard on energy consumption that has been very successful. There is draft European legislation that will phase-out the use of mercury, cadmium, hexavalent chromium and two classes of brominated flame-retardants in electronic and electrical goods by the year 2004.

But my computer is still pretty ugly when you start to look beneath the surface.

2.2. Cup of Coffee

While I reflect on the impact of my computer, I nip out to the coffee bar and get a tall latte. The cup has great graphic design, and the coffee tastes great, but …

…where did the coffee come from and how were the cup and the milk made? Coffee is the second highest user of pesticides (cotton uses the most) and the second leading cause of rainforest destruction (agriculture/ranching takes first prize there). New techniques for coffee production are an environmental nightmare, where trees from the rainforest are cut and burned to dry coffee beans.

Then there's the unfair trade aspect. Farmers receive a fraction of the retail price of coffee. They' re at the beginning of a long chain of supply that ends at my coffee bar. The worst exploitation takes place at the hands of village buyers who pay low prices to farmers and offer expensive credit. Unless you count being exposed to pesticides as worse. Farmers often do not wear the correct protective clothing.

My cup is made of a plastic called polystyrene. It looks and feels like a paper cup, but it isn't. All the hip new coffee bars started out using paper cups, in an effort to appear 'politically correct', but the plastic cup firms have fought back. They developed a special surface texture to feel like a paper cup.

After several million years of being laid down as oil somewhere under the earth's crust, a large oil company extracted the material and refined and processed it extremely complicated ways. The oil was turned into plastic and shipped across the country to the cup manufacturers. The cups were formed and then stacked and packed in cardboard boxes. The cardboard was made from partly recycled material, and partly new trees. The boxes were taken by lorry and eventually delivered to my corner coffee bar. By the time I have drained my cup, it will have seen about 20 minutes of actual use. Then I'll throw it in the bin and it will go, along with the box it and the other cups came in, via a council refuse lorry and a river barge to a landfill site 25 miles away.

To get the milk for my latte, a dairy cow was milked with a machine as she is every day for 10 months of the year. She had been separated from her calf after only a few weeks. The calf, especially if it was male, was probably sold to the veal industry and then kept confined in the dark for sixteen weeks before slaughter. My cow is treated with bovine growth hormone to increase milk output, but this makes her more susceptible to infections and disease, so her feed contains large doses of antibiotics. The milk was taken by refrigerated lorry to a central packing plant where it was pasteurised and decanted into a plastic bottle, and then taken by another lorry to a wholesalers and then onward by another lorry to the coffee bar, a total journey of over 100 miles.

I walk back to the office, wondering if locally-grown peppermint tea might be a better choice of beverage …

2.3. Chair

My chair looks very stylish, and has won several design awards, but beneath the surface …

…the steel for the frame was made in Eu rope from pig iron from ore that had been dug out of huge open-cast mine in Brazil that had originally been forested land. The mining took a lot of energy -- digging, crushing and processing metal ores uses 7% of global energy consumption. The steel mill burned about 20kg of coal to make the steel for my chair.

Most metals are extremely abundant, so running out is not really a concern. There were claims in the 1970s that we would run out of gold and oil and so on, but people have been extremely resourceful in finding new reserves -- the North Sea and Alaska are hardly the easiest places to work in. No, the problem is not the running out of non-renewables, but effect they have on renewables -- the land area poisoned and lost for agriculture, and the fish and other aquatic life damaged by mining effluents going into rivers. Because so much mining goes on in the developing world, companies are getting away with very low standards of pollution control.

The steel for my chair has been chrome plated to make it look shiny. Wastes from the chromium plating process are dumped in rivers, especially in developing countries, damaging fish and making the water undrinkable.

My chair has a classy leather seat. It was made by taking the skin of cow (perhaps the great-grandmother of the cow that made the milk in my latte) and treating it with a variety of substances, including mineral salts, formaldehyde, coal tar derivatives, and various oils, dyes, and finishes, some of them cyanide-based. Most leather is chrome-tanned, so my chair is giving the environment a double dose of chrome pollution. And once again, the workers who make the products I use are at the sharp end of these badly-designed processes. The coal tar derivatives used to make my leather seat such a rich black colour are extremely potent cancer-causing agents. According to a study released by the New York State Department of Health, more than half of all testicular cancer victims work in tanneries.

The plastics in the chair, such as the arms and the polyurethane foam padding, are all products of the oil industry. One of the concerns about oil is that it is inevitably spilt. According to the Institute of Environment and Forecasting in Heidelberg, Germany, each European family' s share of oil spilled in the seacomes to 12 litres – enough to cover 12 swimming pools. On Alaska's North Slope oilfields, thousands of spills have occurred, releasing oil, diesel fuel, acid, biocide, ethylene glycol, drilling fluid and other materials. In the Arctic, the environmental impacts of oil spills are more far-reaching and last longer than in more temperate climates. Diesel fuel, the most commonly spilled product on the North Slope, is acutely

toxic to plant life; even decades later, diesel spill sites in the Arctic show little vegetative recovery. And it' s not just a few accidents. In 1999, BP's flagship Endicott Field, the third largest oil well in Prudhoe Bay, was fined $15 million for deliberately injecting hazardous waste back into groundwater.

Most companies try and comply with the local laws where they manufacture goods. And some of those laws are about the environment. But passively complying with environmental laws is not the same as actively designing to improve the environmental performance of a product.

Legislation allows pollution. Even if all companies comply with the law, there will still be substantial levels of toxic releases that cause damage to ecosystems and people. The pollution is allowed on the basis that releases will "dilute and disperse" in the air or w ater and so be rendered harmless. However, some chemicals do not simply dilute over time – they accumulate in ecosystems and can come back to haunt us.

Are you sitting comfortably?

2.4. Clothing

My clothes are very fashionable, but …

... the manufacture of my T Shirt required the use of 1/3 lb (150g) of chemical fertilisers and pesticides. Cotton accounts for 25% of the world's insecticide use. And farm workers exposed to excess toxins are at risk from poisoning and health problems. A study in Ghana revealed that some farmers are so used to using pesticides without protective clothing that they actually feel proud when they feel a bit sick at the end of the day, because it shows the chemicals are working properly.

My wool trousers were coloured with synthetic dyes made in Germany. The wool came from the UK, where the law requires all sheep to be dipped in strong chemicals. This sheep dip is linked with farmers feeling suicidal and suffering from memory loss. They were sewn together by a part-time worker who made less than the legal minimum wage, working at home on a piecework basis.

Many environmental impacts are literally invisible, making them hard for people to be aware of. Vapours and gases float around unseen, causing damage to people's lungs or to the ozone layer. Pesticides and other pollutants can be found in perfectly-clean looking water. Radiation from nuclear or electrical sources also can't be seen or even sensed without special equipment. You've got to study products closely to see what's really going on.

For example, my new training shoes are made of leather, polyurethane, natural fibres, polyester, nylon, heavy metals, dyes, finishing chemicals, chemical primers and adhesives. Some manufacturers still use a third of a litre (12oz or a typical drinks can size) of adhesive to make just one pair of shoes.

And the toe is scuffed already …

2.5. Lamp

My new desk lamp is by a famous designer, but …

The bulb contains mercury, a toxic heavy metal. When the bulb goes I will throw it away with the normal rubbish, to the annoyance of the landfill companies who are concerned that the mercury may leak into drinking water. Every year, more mercury ends up as emissions to air, water and soil than there is mercury used in products such as batteries, fluorescent tubes, electrical equipment, paint and tooth fillings.

The ABS (acrylonitrile-butadiene-styrene) plastic casing of the lampshade is made from Saudi Arabian oil and benzene (derived from Chinese coal) and ammonia in a Japanese chemical factory.

My office is very dark, so I use the lamp during the day. The lamp will use 1200 kWh of electricity during the ten years I will own it. This would require about half a tonne of coal to be burnt at the power station, or in most countries a more complex mix of fuels such as oil, natural gas and uranium oxide.

The elegant neck of the lamp is made of aluminium. It weighs about 2kg, which means that 100kg of waste was produced in order to make it. The aluminium ore (bauxite) came from an open cast mine in Jamaica. It was then shipped to Ghana, where 1% of the world' s aluminium is made using energy from a hydroelectric dam which flooded an area half the size of Wales.

Ultimately, all products are disposable, so even this design classic will end up in the bin. Waste is produced during the manufacture of the food we eat and the products we buy. When buildings are knocked down, the demolition waste has to go somewhere. While more and more waste is getting recycled, there is still lots that is simply dumped or burnt. The effect on the environment is obvious.

As the industrial ecologist Gunter Pauli says, "Man is the only species capable of generating waste -- things that no other life on earth wants to have".

Oops, the bulb's blown. I burn my finger trying to change it. Maybe I should try to change the world instead …

2.6. Magazine

I read about the lamp in the latest copy of a trendy magazine. It's thick and glossy, but …

The paper was made out of wood pulp that came from a Portuguese forest. No old-growth trees were chopped down to make the wood pulp – most of the original forests were chopped down a long time ago. This pulp actually came from land that had been used for growing food crops. The eucalyptus trees planted there were not native to the area. They sucked up water from neighbouring land, ruining crops, and the local wildlife did not settle in the new forests.

The magazine is really thick and weighs almost 1kg. It took 5kWh of energy to turn the wood into this much paper, and this would have been enough to run my lamp for 100 hours. It takes as much energy to make a tonne of steel as it does to make a tonne of paper. The paper mill has improved a lot in recent years. Instead of pumping effluent containing poisonous by-products including dioxins into the nearest river, the mill re-uses most of its water, resulting in less pollution.

The paper is very glossy, and is in fact only about 70% paper. The rest is made up of fillers and clays, which were taken from a quarry in Spain.

The inks used to print my magazine were made in China. Pigments based on heavy metals such as arsenic, cadmium, and lead have now been largely phased out. However, there are still concerns about the toxicity of the latest generation of dyes, in particular the yellow colours code numbered 2 and 13, which are harmful to aquatic environments. Yellow 12 is widely used in full colour printing, and its ingredients include 3,3'-dichlorobenzidene, a known carcinogen which is also a suspected liver and kidney toxicant. The Environmental Defense Fund ranks it as one of the most hazardous compounds (worst 10 percent) to ecosystems and human health. It enters the environment from industrial discharges or spills.

The printing process produced a variety of wastes, including isopropanol alcohol, contaminated water, some silver from platemaking, and various cloths, inks, solvents and cleaning chemicals.

My magazine was then distributed by road to my local newsagent, the lorry carrying it emitting particulate, NOx and CO2 emissions all the while.

None of the products mentioned in my magazine were sustainable. In fact, some of the products receiving praise cause known environmental problems.

Still, they all look great! And that's all that counts in design, isn't it?

2.7. Ugliness in a Nutshell

What you have just read about the computer, coffee, chair, clothes, lamp and magazine is just a snapshot of what's going on. There are many things about these products, both good and bad, that I have not had the space to mention.

Overall, the design and manufacture of products is certainly not all bad. There has been a lot of improvement. Billions of pounds are being spent on cleaning up industry and environmental laws are getting stricter every day. But are these measures enough? The answer is clearly no, as the environment is still in a mess. "Legalised pollution" is the problem -- firms are allowed to put smoke into the air and poisons into the water, as long as they do not breach a certain agreed level. You are legally allowed to put pollutants into the air when you drive your car. But just because these things are legal does not mean that they are right.

It's no longer enough that a product is pretty on the outside, cheap and available. We owe it to the coming generations who will have to clean up our products in the future to manufacture in harmony with nature.

You've already seen from the product examples above that we impact on the environment in many different ways. Figuring it all out is very complex. There are hundreds of parameters to consider. To really do it properly, you need to do a life cycle assessment study that could take many months and cost tens of thousands of pounds.

But to quickly get to grips the environmental impact of any product, you just need to look at five factors:

- Materials
- Energy
- Toxics
- Sheer volume of Consumption
- People

These five factors cover a big chunk of any product's impacts. If you can get some information on:

- the type of materials used,
- how much energy is used in manufacture and use,
- what toxic releases there are likely to be,
- how much materials and energy is used, and
- how workers and consumers are affected,

then you have plenty to go on. You will be able to understand where the directions for improvement lie. We will explore this approach in more detail later in the book.

It's taken me years to get it that simple! It's not perfect, but it's a very practical approach.

2.8. Learning More about Environment

I've now devoted enough space in this book to covering the state of the environment. You can read more in the thousands of books and magazines that track its degradation. Or just look out of the window! The signs are all around us.

There is a truly massive amount of material out there – it's been calculated that if you get every environmental and ecological journal, book and magazine, you'd spend your whole time just opening the envelopes they come in and putting them in a big pile!

But be aware that most environmental perspectives have a prognosis for the planet's future health that is not positive. It can make you feel helpless in the face of such huge devastation, or an insignificant player in terms of making a difference.

I say don't worry too much about this. Learn enough to convince yourself that this is a real problem that needs fixing. And then start work making things better. Don't end up as some people do, making a hobby of finding out about environment, but not doing anything about it.

This book is solutions focused. Consumers have a role to play – every purchasing choice they make is important. But designers' choices are amplified so enormously by mass production. Your role is critical. Shaving a gramme of plastic off a bottle that is made in the millions or even billions clearly adds up to a big saving.

So let's get on with it.

3. Uniting Industry and Nature

3.1. Overcoming Misconceptions in Environmental Thinking

There are several problems with the way environment is regarded by business, government and NGOs today:

- There is an assumption that nature and mankind are two separate systems, that "nature" is something that has to be fenced off and protected from man's activities. They're not separate. Really there is only one big system. Until we can develop a unified picture of nature and industry as a single interdependent process, debate about environment will always be on an "us" versus "them" footing – mankind versus nature – where one side always has to lose.

- Legislation allows pollution. Even if all companies comply with the law, there will still be substantial levels of toxic releases that cause damage to ecosystems and people. The pollution is allowed on the basis that releases will "dilute and disperse" in the air or water and so be rendered harmless. However, some chemicals do not simply dilute over time – they accumulate in ecosystems and can come back to haunt us.

- One of the main ways that industry is tackling environmental issues is to simply become more efficient. Using less materials, water or energy to get the same job done is deemed to be better for the environment. This is based on the assumption all products are bad, and that if we use less then perhaps someone won't make a product they would otherwise have done. This "eco-efficiency" is rather like giving the Titanic more fuel-efficient engines. It's useful because it means less pollution from the funnels, but the iceberg is still looming.

- An Environmental Management System or "EMS" is a popular tool that provides a framework for continuous improvement by means of target setting. However, the targets are based upon a very basic assessment of the organisation's impacts, and the EMS provides no mechanisms for encouraging innovation. If all companies were to have an EMS, then we would still be a very long way from having an industrial system that worked with nature, rather than against it.

- Another common misconception is that every product has an impact on the environment and we can only make each product a little less bad. A related thought is that energy use is always bad, so using less energy is the main goal. But what about changing the quality of the energy instead? If you can use energy from the sun, in the form of wind, wave or solar energy for example, then energy use is no longer "bad", and in theory, you can use as much as you want – or as much as you can afford, as solar energy is not unlimited and it still costs money to collect it. Products can be made so that they are fully compatible with natural systems.

- Consumers want to consume. Yet "buying less" is a goal promoted by governments and environment organisations worldwide. This notion of "doing your bit" by consuming less is fundamentally unnatural – ecosystems want to maximise their throughput of energy and materials, and they also become more complex over time. Approaches to environmental improvement should work with people' s natural need to consume, not against it.

- Social issues are being incorporated into corporate environmental programmes, usually in the form of stakeholder consultations. This is a good way to avoid having neighbours and customers get angry with a firm, but just because some members of the general public agree with a course of action, it does not mean that it is right. Socially-beneficial activity will always be good PR, but it can be used to draw attention away from a lack of real environmental progress. Bruce Sterling, in his Viridian Manifesto for 2000, says "the human race has repeatedly proven that we can prosper cheerfully with ludicrous, corrupt and demeaning forms of religion, politics and commerce. By stark contrast, no civilization can survive the physical destruction of its resource base. It is very clear that the material infrastructure of the twentieth century is not sustainable. This is the issue at hand."

- A vast amount of effort has been put into making sure that food and drugs are safe for people to ingest. Yet very little is known about the fate and pathways of these and the thousands of other chemicals that are routinely released into the environment. It is possible to be too health- and people-centric. Just as Copernicus challenged the notion that the heavens revolve around the earth, we need to stop thinking that life revolves around us. As famous ecologist Aldo Leopold said, "we are but plain members of the biotic community".

The good news is that all these misconceptions can be overcome, and the global agro-industrial system can become compatible with nature. While systems and targets and social issues and eco-efficiency are all important tools, they must be viewed as stepping stones and not ends in themselves.

Business is responsible for the task of redesigning every product and process used today. It is capable, both technically and financially, of meeting such a design challenge.

Environmental problems can be described using a computing metaphor: the global operating system is sending us a lot of error messages – we need to reconfigure the software to be compatible with nature or else it will crash. This change needs to be very low level – in the protocols that industrial systems use; their inputs and outputs, changing their BIOS (Basic Internal Operating System) to become a "Biocompatible Input-Output System".

Unlike many perspectives on the environment, the approach in this report is creative, positive and optimistic.

3.2. A Tale of Two Systems: The Grown and the Mined

"If it can't be grown, it's gotta be mined" reads a bumper sticker seen by the author during a visit to a mining community in central Alaska.

The "grown" and the "mined" are the two main interlocking systems on earth, and they need to be modified if they are to continue to live together. For a few hundred years they have been fighting unnecessarily – the human mineral system has been physically ousting and chemically disrupting the growing system. Yet mankind needs both to survive.

Both the grown and the mined cycles are driven by collections of free agents – the ecosystem is made up of DNA organisms, has been going for 3.85 billion years and is "sustainable" by anyone's definition. The technosystem is comprised of companies that compete for energy and materials flows in much the same way, and has been going for only 250 years.

Global materials flow is about 450 billion tonnes (Gt) per year. Of this, 50 Gt is mined 400 Gt is grown. Of the 400 Gt of materials flow that is organic, 250 is wild and 150 is utilised by humans.

The flows of human-extracted minerals mix with wild and agricultural flows in a grand dance of carbon, nitrogen, hydrogen and oxygen. Both industrial systems and ecosystems form cycles and food webs. One preys on another. One's input is another's output. A steel factory eats effluent of iron mining, and its own extrusion is eaten by a car plant. An iron atom may flow from the door of a Citröen to the hull of a Japanese supertanker and onto a Swiss railway track.

Mankind relies on both flows for its continued prosperity. Indeed, we are part of this flow as well, being 94% carbon, hydrogen and oxygen. Although no such molecule exists, humans could be described as a collection of atoms in these proportions:

$C_{305}H_{1590}O_{604}N_{30}Ca_6P_6S\ (KNaCl)_{Trace}$ or summarised as: CH_5O_2

The idea that we have all breathed in a molecule of air that Julius Ceasar breathed shows how interconnected we are, both to each other and to the past and future. A carbon atom can be part a blade of grass, be eaten by a vole, which in turn is eaten by a kestrel. Alternatively, the grass could have been eaten by a cow, gone into you and then out via sewage and back on to the land or out to sea.

Being able to quickly build a mental picture of flows of materials is a key skill for understanding the environmental performance of a product. To be sustainable is to have no impact on the environment, but instead to be a part of the continuous cycles and flows of materials that have existed in nature for billions of years.

We often say that we're running out of resources. But there are still the same number of atoms around on the earth's surface - we have simply converted atoms

into molecules that are of no use to us. With continuous cycling of both organic and inorganic materials, we will never run out of the resources we need.

A firm's ecosystem can easily be drawn out, with all the stocks and flows and cycles of materials. This provides a sound basis for understanding how to make a firm or product line 100% sustainable. This mapping approach also reveals that most manufacturing processes throw away 60% or more of their materials, making the idea of value adding a nonsense. It's more like "value subtracting". By mimicking nature and becoming more cyclic, firms find that the same materials can be sold again, and that there is less waste, so they **stop making things they can't sell** .

4. The cyclic | solar | safe Product Protocol

Sustainable products are products which are fully compatible with nature throughout their entire lifecycle. For example, the materials they are made from form part of a continuous cycle, and the energy used to make them does not release persistent poisons into the air or water. Some sustainable products become part of the living ecosystem, such as plant fibres which are grown and then turned into board for packaging. At the end of the package's life, the material is composted and returned to the soil once again. Such a product would be deemed to be mostly within the "ecosphere" – the living ecosystem. Other types of sustainable product are more part of the "technosphere", but follow similar protocols. For example, aluminium sourced from recycling collection, now known as "urban mines" or "above-ground mines", makes an excellent lightweight car body. The aluminium is melted down using energy from biomass or small scale hydroelectricity, and is collected and re-used at the end of the car's life.

The basic protocols needed are very simple: use materials in cycles, and instead of emitting poisons, only emit materials that can be "food" for others. It makes sense for industry to adopt this approach for a number of reasons:

- It is a logical follow through of the environmental approaches adopted so far, which have been piecemeal efforts to increase recycling, reduce toxics and introduce more renewable energy, but with no clear end in sight.

- These protocols are the same ones used by living organisms, which is the only materials and energy system that is proven to be sustainable – it has been going for about 3.85 billion years.

- This protocol-based approach works from the ground up, and once a critical mass is reached, will be self-organising.

- It applies the most basic strategic method – working backwards from an end point to make a plan. Let's have 100% recycling, eliminate toxics, and have all energy sources to be nonpolluting, and all by the year 2050. So the question becomes not "how much can we improve from here?", but rather "what will it

take to get where we need to be?" Does every design choice help us towards becoming 100% sustainable?

Over 500 environmentally-innovative products were analysed by the author during 1999, and they all fell into 24 basic categories of innovation. These 24 inventive principles could themselves be placed into four groups: recycled and recyclable, using renewable energy, low or zero toxicity, and improved eco-efficiency.

The author has translated these into the five design requirements for sustainable products. The first three mimick the protocols used by plant and animal ecosystems:

> **Cyclic:** The product is made from organic materials, and is recyclable or compostable, or is made from minerals that are continuously cycled in a closed loop.
>
> **Solar:** The product uses solar energy or other forms of renewable energy that are cyclic and safe, both during use and manufacture.
>
> **Safe:** The product is non-toxic in use and disposal, and its manufacture does not involve toxic releases or the disruption of ecosystems.

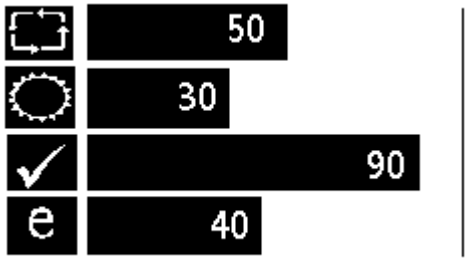
The fourth requirement is based on the need to maximise the utility of resources in a finite world:

> **Efficient:** The product in manufacture and use requires 90% less materials, energy and water than products providing equivalent utility did in 1990.

And the fifth is about maximising human happiness and potential:

> **Social:** The product' s manufacture and use supports basic human rights and natural justice.

For a given product, it is possible to score each of these requirements out of 100, and this information can be expressed in a simple logo, for example:



Or it can be presented in text as an vital statistics-style index: 50 | 30 | 90 | 40.

Potential innovations that would move a product towards true sustainability can be identified by considering each of the four requirements in turn.

The UK today would score about 42 | 2 | -30 | -40. The negative scores for Safe and Efficient indicate that more materials are being used and more toxins are being released than in 1990. See page [x] for more detail on how these scores are calculated.

It is important to recognise that a score of 100 | 100 | 100 | 100 is achievable and that this represents the goal for all products – 100% sustainability.

4.1. Cyclic

The cyclic requirement means that materials are either recycled in a closed loop or are edible or compostable. There is no option for landfill or incineration. Minerals are cycled in a continuous closed loop, with the emphasis on re-use rather than reprocessing. Leasing, rather than selling, products containing such materials eliminates the concept of waste – customers may use them as long as they wish, but when the end-user is finished with their TV, carpet or washing machine, it goes back to the factory for remanufacture. Materials that are grown should be processed in a way that allows their eventual digestion by animals, plants or micro-organisms when they reach their planned end of life. Products that have combinations of these two types of material must include a system for disassembly, either by the end-user or on takeback.

It' s a myth that there is no waste in nature. Sockeye salmon die after spawning and clog the higher streams with their bodies. The leaves of the London Plane tree can take decades to rot down. So nature is not always that thrifty, exhibiting redundancy in systems and also creating much waste, although such waste is always utilised by other components in the ecosystem.

It' s important that the word "cyclic" is used, rather than "recycling". The word recycling includes "downcycling", where high grade materials such as plastic are collected and then used in low grade applications, such as rubbish bags. The goal is to be fully cyclic, so that materials are used again at the same level. For example, many metals can be continuously cycled with no or very little loss of quality, and of course organic materials are broken down to their atomic constituents of carbon hydrogen and oxygen and fully re-used on each cycle.

Examples of fully cyclic products include returnable glass or polycarbonate drink containers, Interface' s ' Evergreen' carpet leasing product, and ' film with lens' cameras. Using recycled materials in manufacture is a step towards full cyclicity, and some firms have adopted closed-loop recycling for elements of their products such as IBM' s keyboards (although the PVC used has drawbacks in other areas). German chocolate maker Loser makes use of a handy consumer bio-digestion system – the trays in its boxes are made of edible wafer.

Financially, product takeback means that manufacturers can sell the same thing twice – something that refurbishers such as Xerox, Dell and ICL are realising can be very profitable. It' s much easier to spruce up an existing component than it is to make one from scratch – and their refurbished products are technically the same standard as new ones.

Some firms don' t want to admit or talk about the fact that their products will break or wear out. But this is just putting your head in the sand. With some good marketing, perhaps using a slogan like, “All good things must come to an end”, it is possible to present takeback as a desirable feature.

The rise in takeback will benefit firms involved in reverse logistics – whoever will be the new "Fedex of Waste and Takeback" will literally double their business as a new stream of products starts coming back to manufacturers instead of being dumped.

Re-use and recycling are not always strictly cyclic, especially for organic materials. For example, in December 1998, some over-enterprising Newcastle florists were caught taking flowers from graves, and then selling them again. A laudable example of product takeback, but it earned them a 9 month prison sentence. It was also more about materials life extension than being truly cyclic. If they mulched down the flowers when they finally died and put them as compost of the next crop of daffodils, then that would have been cyclic.

In much the same way, you can surmise that food and paper production isn't cyclic. Human sewage goes into the sea or landfill, and paper biomass and nutrients tend not to back onto the forest soil. In reality, things are a little more complicated than that. For example, most forestry practices today leave the leaves and branches which have the most nutrients in them to rot down on the forest floor. What is exported is the core of the trees, which is almost pure cellulose and lignin, basically carbon, hydrogen and oxygen. When these are eventually burnt in the form of paper waste, the resulting CO2 and H2O can return to the cycle in gaseous form.

High-tech trading systems are being used to facilitate the exchange of wastes. The Environment Exchange in London trades in Packaging Recovery Notes for materials such as paper, plastic, metals and glass. A publicly accessible internet bulletin board matches sellers and buyers.

Choose a product and study it. What percentage of the materials flow is cyclic (cradle to cradle) and what percentage is linear (going to landfill or being put into a different type of ecosystem or a similar one but far away)? Include all the byproducts as well!

The basic measure of cyclicity is:

(the % of recycled material used + the % that is recycled at end of life) / 2

Japan is a leader in being cyclic. While the UK manages to recycle less than 20% of its glass, Japan has set a target of recycling 100%. Starting in April 1997 a law came into effect that making it mandatory for all plastic and glass bottles discarded by households to be recycled. Some individual companies have forged ahead, for example some of Japan's leading beer companies have a target to achieve zero-waste plants by the year 2000. Asahi Breweries, which produces the top brand of beer in terms of annual sales, achieved a 100% waste recycling ratio at its main plant near Tokyo in 1996. This plant creates about 46,000 tonnes of waste a year. The company has adopted a system of dividing this waste into 54 categories, which are retrieved separately in 110 boxes set up in 22 places inside the plant. The retrieved waste is then sold to reprocessing businesses for reuse. For

example, beer dregs, which account for 85% of the total waste, are reused as fodder for cows, plastic bands for packaging are reused as carpet material, vinyl bags become bathtub frames, bottle caps become construction materials, and cardboard boxes become recycled paper. The key point for the success of this project is the thorough separation of waste for collection. The plant takes special care to prepare separate retrieval boxes for waste that is created in small amounts, such as fluorescent light bulbs and batteries. In November 1997 the company set about cutting waste to zero at two other plants, investing a total of 200 million yen (1.5 million dollars) for the installation of raw waste disposal machines and other equipment. It aims to achieve the 100% recycling of waste at all of its nine plants in Japan by the year 2000.

At the moment, cost involved in establishing 100% recycling considerably exceeds the revenue that they earn from sales to reusable waste businesses, and is more expensive than simply disposing of the waste. However, as waste disposal costs rise, some Japanese firms believe that actively tackling the issue of recycling now will lead to significant benefits in the long term. There are also cases of new jobs being created in companies dealing exclusively with recycling. Many companies also report that recycling has the effect of increasing morale among employees and that the sense of mission involved in contributing to the environment "adds liveliness to the workplace".

In 1995 a record 84.9% recycling rate was achieved for glass in Switzerland, according to Vetrorecycling AG. This means each person collected 37.4kg of glass, and represents an 8.6% increase on 1994 levels.
The United Kingdom is bottom of the league for glass recycling in the EU, recycling 28% of glass as opposed to 77% in the Netherlands. Switzerland leads the world with 84%.

Some 385 million tonnes of steel are recycled each year (or approximately 50% of the global steel production, all applications combined), which effectively places steel in first place among the most recycled metals in the world.

In 1997, steel packaging was recycled in Europe at the record-breaking rate of 52%, with Germany leading at 84% and the UK at 31%. Japan and United states achieved 80% and 61% respectively.

In Copenhagen in 1996, 90% of construction waste was recycled and 9% incinerated for heat recovery, giving a total of 99% cycling – all near the city so minimal transportation costs were incurred.

Products don' t disappear after being sold. Every product is disposable.

4.2. Solar

The solar requirement means that all materials flow and energy use is powered by photosynthesis, muscle or renewable energy. This covers products with mounted photovoltaic solar cells, or those hooked up to a mains supply powered by wind, wave, biomass, or PV, through to products that are grown or operated by hand. This also applies to "embodied energy" – the energy used to provide or service or to manufacture and distribute a product.

The term "solar" is a pointer, as many renewable energy technologies have environmental problems. The goal is to be cyclic and safe as well as solar. For example, large scale hydroelectric dams can silt up and become unusable in a twenty year period, and the wildlife and fish stocks in the river can be destroyed.

Shell scenarios explore how energy patterns may change with increasing energy efficiency and the development of economic renewable sources. Their most optimistic scenarios for renewables suggest that by the year 2050, about half of the world' s energy will come from renewables. (Shell Report to Society 1998)

Photovoltaic (PV) cells are being produced for power stations in unprecedented numbers, and prices per installed Watt are tumbling. A PV-powered PV factory has been designed, known as a ' solar breeder' . Cells built into appliances are have appeared on calculators, robot lawnmowers, radios, watches, refrigerated lorries, mobile phones, boats, bikes, cars, smoke alarms, hearing aids, cameras and even cappuccino makers. Human-powered technologies are also enjoying a renaissance with the clockwork radio and ' kinetic' quartz watches.

The business implications of renewables are long term but profound – once the capital cost of the equipment to harvest the energy is paid off, it' s basically energy for free.

In 1999, 2% of UK electricity came from renewables, with the government target being 10% by 2010.

Green electricity tariffs are already being offered to consumers by UK firms including the Renewable Energy Company/Ecotricity, Eastern Group, London Electricity, MEB , Northern Ireland Electricity, PowerGen, SEEBOARD, Scottish Power (and subsidiary MANWEB), SWALEC, SWEB, WRE and Yorkshire Electricity – although some of these are not where the amount of renewable energy sold is matched over 12 months by the supplier' s purchase of renewable energy, but instead are where the customer pays into a fund to stimulate investment in renewable energy.

Research by Future Energy, a labelling scheme for green tariffs, found that 71 percent of home owners are interested in buying from renewable sources and that one in five of householders questioned said they would pay a premium of as much as five pounds ($7.78) per quarter.

Agriculture is a big energy user, and as David Coley and Exeter university says, "we all eat oil", because 6 calories of fossil energy is used to make one calorie of food.

Iceland aims to have the world's first "hydrogen economy" — eventually replacing gasoline and diesel on all of its cars, buses and fishing fleet with nonpolluting hydrogen. An Icelandic consortium, Vistorka hf. (EcoEnergy Ltd.), signed a Cooperation Agreement in 1999 with DaimlerChrysler, Norsk Hydro and the Royal Dutch/Shell Group setting up a joint venture called the Icelandic Hydrogen and Fuel Cell Company Ltd. With an equity capital of $1 million, the venture will test various applications utilising hydrogen fuel cells or hydrogen carriers. One of the first could be a hydrogen/fuel cell-powered bus service in Reykjavik, with further projects being introduced between 2000 and 2002.

Iceland has large potential for renewable energy sources which, so far, have only been harnessed to a limited degree. Some 67% of its primary energy consumption is supplied by hydro- and geothermal sources, the highest percentage share among OECD countries. However, it is not clear that geothermal energy will be used to make hydrogen from water, as Shell Hydrogen are partners and they have a process that makes a hydrogen-rich gas from liquid fuel.

Fossil fuels are stored solar energy, but they are not cyclic or safe. If they could be made to be so, it would mean extracting fossil fuels without spilling any, and having prefect combustion (which means no NOx, SOx, particulates etc.), then all you are doing is releasing solar energy that has been in extremely long-term chemical storage. Every year we use fossil fuels that took about 12 million years to lay down. If you were to try and manufacture gasoline in the same way nature did, with temperature and pressure, it would cost about $1 million per gallon. In the process of releasing energy, however, you are using up today' s oxygen and releasing fossil carbon into the air in the form of CO2. Having higher-than-historical levels of CO2 in the atmosphere will cause disruption to ecosystems, and so is not "Safe" as defined below. While some may argue that global warming is merely inconvenient, in terms of flooding and weather disruption, there will be profound effects on habitats and agriculture. These changes will be large and a mix of helpful – the ability to grow wheat in Siberia, perhaps – and unhelpful – altered geographic ranges for disease vectors such as the malaria-bearing *Anopheles* mosquito. The rate of change will be a great strain on human and non-human systems alike.

While fossil fuels have a limited use in the future, they have enabled today' s industrial society to come into existence – it' s rather like the earth' s mother' s milk which supports the industrial baby. When the milk dries up, it' s time for the baby to be weaned off fossils and onto proper food – current solar income. A bit of toilet training wouldn't go amiss either …

Biofuels are one way of using current solar income – they are made from fermented sugar alcohols or oils from crops such as rapeseed. While they give off

CO2 when burnt, this CO2 is part of the current carbon cycle, not adding to it as fossil fuels do. A recent innovation in Switzerland allows the making of ethanol from waste cellulose, a major breakthrough as previously only food crops such as sugar beet could be used for this purpose.

Passive solar is used to heat water, buildings and to dry fruit and vegetables.

Wave power is a dark horse. Disillusioned nuclear scientists put their own money into a wave energy project at Dounreay. Wavegen, an engineering company based in Inverness designed and built a 28 metre high oscillating water column called the OSPREY - short for 'Ocean Swell Powered Renewable EnergY'. This was launched off the coast of Dounreay in 1995 but was damaged by a storm during a vulnerable stage in its installation. Despite this setback, the potential is vast – the energy contained in the waves off the Scottish coast has the potential to provide almost three times the electricity needs of the whole of the UK. There are three other main types of wave energy machine. The Limpet (Land Installed Marine Powered Energy Transformer) is based upon an oscillating water column that collects energy from waves smashing into a gully which force air through two Wells turbines, producing 500 kilowatts (kW) of electricity. The Pelamis (Latin for swimming snake) is a series of floating articulated concrete cylinders anchored to the sea bed. As they undulate in the waves, hydraulic rams drive a 375kW generator. The Barge resembles a huge floating steel box and works by waves rushing up a sloping ramp and splashing down into a reservoir before being released back into the sea via a 750 kW generator.

In 1999, European Commission announced their Renewable Energy Plan:

One million PV Roofs
15 million m2 of solar collectors
10,000 MW of wind turbines
10,000 MWh of CHP Biomass
One million dwellings heated by biomass
1000 MW of biogas installations
5 million tonnes of liquid biofuels

4.3. Safe

"Don't kill your customers" seems like a sound maxim. But the facts speak for themselves: the European Environment Agency reports that there are between 20,000 and 70,000 types of chemicals on the market, and little is known about the toxicity of 75% of these – not even the minimum data required by the OECD for a preliminary assessment of health hazards to humans. Data on pathways, fate and concentrations of chemicals in the environment is even more scarce, as is research into the effects of combinations of chemicals. The European Chemicals Bureau has identified 2,500 high production volume chemicals for priority risk assessment, and as of 1997 they had completed studies on ten of them.

The implication is that some or many of these untested compounds are toxic, and of particular concern are those compounds which are persistent and bioaccumulative. A 1998 study by Cornell University – to be taken with a pinch of salt put placed here for context – estimates that 40% of deaths worldwide are caused by environmental pollution such as air pollution and water contamination.

The only way to be sure is to not release anything that is not food for another process, and to do that it is necessary to do the research and "show me the pathway".

To be safe, products and process have to be free from toxic compounds and releases at all stages.

This means that releases are food and they do not disrupt ecosystems or are inert. A safe process or product cannot chemically or physically disrupt people or other life. Toxic releases are releases of things that are not food for something else, or are releases of potential food, but in the wrong place.

A release is a deliberate or accidental discharge of materials to air, water or land. This obviously includes liquid effluent from pipes, smoke from chimneys, and spills onto the ground. However, as all product are ultimately disposable, it also includes products themselves. If there is no plan or system for product takeback and full reuse and cyclicity, then every product sold represents a toxic release.

The definition of "safe" includes both chemical and physical disruption to people as well as to other forms of life:

	Chemical Disruption	**Physical Disruption**
People	Human toxicity	Physical Injury, Noise
Other Life	Eco-toxicity	Land take, Noise, Enclosure, Ecosystem unbalance

Another way of looking at "safe" is that it's the opposite of hazardous. The legal definition of "special waste" in the UK is defined in the Control of Pollution Act (1974) Special Waste Regulations (1980) as "materials which, if a 45 cubic

centimetre sample was ingested by a child of up to 20kg in weight, it is likely to cause death or serious tissue damage". So in vernacular terms, "safe" means that you should be able to eat a handful or drink a glass of it. Another perspective would be that a firm should be happy for its water inlet to be downstream of the waste pipe.

The release also must not disrupt the system into which it goes. For example, a small amount of milk spilt into a stream will be utilised by micro-organisms, but a large spill will cause a large growth in micro-organisms, starving other aquatic life of oxygen and so disrupting the balance of species.

Ecosystems are pretty resilient, but they are not indestructible. While many natural forces – drought, fire, flood, frost or species migration – can affect it, an ecosystem will usually continue to function in a recognisable way. For instance, a pond ecosystem may go through flood or drought but continues to be a pond. This natural resilience of ecosystems enables them to resist change and recover quickly from disruption.

On the other hand, toxic pollutants and other non-natural phenomena can overwhelm the natural stability of an ecosystem and result in irreversible changes and serious losses, as illustrated by the following examples: decline of forests, due to air pollution and acid deposition; loss of fish production in a stream, due to death of invertebrates from copper pollution; loss of timber growth, due to nutrient losses caused by mercury poisoning of microbes and soil insects; decline and shift in age of eagle and hawk (and other top predator) populations, due to the effects of DDT in their food supply on egg survival; losses of numbers of species (diversity) in ship channels subjected to repeated oil spills; loss of commercially valuable salmon and endangered species (bald eagle, osprey) from forest applications of DDT.

Biomagnification is illustrated by a study of DDT which showed that where soil levels were 10 parts per million (ppm), DDT reached a concentration of 141 ppm in earthworms and 444 ppm in robins. Through biomagnification, the concentration of a chemical in the animal at the top of the food chain may be high enough to cause death or adverse effects on behaviour, reproduction, or disease resistance and thus endanger that species, even though contamination levels in the air, water, or soil are low.

There is an mistaken assumption that to be effective, a "nasty chemical" is necessary. In a now-famous example, Rohner Textil commissioned an analysis of 8,000 chemicals used in fabric manufacture, and found only 38 that were completely free of any concerns about causing birth defects, genetic mutations, or cancer. Fortunately, they could get all the colours and meet all the performance criteria such as fire retardance and strength with fabric made using just these 38 compounds. The other superior aspect is that the effluent coming out of the plant met Swiss drinking water standards, causing pollution inspectors to think their equipment was broken. Needless to say, the absence of compliance requirements and pollution abatement equipment meant useful cost savings.

We deal with toxic compounds every day, in a "death by a thousand cuts" kind of torture, where the effect of each exposure is too small to measure using today' s science. Sheep dip is linked with farmers feeling suicidal and suffering from memory loss. In our tooth fillings, mercury vaporises due to saliva corrosion, causing identifiable problems. The British Dental Association say in a 1997 statement that this is no problem as only 3% of the population are sensitive to mercury – yet if even a tenth as many people were affected it would be considered a problem of epidemic proportions (defined as 0.4%).

The fluoride in just one tube of toothpaste is enough to kill a small child, according to Procter and Gamble, and another toothpaste ingredient, saccharin, is on the US list of suspected carcinogens.

A 1999 report by WWF found that breast milk in Britain contains a chemical cocktail of pollutants that exposes babies to higher than recommended levels of toxic substances. Some 350 contaminants were found, including pesticides and 87 dioxin and dioxin-like substances. The report found two-month-old British babies were being exposed to 40 times the World Health Organisation' s daily limit of a range of chemicals. (Despite this, WWF say that breast feeding is still the best way to nourish new babies, as it provides immunological advantages, important nutrients and encourages bonding between mother and child)

20% of all the PCBs ever made (some 1.2 million tonnes) is now in the oceans. Some marine mammals now have such high levels of PCBs in their bodies that they are classified as toxic waste.

Pharmaceuticals are turning up in drinking water, having passed through people' s bodies. The UK does not monitor drugs in the water supply at all, even though concentrations can rival those of pesticides. Drugs administered to farm animals also contribute, especially antibiotics, giving rise to concerns about spreading antibiotic resistance, and the toxicity of many pharmaceuticals to aquatic life including algae and crustaceans. A 1999 Danish School of Pharmacy report showed that drugs are highly mobile and persistent – up to 90% can be excreted in urine.

The US Environment Working Group produced a 1998 report *Overexposed* on pesticide residues in food. It found that one million children under five consume unsafe levels of organophosphate insecticide residues, particularly from peaches, grapes and apples. In the US, the Food Quality Protection Act required that regulations must address the cumulative exposure to pesticides with similar health effects. The five highest risk organophosphates are methyl parathion (not in the UK) , dimethoate, chlorpyrifos, pirimiphos-methyl and azinphos, and health and environment groups are calling for an immediate ban on them.

Nuclear waste is widely known as a problem, but less well known is the fact that all nuclear power stations emit radioactivity to air and water on a daily basis.

Some of the most poisonous substances known are natural toxins. An extremely potent carcinogen is the mycotoxin Aflatoxin found on badly stored nuts, maize and grains. Zearalenone, found in grains, maize and hay can mimick hormones like oestrogen. Livestock, and as a consequence human beings, may be exposed to traces of these toxins through concentrated feedstuffs that has been inappropriately handled and stored. Some phytoplankton can under certain circumstances produce potent toxins, killing off all other life in the sea in the vicinity. However, most natural toxins are less accumulative and less persistent in comparison to many synthetic hazardous substances.

Gold, silver and copper were mined in great quantity from the Panguna mine on Bougainville in the North Solomons province before a guerrilla war against the mine by inhabitants forced it closure in1989. Located near the centre of Bougainville, the copper mine is one of the world' s largest artificial holes. Philip Hughes, Associate Professor in Environmental Science with the University of Papua New Guinea, describes the damage caused: "No environmental impact studies were carried out, and between 1973 and 1989, when the mine was forced to close, about one billion tonnes of ore and waste were processed. About half of this was deposited in rock waste dumps adjacent to the mine. The remainder, mostly tailing from ore processing, was discharged into the Jaba River valley. All aquatic life in the Jaba River and its floodplain was destroyed as a result of this chemical and physical pollution." The copper sulphate turned the rivers turquoise.

Every year, more mercury ends up as emissions to air, water and soil than there is mercury used in products such as batteries, fluorescent tubes, electrical equipment, chloralkali, paint and tooth fillings.

The list is endless: chemical manufacture, tobacco, drugs, incineration, pesticides, asbestos, electromagnetic radiation, vinyl chloride monomer, microchip manufacture ...

In each case, we have to ask, "Show me the pathway where these compounds are safely absorbed by nature", and in each case the approach of dilution and dispersal is insufficient.

The idea of risk has been used to justify these releases. For example, a firm may say, "there is only a small change that the radioactivity will actually damage one of your cells, and an even smaller chance that this damage will give you cancer or other problems." This is like the snake story. Imagine that there is a poisonous snake somewhere in the playground. As a parent, you have been told that the risk of your child being bitten is very small. Do you let the child play? Of course not, especially when you are told that it is an invisible snake whose bite will only be felt in 20 years' time.

So which ones are the real bad compounds? Surely some are better than others. Volvo has a very useful "black list" of compounds. New products containing one or more of these chemical substances listed must not be put into use in Volvo products. Phase-out plans with final date of use are required for those listed

chemical substances, which have not been fully phased out. The black list includes: CFCs, Asbestos, Halons, PCBs, Carbon tetrachloride, 1, 1, 1-Trichloroethane, Tetrachloroethylene, Lead chromate, Cadmium and its compounds, Mercury and its compounds, Chlorinated paraffins, and Mineral oil with Polyaromatic Hydrocarbons (PAHs).

This is a very basic starting place. Also worth looking at are the Grey List, compounds which are of doubtful safety, and the White list, a list of suggested alternatives to black and grey list compounds. See:

http://www.tech.volvo.se/standard/docs/10092.pdf
http://www.tech.volvo.se/standard/docs/10091.pdf
http://www.tech.volvo.se/standard/docs/100911.pdf

The Grey list restriction refers to each deliberate use of the chemical substances specified in the standard at concentrations exceeding 0.1% by mass.

The white list is not inclusive, and there might be other alternatives with acceptable properties, and technical development may lead to new applications not yet appearing on the list. By changing the working process, it may even be possible to perform the task without the use of chemicals. However, it still some way off a fully sustainable list – perhaps a "green list" or "ultra-white" list will appear eventually.

It is really quite simple. Things that go into the biological metabolism should not contain mutagens, carcinogens, heavy metals, endocrine disrupters, persistent toxic substances, or bio-accumulative substances. We can no longer emit and forget.

In 1999, the Swedish parliament approved 15 environmental goals that it hopes will contribute to the achievement of sustainable development within one generation. The fifteen goals call for the achievement and maintenance of clean air, unpolluted groundwater, living lakes and waterways, vibrant water meadows, a sea in balance and a living coastline, balanced use of fertilisers, absence of acidification, living forests, a rich landscape, healthy mountain ecosystems, a good built environment, a poison-free environment, absence of radiation, a protective ozone layer, and limited climate effects.

The targets relating to chemicals policy are particularly far-reaching, aiming to ensure that all products sold in Sweden by 2020 are free from carcinogenic, teratogenic and endocrine-disrupting substances. In particular, it envisages eventually banning the use of persistent or bioaccumulative substances unless producers can demonstrate that they will not harm health or the environment. Significantly, both Greenpeace and The Swedish Chemical Industries Association broadly welcomed adoption of the policy, which it described as "negotiable and workable".

The problems and solutions described so far relate to chemical toxicity. Despite the enormity of the chemical problem, the physical disruption of whole communities may be even more serious. Ecosystems can be damaged in many ways, ranging from fish and wildlife kills to forest decline, resulting in biological, economic, social, and aesthetic losses.

A 1998 study found that alien species are behind the disappearance of nearly half of the imperilled species in the United States. Alien species are plants and animals that are not native to a given region, but which have been brought there by people. Some are brought there accidentally aboard ships or planes; others are intentionally released. Once in these new areas, they can increase in numbers and displace native species from their habitats. For example, Chinese Mitten Crabs are burrowing under the Millenium Dome in London. The crabs were first spotted in the Thames 50 years ago and the population is booming as a result of improved water conditions. They arrive when bilge water or water used for ballast is discharged into a harbour, and have also been found in San Fransisco Bay, where they have spread with amazing rapidity since their introduction in 1994. The crab was first identified in Europe in 1912, and by the 1930s millions of crabs migrated up Germany' s major rivers clogging dams and climbing onto shore, where they wandered city streets and entered homes. They devastated fisheries and destroyed river banks and levees causing floods and other damage.

Species frequently balloon in numbers shortly after their arrival in a new ecosystem, later levelling off as they settle in to their new niche. Other ballooning populations never collapse, such as the zebra mussel in the Great Lakes, which has completely overrun entire ecosystems. The main point is that you never know what' s going happen when you introduce a new creature into an ecosystem.

To be safe, we must look after the health of the land and sea and the living things, including us, that inhabit it. Aldo Leopold said it nicely back in 1949: "Land is not merely soil; it is a fountain of energy flowing through a circuit of soils, plants and animals... A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."

4.4. Efficient

Materials efficiency makes obvious sense for business, as it means you can sell the same chunk of stuff to more people. Energy efficiency saves money. What is the efficiency of nature?

Trees are efficient when they are young, converting sunlight to biomass in order to gain height and compete for access to sunlight. However, once at the top of the forest canopy, the mature tree then takes things easy, capitalising on its market position and efficiency decreases, rather like an old established firm with a solid monopoly or cartel-like stability.

It seems that it' s natural to use energy, and the more the better. Lotka (1922) and Odum and Pinkerton (1955) suggested that those biological systems that survive are those that develop the most power inflow and use it to best meet their needs for survival. Schneider and Kay (1994) proposed that a better description of these "power laws" would be that biological systems develop in a manner as to increase their degradation rate, and that biological growth, ecosystem development and evolution represent the development of new dissipative pathways.

So ecological theory shows us that ecosystems strive to maximise throughput of energy and materials. While each product or species may develop through competition to become very efficient in their use of energy and materials, the number of individuals will increase, as will the number of species or product types, giving the whole system the same or more likely an increased level of total energy and material throughput.

As ecosystems develop or mature they should increase their total dissipation, and should develop more complex structures with greater diversity, more cycling, more energy flow and more hierarchical levels.

That' s the story for the system as a whole. For an individual organism or organisation, efficiency is the key way in which to compete for a set of resources such as sunlight, water or minerals.

How efficient is materials flow through your company? Include Water! What percentage by mass of what you buy in do you sell? For many firms, 60% or more of they buy as raw materials is thrown away. Overall, the economy uses 10 tonnes or more of materials for every tonne of product that is finally used by consumers.

There is a growing movement that believes we can be much more productive with the materials used by industry. Improvements of a factor of ten or more are possible.

4.5. Social

Product manufacture and use must support basic human rights and natural justice.

Unfortunately, workers are all too often treated badly. A totally-beautiful product will have been made by people who are living a decent life and are treated fairly. So the social requirement means checking working conditions all the way up the supply chain – which is something of a recurring theme in sustainable product development. You have to know where materials and components are coming from and how they are being made.

For the details of exactly what 'natural justice' entails, I have adopted the principles of the SA8000 standard, which is based on a consensus on what organisations working in this area think is important. It's also based on the conventions of the International Labor Organization, the Universal Declaration of Human Rights and the UN convention on the Rights of the Child.

SA8000 specifies that, at a minimum, companies should:

- not engage in or support the use of child labour;
- provide adequate support to enable such children to attend and remain in school;
- not engage in or support the use of forced labour;
- provide a safe and healthy working environment and ensure that all personnel receive regular and recorded health and safety training;
- respect the right of all personnel to form and join trade unions of their choice and to bargain collectively;
- not engage in or support discrimination in hiring, compensation, access to training, promotion, termination or retirement based on race, caste, national origin, religion, disability, gender, sexual orientation, union membership, or political affiliation;
- not allow behaviour, including gestures, language and physical contact, that is sexually coercive, threatening, abusive or exploitative;
- not engage in or support the use of corporal punishment, mental or physical coercion, and verbal abuse;
- not, on a regular basis, require personnel to work in excess of 48 hours per week and provided them with at least one day off for every seven day period;
- ensure that overtime work does not exceed 12 hours per employee per week, is not demanded other than in exceptional and short term business circumstances, and is always remunerated at a premium rate;
- ensure that wages paid for a standard working week shall meet at least legal or industry minimum standards and shall always be sufficient to meet basic needs of personnel and to provide some discretionary income; and
- comply with prevailing laws, regulations and other applicable requirements

To make sure that these principles are not just a piece of paper, the "plan, do, check, act" management system concept underpins SA8000, requiring executive responsibility, control, and continuous improvement in performance.

4.6. Semi-sustainable Products Today

In practice, many sustainable product design (SPD) achievements to date have been relatively modest. There are no products on the market that are 100% sustainable as per the cyclic | solar | safe scoring system outlined below. Having said this, it is straightforward to define in a "blue sky" way exactly what would be required to achieve 100% sustainability for a product line. The catch is that it can be hard to apply these requirements to a marketable and competitive product on a strict development and introduction schedule. However, this is the grand goal that this report seeks to espouse. The cost of starting out "blue sky" is almost negligible compared with the overall product costs, so there is nothing to lose and everything to gain by thinking big.

The examples of environmental innovation in products so far are diverse. Consider this scenario of a typical day:

> *I'm woken from slumber by the sound of letters landing on the mat, and I rise quickly to see the postman riding off down the road on his bicycle as I watch through the large conservatory on the south side of my zero-energy house. After using the loo, I select the flush setting from "high", "medium" or "low" and then wander into the kitchen where I take a returnable polycarbonate bottle of organic milk from a local dairy out of the CFC-free, highly energy efficient larder fridge. As the fair trade coffee is brewing on the biogas stove, I whip the milk with my solar-powered "Solait" frother and listen to the news on the clockwork radio.*
>
> *I put on my organic cotton trousers, naturally coloured red Foxfibre socks, hemp shoes and a Patagonia fleece top made from recycled plastic bottles, finally strapping on my Seiko spring drive quartz watch. Then I get into my Toyota Prius hybrid engine car, which I run on electric power through the village, before switching to petrol to go down the motorway to work.*
>
> *After dropping off some clothes at the wet cleaners, I go into the office. It has a passive solar facade and solar panels for electricity, and is painted in organic paints. My chair is made from recycled bottle tops, and my desk is made from a biocomposite material stronger than oak. Admiring the smart recycled casing of my IBM Intellistation E-Pro PC, I load the printer with locally-recycled Evolve paper. The printer is a Kyocera, which has a long life drum and needs only the toner replacing. After printing out a brochure proof and emailing a memo or two, lunch arrives. It is delivered by a Brox human power vehicle and I choose a packaging-free burrito wrap and an eat-the-stick ice lolly.*

I've refilled my tea mug several times today, so I need to use the waterless urinal on the way to a meeting. I contribute a few ideas, drawing them on the flipchart with Prang soya bean crayons. Afterwards, I stop off in facilities and give them my solar powered mobile phone, which has finally kicked the bucket. They'll take it to Shields Environmental, who recover and recycle 98.7% of the electronic waste they handle.

As I walk across the EarthSquare recycled carpet to the photocopier, I pass partitions covered in Rohner Textil Lifecycle fabric, which uses no toxic dyes. The remanufactured and recyclable Xerox DC265 wakes up to run off some copies before going into sleep mode again, and I call it a day.

On the way home, I stop at the shopping centre to buy an Ikea a.i.r. inflatable armchair (5% of the weight of a conventional chair) and drop off my Kodak single use camera for processing and recycling. I pay with my bioplastic Co-Op credit card.

Back home, I throw some laundry and some electrostatic washing disks (no detergent needed) into the AEG86720 on cold wash setting, and don my recycled Dunlop wellies to go into the garden, where I check on the solar powered ultrasonic mole repeller.

After a lovely dinner of organic Welsh lamb and local veg and potatoes, I relax by playing my guitar, which is made of FSC-certified sustainably-grown wood, and then watch some TV on the computer before getting ready for bed. The house has sensed that it is dark and has closed the blinds in the conservatory to retain heat overnight.. Another green day has ended.

This scenario uses products that are available today. While all the innovations described are worthwhile, very few are entirely cyclic, solar and safe. Most of the "greener" products available today exhibit improvements in one or two of the protocols. For example, they are recycled and recyclable, but were not manufactured using renewable energy. Or they are solar powered but require toxics in the form of the PV cell and the accumulator batteries which provide power during darkness. However, it would not take much to make many of the products described 100% cyclic, solar and safe.

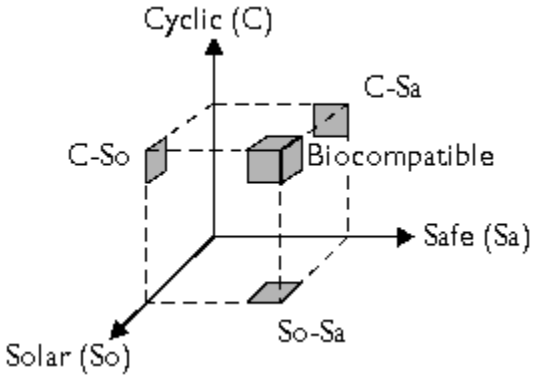
4.7. Tomorrow's Sustainable Products

Meeting one or two of the biothinking requirements represents a major step forward for any product. But to be a true component of a sustainable industrial ecosystem, all aspects of the product's life must meet all three requirements. For example, Rohner Textil's fabric is fully biodegradable, but will it actually get separated from the chairs (which are made by another firm) at the end of their life and properly composted? Are renewables used to power all the factories in the chain?

Craft products and organic smallholdings, locally sold, are among the tiny handful of today's products that meet all three requirements. Yet we are on the

cusp of seeing many more. Many firms would qualify if their local utility company was hydroelectric or other renewable, or if they could contract with a specialist renewables-only supply firm where the local market is deregulated.

The solution space for sustainable product design can be imagined as an 3-D xyz graph with the axes being cyclic, solar and safe:



Some solutions are Cyclic and Solar (C-So), some are Solar and Safe (So-Sa), some are Cyclic and Safe (C-Sa), and the furthest corner of the volume is fully "biocompatible" or sustainable.

If all an organisation' s activities are 100% cyclic, solar and safe, across the full lifecycle of all materials used, then that organisation would be sustainable. This means that we can score any organisation or product according to:

- % cyclic – % of total materials that are continuously cycled
- % solar – % of total energy and embodied energy that is form renewable sources
- % safe – % of lifetime releases that are non-toxic

It is then possible to average these scores to give a single number sustainability index.

An entirely sustainable industrial system would look very similar to that of today. Biomaterials are showing enormous promise. The ' carbohydrate economy' is already starting to displace unsustainable incumbents with fuels, drugs and plastics that are grown from seed. For example, cars would run on fuel cells powered by biogas, or solar-generated hydrogen. Trains would look identical, but be run with renewable electricity, and their interiors would be built from plant fibres (a luggage rack is being piloted in Denmark already), the seating fabrics would be organic and safely dyed, and the metals would be part of an ongoing closed loop reprocessing and fabrication system. Food would be grown using manure and sewage cycling systems, and would have no persistent or accumulative chemical applications or artificial fertilisers.

What would a sustainable car look like? Almost 80% of every car is already recycled, but they are not solar powered and they release many toxins, both in use and manufacture. To become solar powered, simply buy your electricity from a

wind, biogas or solar utility company, and charge up your electric car. Electric motors are very efficient, and to the chagrin of today' s auto firms, they can last for 90 years, requiring none of the lucrative sparkplugs, exhaust replacements and so on that combustion drives need. Performance is already acceptable today –the Lotus Elise sports car and the Toyota RAV four-wheel drive are both available in speedy electric versions, and the German Post Office has a successful programme using electric vans.

Vegetable cars are also likely to be viable – and have already been in the past, as evidenced by Henry Ford' s 1938 car which had a wood frame and body panels of soy and linen fibres. New biocomposites made from cashewnut oil, sisal, flax and jute are starting to emerge from laboratories and into production, offering car designers the strength of kevlar, low cost, light weight and recyclability. An all-vegetable car would have natural rubber tyres, cotton upholstery and a ceramic engine grown in the same way mother of pearl is made by mussels. It would run on biodiesel from rapeseed or methanol from wood pulp.

The cars of the far future will most likely be a mix of animal, mineral and vegetable, probably in an unimaginable combination – genetic engineering points the way to animal engine technology, perhaps using antelope muscles which are given a supply of suitably glucose-charged blood (which can be generated by a fixed or on-board biodigester) and which are controlled via artificial nerves. Or of course the large cats are also immensely strong – you really could have a tiger in your tank.

Most of the staple technologies of the sustainable future already exist:

- Composting
- Metals and plastics recycling / "above ground mining"
- BioFuels
- Bioplastics
- Electric / Biodiesel hybrid vehicles
- Product Repair and Takeback Centres
- Extremely low energy buildings

Only a few will require major new innovation, in particular electronics and microchip manufacture. This is mainly because of the honeymoon effect over IT which means that few people are really questioning the need to have toxic metals and solvents in chip fabs. With enough incentive, these problems could be overcome.

Likewise, there will be many disappeared technologies, including nuclear power, landfill, fossil fuel combustion, chrome plating, and so on.

We have the technical building blocks for a 100% sustainable industrial system in all but a few key areas – Already a composite country exists that aims to achieve this – "Japiceden". Combining the current policy goals of Japan, Iceland and Sweden would result in a completely Cyclic, Solar and Safe nation.

- Japan set 100% packaging recycling targets in 1997

- Iceland is aiming for 100% renewable energy by 2002

- Sweden aims to ensure that all products sold in Sweden by 2020 are 100% free from carcinogenic, teratogenic and endocrine-disrupting substances.

There is a long way to go. Only about 0.001% of industrial products and services on the market today could be described as having good environmental performance. A relative handful of firms have already come up with product innovations – there are maybe 1000 potentially sustainable products on the market – out of an estimated 100 million products on sale worldwide. (they are "potentially sustainable" products because they currently exist in a system that does not distribute, sell or recover them using sustainable methods.)

What seems radical today, will be mainstream tomorrow.

It also seems likely that environmental sensibilities will become incorporated into culture. Products have already evolved in terms of safety, then came quality, and then design and aesthetics. Environment will be next – product that do not just look nice, but which are nice underneath and in the way that they were made. People are aware of manufacturing and the environmental and social costs is can have. People are starting to become aware of depth, and are finding that pure facade and surface beauty is not enough.

Design students have always been taught Form and Function, but need more on Fabrication, so they can understand the provenance of products and the full implications of their design choices.

Sustainable design looks towards the future. Nigel Cross, in a 1981 article "The coming of post-industrial design", cites examples such as an earth-walled house with electronic control of heating to show that "ecodesign... is not simply regressive to pre-industrial approaches, or romantically anti-industrial, but offers a post-industrial way forward that utilises the full range of appropriate human knowledge".

Finally, the new sustainable products must be new variants on existing mainstream products. The transition can be phased – for example, Nike realised that a 100% organic cotton T Shirt would always be a niche product until the price came down. And the price would not come down until there was more demand and then more supply. So they adopted a policy of making each shirt 3% organic cotton – overall representing a huge amount of organic cotton, and doing a good job of stimulating its market viability.

4.8. Commercial Advantages of Sustainable Products

There are many advantages that have been uncovered by firms already engaged in the process of becoming more cyclic, solar and safe. Here are a few of the main types of commercial benefit:

- Less energy cost and energy taxation or even free energy
- Sell the same product twice
- Sell waste
- Reduced or no liability
- Sell more of what you make
- Less hazardous materials handling costs and insurance
- Less pollution monitoring and compliance costs
- Less waste disposal costs
- New product and process design ideas
- New business model directions
- Higher margins
- More attractive product
- Better data
- Future proofing
- Enhanced materials productivity
- Savings from safer workplace conditions
- Lower packaging costs
- Safer products and reduced product liability
- Lower costs to consumer of use and consumables and eventual disposal
- Higher labour intensity and upsizing,
- More value from a given mass of raw materials,
- Early colonisation of new product and service areas.

Downsize unproductive kWh, tonnes and litres, not people. Ensure that "All wastes will find an economic use, or be placed into the environment without disruption".

Sustainability is inevitable – it' s just about who will be first to gain a beachhead.

Already firms are making major strategic stakes in the Trillion Dollar Opportunity. Do you want to get there first? Or be locked out? It' s First Come, First Served.

Here are just a few examples of organisations that have recognised the opportunities and have decided to stake a claim in the area:

- Shell International Renewables have committed $500 million to developing renewables like solar, biomass and wind. Shell Renewables solar business produces one million photovoltaic cells a year and 50,000 panels at its factory in Helmond, the Netherlands, which employs 130 people. Capacity is set to increase significantly during 2000. Shell' s second solar factory – and set to be

the world' s largest is currently being constructed in Gelsenkirchen, Germany. It will produce around 13 million solar cells a year.

- Likewise, BP aims to have a billion dollar PV business, and it purchased PV manufacturer Solarex during 1999.

- DaimlerChrysler is investing $1.5 billion in its fuel cell car project. In 1999, Ford opened a $35million environment research centre in Aachen.

- The European Commission is calling for $30 billion in private investment for renewable energy projects by 2003. Based on strong interest from the private sector, some officials predict renewables could capture 50 percent of the market in the near future. Funding would be divided evenly between solar, wind and biomass.

- A 1998 study by Miriam Pemberton and Michael Rennerhe showed that the world market for environmental technologies is currently worth $400 billion-plus – double the size of the world market for all types of military hardware. All forecasts for the global envirotech market point to continued strong growth.

It is clear that there is a lot of money involved in sustainable products, enough to be labelled a "Trillion Dollar Opportunity":

Sustainable Industry Sector	**2005 Expected Sales ($ bn)**
Environmental Technology	644
Reverse Logistics and Recycling	7
Remanufacturing	149
Renewable Energy	37
Biomaterials and Biofuels	12
Energy savings	430
Organic Foods	11
TOTAL	**1290**

(All figures in 1999 dollars)

According to Dr Robert Constanza at the University of Maryland, Global GNP is about $20 trillion. The free services that we get from the ecosystem, such as cleaning of air and sunlight are worth about $33 trillion. It' s not capitalism if not all the capital is on the balance sheet!

5. Sustainable Product Techniques

5.1. The Top 24 Techniques

These techniques are based on an analysis of 500 products. The innovative principles behind all of them are rather similar. This should be no surprise. Genrikh Altshuller, a Russian patent agent, noticed that all engineering inventions had something in common. He developed his theories and enlisted the help of engineers and scientists to analyse over 1.5 million patents. The surprising results were that only 40 design techniques were needed to solve any engineering problem. These techniques include such principles as nesting, use of counterweight, feedback, pneumatic construction, and thermal expansion. Moreover, over 99% were found to be variations on solutions already in existence, and 90% were from within the same industry sector in which the innovation arose.

One can infer from this that almost all the sustainable products of the future will be based on recombinations of existing, proven approaches, and that very few will require the pioneering of substantially newer technologies. Evolution always takes what is to hand and then builds the unexpected from reliable parts fitted together in new ways. The same is true of business innovations. One example of recombination within the sustainability solution space would be to use biogas to power a fuel cell. This links the zero-emission and safe fuel cell technology with the use of cyclic biofuels.

The basic techniques are:

Cyclic
- Recycled Materials
- Re-use
- Organic Materials and Composting
- Takeback, Refurbish and Remanufacture

Solar
- Muscle Power
- Hydrogen and Electricity
- Photons

Safe
- Substitute Materials
- Stewardship Sourcing
- "Bio-Everything"

Life Extension
- Durability
- Upgradability
- Repairability
- Complementary Components
- Extremely Long View

Using Less
- Increased Efficiency

- Increased Utility
- Dematerialise
- Every Little Counts
- Be More Local
- Multifunctionality
- Fine Control
- Work with the Seasons
- Biomimicry

5.2. Cyclic Techniques

5.2.1. Recycled Materials

The goal of being cyclic is to have continuous cycles of materials, and it is easy to see that once this state has been achieved there will be no underground mining, as all mineral materials will be sourced from the collection of end of life products and byproducts. This will also require "closed loop" or true cycling, and not "downcycling", which is when materials become contaminated in use and can only be recycled as lower grade materials. For example, plastic packaging is often coloured or printed on, making closed loop recycling difficult.

Most of the examples of using recycled materials today are actually downcycling, although all users of recycled material recognise the need for purity of sources, and this is starting to be reflected in the design of products. Designing for recyclability involves:

- making sure that the product can be disassembled easily
- labelling of parts to indicate materials types uses – usually by embossing to avoid contamination
- ensuring that surface finishes and graphics or decoration do not irreversibly contaminate the materials

The SPI labelling system has the recycling triangle with a number inside to indicate the type of plastic:

1 is PET (Polyethylene Terephthalate)
2 is HDPE (High Density Polyethylene)
3 is PVC (Polyvinyl Chloride)
4 is LDPE (Low Density Polyethylene)
5 is PP (Polypropylene)
6 is PS (Polystyrene)
7 is Mixed Plastics

Recycled materials of various grades already appear in almost every product type. There are over 6000 products on the US "Buy Recycled" programme, and a large number can also be found in the UK. See www.nrf.org.uk for a huge selection. Some typical examples would be:

Recycled PET from old fizzy drinks bottles is recycled into a fibre for carpets and clothes, including the Patagonia brand of outdoor wear. Erasers are made from recycled car tyres by Tombow in Japan. Recycled plastics appear in plastic bags, wellington boots, video cassettes, computer keyboard casings, letter trays, plant pots, and benches. The US Environmental Protection Agency now has a system of standards, the "Comprehensive Guideline for Procurement of Products Containing Recovered Materials" that cover an impressive array of products: Traffic Control Cones, Traffic Barricades Park and Recreation Products, Playground Surfaces, Running Tracks, Landscaping Products, Hydraulic Mulch, Yard Trimmings, Compost, Non-paper Office Products, Office Recycling Containers, Plastic Desktop Accessories, Toner Cartridges, Binders, Plastic Trash Bags, Paper and Paper Products, Vehicular Products, Engine Coolants, Re-refined Lubricating Oils, Retread Tires, Construction Products, Structural Fibreboard , Laminated Paperboard, Carpet Floor Tiles, Patio Blocks, Building Insulation Products, Cement and Concrete, Granulated Blast Furnace Slag, and Transportation Products.

It' s a basic data requirement to keep track of what percentage of a product by mass is composed of recycled parts. For example, the Aeron office chair by Herman Miller has 67% recycled parts, mostly achieved by the use of 100% secondary aluminium, which makes up much of the weight of the chair. A further innovation is the use of a suspended trampoline-like seat and back, which dematerialises the conventional wood, foam and fabric upholstery.

A prototype Dodge Stratus, due to be presented at Earth Day 2000, has been developed by engineers in DaimlerChrysler' s Concept for Advanced Recycling and Environmental (CARE) project. Recycled materials are used in tyres, seats, trim, floor mats, sunvisors, fuel tanks, air bag systems, door handles, carpeting, mirrors and seat belts. The company challenged two dozen of its top suppliers to come up with new manufacturing processes and components using recycled materials that would cost no more than traditional ones. The suppliers rose to the challenge, collectively volunteering nearly US$3m in services. They also worked with DaimlerChrysler engineers to design vehicle features that improved the recyclability of components by using more recycled materials, including plastics.

The Scandic hotel chain has 2,500 rooms that are 97% recyclable. They consist of parquet flooring, wood, pure wool and cotton interior textiles and a minimum of metal, plastic and mercury, cutting the use of plastics by 90 tonnes and metals by 15 tonnes. Scandic has plans to convert the rest of its 17,000 rooms at a rate of at least 1,500 per year.

What is recyclable? In theory everything is recyclable, but in practice there are technical and economic limitations. A pure material becomes less recyclable as colours, barrier coatings, adhesives and labels are added to it. This suggests that we should move towards mono-material packs. However, the solution is not so simple. Imagine a PET bottle with a PET label. If the label was paper, the label and inks could be floated off during the recycling process. However, with a PET label, it cannot be separated in this way, and therefore the inks contaminate the recyclate

– there is a good market for clear PET recyclate, but a limited market for coloured PET recyclate. New techniques may become available in the future to allow monomaterial packaging, such as etching for refraction of light to display different colours, which is a technique found on butterfly wings.

5.2.2. Re-use

The examples above rely on the raw materials being crushed or melted down before they are reformed into a new product. But it is often easier to keep the form of the original product, and simply clean it or re-use it again. Examples of this are familiar to us all – pallets, returnable beer and milk bottles, and reconditioned car engines.

State Farm Insurer's worked with their printers to eliminate 2.7 tonnes of waste annually. By shipping paper in corrugated containers holding 2,500 sheets of paper (the maximum capacity of the company's high speed copier) rather than individually wrapped reams of 500 sheets they have eliminated the need for 240,000 ream wraps. The containers have proven to be useful not only in that they are returned to the printers for re-use but they have also been useful in sending shipments out to regional offices and back again, therefore saving further wastage.

Companies are literally closing the loop take their products back at the end of their useful lifespan and use them to create valuable new products. For example, GE Plastics Europe have created durable, lightweight Lexan (a polycarbonate) milk bottles that can be sterilised and reused up to 100 times, then melted and used for other high-value products, so that the original polymers may still be in use 100 years from now. This compares very well with glass milk bottles, which are heavier and only last about 20 trips.

Retailers are increasingly adopting Reusable Secondary Packaging in the form of stackable plastic containers. Firms such as Boots and M&S use these to transport goods from the depots to stores, sending back empty containers on the same vehicle. This save considerable amounts of cardboard, and the containers last for many trips.

5.2.3. Organic Materials and Composting

Plant materials are cyclic in origin, as they are made from CO2 and water, and small amounts of minerals recycled from the soil. Likewise animal-derive materials are themselves derived from plants, and they can be broken back down and returned to the ecological cycle by means of composting.

While many products are actually biodegradable, in most OECD countries they will end up getting burnt or put into landfill. In neither case will the nutrients end up getting returned to the soil. Composting has enormous potential as a means of processing waste and returning materials to their natural cycles. Unlike a landfill site, a composting facility will never fill up – it' s a continuous resource.

However, a biodegradable product must be disposed of properly for its components to decompose properly. For example, when soapy water from a bath

is let out into our garden, we see a lush growth of plant life because the soap breaks down in a natural aerobic (oxygen-rich) environment. When soap from thousands of baths enters the sewage system and empties into a bay, it overloads the natural ability of microorganisms to degrade the material and overwhelms the environment as a toxic pollutant.

Labels that clearly state under what conditions the product is biodegradable are helpful, and there a few definitions of biodegradability and some testing procedures make interpretation of claims more reliable.

- The Federal Toxic Substances Control Act defines ultimate biodegradability as the breakdown of organic (carbon-containing natural and synthetic) compounds to carbon dioxide, water, the oxides or mineral salts of other elements and/or products associated with normal metabolic processes of microorganisms.
- The simplest definition is in The American Society of Testing and Materials (ASTM) standard for compostable products, which requires that any product that claims to be biodegradable must completely decompose into CO2 and water within 180 days.
- The European Committee for Standardisation (CEN) has recently developed a draft standard with requirements for compostable products, prEN 13432 – *Requirements for packaging recoverable through composting and biodegradation.* According to this standard, the individual components of compostable products shall be completely biodegradable; shall disintegrate completely, and shall not have negative effects on the composting process or the quality of the final compost.

Be wary of "photo degradable" plastics break which simply down into small pieces when exposed to sunlight – they are made from petrochemicals and cannot return to their base elements no matter how small the pieces become, and therefore they cannot be biodegradable and are not part of a sustainable process.

While wet organic waste will readily compost down, organic materials used in durable products tend to be treated so that they will not break down – so after any re-use, their eventual composting may take a long time. For example, cotton may take 3 months, wool may take 3 years and leather can take 30 years. Paper can degrade in about 3 months.

One good way of composting is to use living biodigesters in the form of animals or even people. Edible packaging has been around in the shape of ice cream cones and Dolmas (Greek rice snacks wrapped in Vine Leaves) for many years, but new products are starting to crop up. The tray in a box of chocolates by German firm Loser (pronounced "Low-zuh") is made of an edible wafer. This sort of approach can replace "inside" packaging, such as the chocolate box tray ... and the ice cream cone does replace a cardboard tub from point of sale to mouth. But this wouldn' t work for outer tertiary or secondary packaging, where you "don' t know where it' s been". Overall, edible packaging could be used much more, especially as

structural packaging inside sterile packed goods, to replace for example the trays that prevent things like croissants and cakes getting crushed. The edible stick lolly or popsicle is a blackcurrant ice lolly that has a liquorice stick instead of a wood one. An own brand of the UK supermarket chain ASDA, this lolly is made by a joint venture between Richmond Foods plc and the Spanish ice cream producer Menorquina.

Other innovative uses of organic materials are straw bale house construction and biocomposites – fibre boards are made from waste cartons (Tectan by Tetrapak, as used in some Sony speaker cabinets), or soy flour and recycled newsprint (Phenix Biocomposites), which can be milled, sawed, drilled and nailed and is harder than oak.

There are other ways of getting microbes to do the work, such as digestion by bacteria for compost toilets, bioremediation cleanup of toxic waste, and cardboard coffins. Or use higher animals, such as eel farms making use of warm waste water, and sewage to electricity projects like the one built in a UK seaside town in 1999 that uses methane from sewage and also burns sewage sludge to generate electricity.

5.2.4. Takeback, Refurbish and Remanufacture

When manufacturers collect their own products once the consumer has finished with them, it is known as product takeback. The manufacturer then has a choice of melting down the materials and reforming them, or keeping the components and refurbishing them to go into new products. The refurbishing route is the more sustainable, and if the process (also known as remanufacture) is technically sound, then the remanufactured products can be as good as new. Examples include photocopiers (Xerox), computers (Dell, Compaq and ICL), car engines and single use cameras.

Rank Xerox now sell the service "document management" rather than photocopiers, by leasing their copiers. They lease two types of photocopier – new and "remanufactured"– which people lease because it is cheaper. Eighty thousand of the 120,000 copiers discarded annually in Western Europe were recovered by 1996, three quarters of these were remanufactured and the other quarter used to provide components. Rank Xerox claim to have saved £50 million in a year on purchases of raw materials by reusing and recovering equipment. To do this they have, for example, designed for ease of disassembly, standardised parts and designed parts to be easily identifiable. The DC265 digital copier, for example, has only 260 parts instead of over a thousand.

Xerox refurbish used copiers and sell them as remanufactured machines in Europe, and use recovered parts in new machines in the U.S. They use recovered parts to service machines. Xerox gets a steady supply of parts from returned machines and customers get a quick turn around for parts – the wait is now two weeks instead of six months. Over a five year period, this programme has saved Xerox $200 million in parts, inventory and labour costs. In Europe, adding

remanufactured machines to their product mix allows Xerox to compete in a lower price segment than they could before. They sell their copiers under such names as "EcoSeries" and "Renaissance." Customers receive the same three year warranty as for new machines.

Renting and leasing services have potential environment benefits as firms have more control over the cycling process. Interface in the US has been developing an "Evergreen" service which leases carpeted flooring, coming in to replace and refurbish or recycle the carpet as it wears out.

Takeback is starting to take off. In July 1999, Sharp and Mitsubishi Materials announced a joint venture in Osaka to recycle Sharp-made electric home appliances. The new plant will recycle TV sets, refrigerators, washing machines and air-conditioners, starting operation in April 2001 with an initial recycling capacity of 360,000 units a year.

Also in July 1999, European Union governments yesterday voted to approve a draft law to make carmakers bear the cost of recycling or reusing all cars sold after January 1, 2001, when they reached the end of their lives and were scrapped. The law would also force carmakers to recycle or reuse 80 percent of car weight from 2006, rising to 85 percent within a decade. Besides setting recycling targets and guaranteeing free takeback, the law includes measures to reduce the use of lead, mercury, cadmium and other hazardous heavy metals in car manufacturing.

5.3. Solar Techniques

The solar definition includes any renewable energy that is also cyclic and safe. This includes wave and wind power as well as direct solar power. Renewable energy technologies are widely understood, so large scale electricity generation and supply is not covered in this report – just a few innovative approaches that can be embedded into products themselves.

5.3.1. Muscle Power

Muscle power is a form of solar energy. Examples of using muscle power include:

The Brox human power vehicle, which is basically a 4 wheeled freight bicycle, used widely in the UK for applications including park gardening and the Red Star courier service which uses the Brox and trains in the London City area instead of cars.

Seiko's Kinetic drive watches provide quartz accuracy by converting body movement into electricity. Most versions use a capacitor to store the energy, but a new Spring Drive model will be available in 2000.

Folding bicycles by Brompton, Bernd, Moulton and Birdy allow cyclists to take their bikes on trains and keep them inside offices, removing two of the major barriers to urban cycling. Budget Car Hire in the UK offer "Boot Bikes" – full size mountain bikes for $18 a day that fold up into the boot (trunk) of their cars.

The Freeplay S360 is the latest model from the clockwork radio company Baygen. It' s a lot smaller than the original wind up radio, and uses power more efficiently. It takes energy from three sources – daylight, via a solar panel, the wind-up spring mechanism and it can also run off the mains. By having a rechargeable battery built in, the radio can be on for up to 15 hours with no winding needed. While these new features clearly bring benefits to users, the environmental performance of the radio seems to have been overlooked. The internal battery may only last a few years, and the plastic housing is neither recycled nor recyclable. Overall, the environmental performance is not a lot better than that of using rechargeable batteries with any portable radio. The Freeplay is designed for use when you' re permanently isolated from mains electricity, and it serves this function well, for under £60.

5.3.2. Hydrogen and Electricity

Electric Vehicles, both Battery and Fuel Cell driven are included here because their power will eventually all be provided by non-fossil and non-nuclear sources. In Japan, Toyota sold more than 10,000 of its hybrid-electric 51mpg "Prius" cars in Japan in the first 6 months since its December 1997 launch.

Over 800,000 electric bicycles were sold in Japan during 1998, and the approach is starting to catch on in Europe and the US. In the UK, the £500 Powabyke does not need road tax, can be ridden without a licence, costs nothing to park and will zip through gridlocked city streets at a nippy 15 miles per hour (it could probably go faster if tinkered with, but is limited by law). It has a range of more than 20 miles, and can be recharged wherever there is an ordinary mains power socket for 1.5p a mile . It has all the benefits of independent motorised travel, without the costs and hassle. It also overcomes the key drawbacks of ordinary bicycles – most people who work in an office find it a problem to arrive sweaty in their work clothes, or face problems with finding a place to change or shower. Powabykes are fast, stress-free and great fun. Commercial applications include the police, couriers, pizza delivery services, meter readers, environmental health inspectors and park rangers. Powabyke has set up a battery recycling centre, so that batteries can be reconditioned and also ensure their safe disposal when they eventually wear out. The author estimates that for a typical commuter with a daily there-and-back journey of 16 miles, the cost of ownership including charging and annual battery replacement is less than £75 per year.

5.3.3. Photons

Photon power is the secret to life on Earth. Photosynthesis can be a key energy provider via biofuels and biomass, and plants are being used for a wide variety of industrial purposes such as oils, fibres and plastics – soya crayons, Unpetroleum Jelly, Citrasolv degreaser, Earth Shell packaging, and cornstarch pens, for example. And of course our whole economy is very reliant on solar power to keep the water cycle going and to provide direct light, heat and warmth. Anyone who' s seen an eclipse of the sun will tell of the sudden chill when the sun is obscured, even for only a few seconds.

Photovoltaics (PV) are particularly useful for local and mobile applications, although their manufacture is not yet entirely cyclic or safe. While some firms are pursuing techniques using toxic compounds such as cadmium telluride, there is also research into completely safe methods that mimick plant structure and films, including a NASA project.

Embedded PV is a solar solution, but can also be described as a Safe or Efficient improvement, because over their lifetime, these devices are typically replacing battery-powered versions which would otherwise consume ten or twenty times their own weight in disposable batteries, or perhaps twice their own weight in rechargeables. The range of products with PV cells is amazing: Calculators, Radios, Watches, Mobile Phones, Boats, Planes, Electric Fences, Parking Meters, Bikes, Cars, Smoke Alarms, Hearing Aids, Cameras and even Cappuccino Milk Frothers.

PV can also be used as cladding for buildings, a solution which is cheaper than polished granite or marble. BP Amoco are fitting 400 new service stations in Europe with PV in a move which will make it one of the world' s largest users of solar power. On average each solar installation will provide enough power to run 55 television sets for five hours a day, every day of the year. With its acquisition of solar power company Solarex in 1999, BP Amoco is one of the world' s largest producers of solar photovoltaic cells.

Another option is to use PV roof tiles like the Uni-Solar shingles installed on the Solar Century showhouse in Richmond. A typical UK house can be fitted out for about £12,000, and the tiles look just like a normal roof, albeit with a slight purple sheen.

5.4. Safe Techniques

5.4.1. Substitute Materials and Compounds

For every product, there is always a safer material or compound that can be used, but the challenge is to match or exceed the performance of the original toxic solution. Three cases illustrate how this challenge can be met: Climatex Lifecycle fabric, the Fuel Cell Car, Foxfibre and Greenfreeze.

DesignTex are a US company that went to their Swiss suppliers **Rohner Textil** and asked if they could supply a new fabric. It had to be environmentally safe, but it also had to be mass produced and competitively priced, plus it had to meet all performance standards established by the Association for Contract Textiles The first step was to find alternatives to the man-made fibres often used in the construction of contract textiles. After narrowing the options, the team selected wool and ramie. The wool, which comes from free-range sheep, is collected during the natural shedding process. Ramie, a natural, linen-like fibre grown in the Philippines, was found to be an excellent alternative to polyester, providing moisture-transport capability. The combination of the two fibres created a fabric

that proved strong enough for commercial use. Next, dyes and finishes were checked to ensure the fabric would be toxin free. Most chemical companies weren' t willing to reveal their secret formulas, known as "deep chemistry", but eventually, chemical giant Cibageigy agreed to open its books. The German chemist Michael Braungart worked with the Swiss mill and Cibageigy, narrowing an initial list of more than 8,000 chemicals used in the textile industry by eliminating the 7,962 that were carcinogenic chemicals, toxic chemicals that bioaccumulate in tissues, heavy metals or mutagenic substances. The fabric – in fact, an entire line of fabrics – was created using only the resulting thirty-eight chemicals, which by a stoke of good fortune, are able to create any colour. When quizzed about why these safe compounds were not already widely known, the chemical engineers were reputed to have said, "Well, you never asked us for safe chemicals before – it' s not one of our usual criteria."

The resulting product, known as ClimaTex Lifecycle, eliminates all toxic products at every step in the manufacturing process, emits no indoor pollution, and biodegrades safely into ordinary soil. The fabric is priced competitively with other wool fabrics. It does not sacrifice aesthetics. The fabric eliminates indoor pollution such as formaldehyde. The combination of wool and ramie wicks away moisture, keeping the sitter cool and dry. Amazingly, regulators found that the effluent leaving the factory was actually cleaner than the water going into it, because the fabric was filtering the water. The fabric mill recycles all scrap and waste. It contracted with a consortium of strawberry farms to press the scrap fabric into felt used instead of plastic as a ground cover, insulator, and weed inhibitor. After repeated composting trials, the product was proven to be biodegradable into soil. It left behind no carcinogens, persistent toxic chemicals, heavy metals or other toxic substances. "The implications of redesigning the entire manufacturing process are incredible for industry," the company says. "No pollution, therefore no regulations." The collection supports the idea that with a little ingenuity and a lot of dedication, industry can work in accordance with nature, and still be profitable.

Another good example is that of **fuel cell technology**. DaimlerChrysler are developing the NECAR 4 (New Electric Car), which uses fuel cell technology to generate electricity and water vapour. Based on a Mercedes-Benz A-class compact car, it reaches top speeds of 90 mph compared to a top speed of 68 mph in its technological predecessor NECAR 2. It can travel nearly 280 miles (450 km) before refuelling. In addition, engineers have been able to mount the complete fuel cell system in the vehicle floor for the first time allowing room for up to five passengers with plenty of cargo space in a compact car. DaimlerChrysler plans to have fuel cell vehicles in limited production by 2004. The company will invest more than $1.4 billion on fuel cell technology development by the time the first fuel cell vehicles come to market. Juergen Schrempp, the DaimlerChrysler chairman said, "We are investing in fuel cells because we are committed to sustainable mobility and because we believe this investment will pay off. Fuel cells have the potential to be the most attractive alternative propulsion system for

the long term. The race to demonstrate the technical viability of fuel cell vehicles over. Now, we begin the race to make them affordable."

The NECAR 4 is powered by liquid hydrogen stored in a cryogenic cylinder resembling a large thermos at the rear of the vehicle. The fuel is then processed by a Proton Exchange Membrane Fuel Cell (PEMFC). Inside the PEMFC, a platinum-coated membrane separates hydrogen into protons and electrons and combines them with oxygen in the air to form water. This surplus and deficit of electrons and protons creates positive and negative terminals that, when connected, produce electricity, which in turn, powers the vehicle. Fuel cells give you the range of conventional gasoline engines and the emission benefits of electrical vehicles. There is a quick refuelling process, unlike electric vehicles which need to be plugged in overnight. It also has few moving parts like an electric vehicle and is quieter than a conventional car.

FoxFibre is an organic, inherently coloured cotton, based on green, brown and rust coloured wild varieties, so needing no dyes at all. Coloured cottons have always existed in nature. Native peoples have used their short fibres for hand spinning and weaving. A breeding programme was initiated to select coloured cotton with improved fibre and agronomic characteristics that could be grown organically, achieving success in 1989. Available in reddish brown, bronze brown and green, all varieties have good fibre length and some are inherently flame resistant. It' s also up to 20% cheaper, as although the fibre is more expensive, the cost of dyestuff, energy, water, and toxic dye waste disposal is eliminated. All FoxFibre varieties share a unique property – their colour intensifies with washing (and presumably doesn' t run and ruin your whites). According to their web site (www.foxfibre.com), it' s also up to 20% cheaper, as although the fibre is more expensive, the cost of dyestuff, energy, water, and toxic dye waste disposal is eliminated.

Worldwide, cotton farming is reputed to use only about 3% of the farmland but consumes 25 percent of the chemical pesticides and fertilisers. Organic cotton obviously removes a whole lot of toxics, and the elimination of dyes clinches it – Foxfibre does very well on the Safe criterion.

Back in 1991, the author organised a seminar on refrigerators and the environment. The large chemical firms such as ICI and Rhone Poulenc were speaking, as were some fridge manufacturers. They we all totally committed to replacing CFCs with HFCs such as R134a, a compound with a global warming potential three thousand times greater than CO2. When a professor from South Bank University came to give his talk on using propane/butane instead, people literally laughed at him and said it was unfeasible and dangerous. Yet within two or three years, the greenfreeze revolution took off, led by Greenpeace and the small German manufacturer DKK Scharfenstein, and now all manufacturers use hydrocarbon refrigerants, finding that they are efficient, have no ozone depletion potential and very low global warming potential. The explosion risk is negligible – a fridge contains as much propane as a cigarette lighter does.

5.4.2. Stewardship Sourcing

The maintenance of ecosystem integrity requires that biomes such as forests and seas are not over-harvested. For example, clearing of virgin forests or overfishing are not sustainable. Ecosystems can also be disrupted by physical means, such as the building of roads and fences through habitats which may prevent migration of wildlife. This process is known as "islanding", where animals are sectioned off into smaller and smaller areas, and subsequently the animals with large ranges, like the big predators, cannot support themselves and diversity beings to decrease.

Finally, one of the major threats to habitats worldwide is the introduction, accidental or otherwise, of alien species. In 1860 Eugene Schieffein sponsored the release of English sparrows into New York, in the hope that they would eat the caterpillars infesting the local trees, despite that fact that sparrows were regarded as pests in Europe. After several attempts, the sparrows became established and thrived – but at the expense of native species such as robins, swallows, bluebirds and orioles. They also turned out to prefer fruit, grain, plants and trees to insects, and they especially disdained the caterpillars they were meant to catch. Typically of this sort of release, there was a seeming revenge effect as the sparrows also displaced the caterpillar' s natural predators, exacerbating the problem. The sparrows thrived on recycling grain in horse droppings, another food source unanticipated by Schieffein. Despite this disaster, many other birds were deliberately introduced, including thrushes, chaffinches, skylarks, nightingales and starlings. Of these, only the starlings took hold, and in a sensational way. They spread throughout all the US states. They reached California in 1941 and by 1966 some roosts had populations of several million and a serious pest extermination project was needed.

To avoid disruption by overharvesting, islanding or aliens, a resource needs to be sustainably managed. Tracing the origin of raw materials can be difficult, however. For example, it is easy in theory for a company to develop a timber purchasing policy supporting sustainable forest management, but in practice it is difficult to verify the source of timber products. Certification offers a solution which makes it clear which products have been grown according to specific standards that ensure sustainability. A third-party certification scheme is also more credible than self-declared claims and labels that can be meaningless or even misleading. Good forest management should include harvesting and restocking plans that do not jeopardise the long term productive potential of the forest, species that are suited to the site, efficient harvesting with minimum loss or damage, avoidance of chemical and GMO use, and a minimum of 15% by area managed with conservation and enhancement of biodiversity as a major objective.

Two schemes exist. The **Forest Stewardship Council** (FSC) allows for the accreditation forest assessors and the use of an FSC logo on products from certified forests. The **Marine Stewardship Council** (MSC) uses a similar approach for the fishing industry. The MSC has a key role to play, as the fishing industry is extremely wasteful – the "wrong kinds" of fish are thrown back to die in the sea,

and the processing is very inefficient. One issue that needs more publicity is that of albatross bycatch. Now that driftnetting for tuna is banned or discouraged in many parts of the world, tuna is fished using rods and long lines. The albatross fly behind the boats, see the bait before is goes below the water, swoop down and are dragged underneath. Hundreds die every year from a populations of only a few thousand, yet all it takes to prevent it is long scare-streamer to be fitted to each boat.

Think about your raw materials and find out about how they are harvested or extracted, particularly from overseas. Make an effort to go and visit suppliers – you' ll always learn something interesting.

Also consider other ways in which the land that is used on your behalf can be better managed, for example by purchasing **organic** or **biodynamic** food, wool, cotton and leather.

5.4.3. "Bio-Everything"

Products and processes are being transformed as plastics, fuels, and drugs are being mass produced from plants. Traditional mineral based industries are becoming more organic by reusing materials and reducing toxicity. Here are some examples:

BioFibres as strong as E-glass or even kevlar are made from hemp and flax and have applications as panels, building materials, TV and computer cabinets, furniture, packaging and various reinforced materials. Plant fibres are also being used as filters for air and water, and the Centre for Plant Fibre Technology in Denmark is developing glues based on enzymes which activate surface lignin of Norway Spruce and beech wood, giving equal or superior performance to synthetic glues. Hemp fibre and seed can be used to make over 25,000 consumer products, including paint, oil, medicinals, cosmetics, paper, textiles, rope, and glassfibre substitute. Hemp fabrics are used by Calvin Klein and Ralph Lauren, Adidas makes training shoes from it, and Mercedes uses it as a filling for car seats. It should be noted that Industrial strains of hemp have negligible amounts of THC, the psychoactive ingredient in marijuana. However, the plant still has a bad image in the US, where the very similar kenaf is more popular. In the EU, on the other hand, hemp production has gone from 30,000 tonnes in 1992 to 240,000 tonnes in 1998. The worldwide hemp market is forecast to be worth £1 billion by 2001.

BioDrugs is almost a tautological term – many drugs are derived from plants, and many companies such as Phytopharm are dedicated to analysing the huge variety of wild plant species for potentially useful compounds. Genetic engineering has allowed drug manufacturers to grow micro-organisms in vats and have them produce drugs, and also insert drug-producing genes into crops and even cows, from whose milk the drugs are extracted.

BioFuels have always been around – Brazil in particular has used petrol with 20% ethanol from sugar cane for 30 years. Biodiesel made from rapeseed oil can be used in vehicles with very little modification. The range of potential feedstock has exploded in the late 90s with the development of ethanol production from general biomass, rather than relying on low-volume supplies of sugar cane. Methanol can be extracted from wood, and can be used in fuel cells, giving a completely clean, combustion-free and solar-powered vehicle powering system. Rape Seed Methyl Ester (RME) contains oxygen and thus has clean combustion characteristics, albeit also less heat content. More than 500 filling stations in Germany are already supplying biodiesel, and increasing production capacities hold out promise for further market penetration.

BioChemicals are replacing speciality petrochemicals, building what is predicted to be a $20 billion business by 2020. Soy is used to make inks, paraffin substitutes (for use in crayons, for instance). Applied Carbochemicals has a process to convert corn into inks, dyes and plastics at 20% less than the equivalent costs for using petroleum.

BioPlastics like Biopol and Mater-Bi are made from plant starch, and have good structural performance, even though they are biodegradable. Bioplastics are plastics made from plants, usually polymers of starch or polylactic acid (PLA). They are being used for bags, cutlery and plates, pens, clothing, credit cards, food packaging, agricultural films, teabags, coffee filters, diapers and napkins. The main brands of the plastic itself are: Biopol, Bionolle and Mater-Bi. These plastics are cyclic in their sourcing, with starch coming from plants, particularly in Europe where the "starch mountains" some years ago prompted the research that led to the development of starch plastics. It is also possible to make PLA from milk residues and even household waste.

Uses for bioplastics include Agricultural films, which can be ploughed into the ground after use, Compostable garbage bags, Medical applications such as surgical stitching material; and, bizarrely, Grave decorations: so candles and other materials used to decorate graves can be composted together with flowers. This implies that bioplastics are not suitable for more durable applications. However, control of degradation has been achieved for wood, leather, cotton and most other plant products, so it must be possible to use bioplastics for more durable applications.

Biocorp manufactures and sells biodegradable food serviceware, including cutlery, plates, cups, and plastic waste collection bags. In 1998, significantly expanded its operations in Europe by opening offices in Austria, Spain and Italy. Biocorp hold the exclusive American rights to Mater-Bi, which is owned by Italian firm Novamont. Biocorp biodegradable plastic food utensils were used at the World Ski Championship held at Ramesau, Austria, in February 1999 – more than 200,000 people came, and Biocorp cutlery is also being used by McDonalds in Austria and Sweden.

Finally, Welland Chemical has developed a cellulose-based plastic that can be used in colostomy bags – perhaps the ultimate challenge as the bags need high strength and flexibility – which are also biodegradable, greatly easing their disposal.

BioWarfare is sadly very effective – a few canisters of infective agent can kill all the people in a whole town. Rumours persist of strains of airbourne diseases such as flu and anthrax cross-bred with fast killers such as ebola and smallpox.

BioDigestion is the obvious solution for disposing of organic materials, yet digestion vat technologies are still quite primitive. In areas of rural India they are becoming widespread, converting sewage and animal waste into biogas, a mix of CO2 and methane, which is used for cooking. Many rural areas in the UK have reedbeds for sewage treatment, and the firm Living Machines has developed complex in vitro ecologies to effectively treat wastewater that includes heavy metals and other industrial effluents. See the Case study below for more on this.

BioMining – mining companies are starting to use bacteria to extract mineral ores from spent mine tailings. For low yield ores such as gold, bacteria are a patient, persistent and cost-effective way of extracting metals. *Thiobacillus ferroxidans* oxidises metal sulphides, essentially eating the rock and leaving the ore. India, Spain, Brazil and Pakistan are rumoured to be developing *T. ferroxidans* techniques to extract uranium from reserves once thought already depleted.

BioVillages are being developed in China, India and Africa to integrate biosystems for small scale industry and agriculture, utilising a huge range of newish methods to extract value from sunlight and biomass, including: mushroom production, earthworm raising, fly pupae production, chicken waste as swine feed, rice field fisheries, multilayer fish culture, rabbit rearing, fruit processing, and apricot-and pomegranate orchards.

Living Machines like fish ponds, mussel farms, and Reed Bed sewage treatment, make use of human and industrial effluents, rendering them harmless and often creating biomass or food in the process. Living Machine' s flagship facility, a sewage treatment plant in Providence, Rhode Island, uses snails to break down the heavy metals used by costume jewellery manufacturers. It took researchers nearly a decade to find snails that could thrive in that environment.

In China, the biovillage effort is based on biogas digesters, improved stoves, mushroom production from byproducts, earthworm raising, fly pupae production, chicken waste as swine feed, rice field fishery, multilayer fish culture, biopesticides, biological erosion control, windbreak building, firewood production, agroforestry techniques, biological waste water treatment, inter-cropping, solar heaters, micro-propagation of bananas, new cultivars for rice, tobacco and herbal drugs. Its current emphasis is on intensified wheat and maize production, rabbit rearing, fruit processing, apricot-and pomegranate orchards, market yards and Biocenter support.

Next stop, BioCities – in Curitiba, Brazil, the self-proclaimed 1.6 million inhabitant, "Ecological Capital of the World" the "Green Exchange" program encourages where poor families to bring their trash to a central location in exchange for food, thus raising the city' s recycling rate to a staggering 70 %. The exchange costs the city no more than traditional garbage collection, and at the same time provides relief both to poor families and to struggling farmers.

BioCleaners use organic ingredients instead of petrochemical ones. Citra-Solv is an concentrated cleaner with an active ingredient called d-limonene, derived from the peels of oranges. You would usually use a dilution, but the neat concentrate can deal with ovens, grills, engines, bike chains, parts, tar, grease, chewing gum, blood, fresh paint, crayon, waxes (paraffin), adhesives, and permanent marker stains.
Because d-limonene is a relatively safe and highly effective organic solvent, it is finding increasing use in household and industrial cleaning products, replacing dangerous petroleum-based solvents and environmentally hazardous chlorinated hydrocarbon solvents. However, while d-limonene is not carcinogenic (in fact human clinical studies involving d-limonene as a treatment for cancer are underway.), not teratogenic, not mutagenic and holds an FDA-GRAS rating ("generally recognised as safe"), just because it comes from a plant source does not automatically make it safe. According to the data sheets, it "may be toxic to aquatic organisms" and can definitely can cause skin allergies; gloves are essential. The probable lethal dose in a human adult would be 1 fluid ounce – so it' s not like orange juice!

BioPaint There are an increasing number of paint manufacturers that make paint which is water soluble, solvent free, petrochemical free, and that use non-azo and non-heavy metal pigments. Auro are based in Braunschweig, Germany, and they have an impressive line-up of ingredients as well as a pile of environmental awards. They make everything from gloss paints and varnishes to adhesives and polishes. Their paint range uses:

- plant oils like linseed oil which is mostly from organic sources and all from within 20 miles of the factory;
- plant resins like dammar resin, fairly sourced from tapping a tropical tree, and pine wood resin;
- plant and animal waxes like carnauba wax and beeswax;
- earth pigments like umber, ochre and iron oxides;
- plant colours like madder, indigo and mignonette; and
- water, (unless the paint is supplied as a powder) some of which is rainwater collected at the factory site.

BioPest Control eliminates the use of poisons. For example, cockroach can be removed using the Zap-Trap, a non- poisonous insect trap designed by British entomologists. It uses an exclusive non-poisonous pheromone lure to bring the roaches to a safe electrified trap and sticky glue tray.

5.5. Efficient Techniques

The techniques for improving product efficiency can be grouped into two main types – extending the life of a product in use, so that new ones don't have to be made; and ways of using less materials, water and energy.

5.6. Efficient: Life Extension

5.6.1. Durability

There has always been the story about the light bulb that never wears out. If it did exist, it might well be more expensive than most consumers were willing to pay for. So there you have the fundamental problem with making durable products. One way round this would be to lease or rent the product , something which encourages the manufacturers to make durable products so they don't have the expense of replacing them.

In general, durability equates with the high end of the price spectrum, and is a characteristic of luxury goods. However, there are engineering solutions that do allow for high durability at low manufacturing cost. For example, **Kyocera** make toner-only laser printers with a long-life drum, unlike most other types of printer, where both the drum and tones are replaced each time.

A **"Bag for Life"** is being tried by supermarkets such as Waitrose and Tesco in order to try and reduce the amount of disposable plastic shopping bags used. The customer purchases a specially-sturdy plastic bag for 10p and uses this for shopping, and if it wears out, the bag is replaced for free. The bag for life weighs about 5 times the weight of a disposable bag, is about one and half times as big, and may last a year, so replacing 75 bags, a 93% saving.

5.6.2. Upgradability

Another aspect of durability, but distinct from it, is the tendency of consumers to want the latest model of a product. This usually requires the replacement of a product, but if it can be engineered to be upgradable, then the life of the original product can be extended.

For example, telephones can have a removable outer casing and buttons, allowing for changes in style and fashion while retaining the internal workings. Many personal computers have been designed to allow the upgrading of the PCU, the RAM, harddisk, graphics card, and so on, often with easy access ports and slots so the end-user can perfrom DIY upgrades.

The new Smart car has cheap and easy to replace body panels, which come in many colours, allowing a change in style while retaining the main car itself. This approach, coupled with the fact that electric cars can have excellent durability compared with combustion engines (an electric motor cam last 90 years), indicates that upgradable cars could be prevalent in the future.

5.6.3. Repairability

Consumer products may have environmentally sub-optimal life spans for many reasons. Several types of product obsolescence have been identified. These include:

- Technical: the product is irreparable.
- Economic: the cost of repairing the product is uneconomic.
- Functional: new products have improved features.
- Psychological: the desire for new and fashionable products.

Indeed, high quality products designed for durability are often available but meet with relatively low demand because they are relatively expensive. For example, it is possible to purchase washing machines designed to last for at least 15 years watches that will last for a hundred and toasters which have the strength to withstand commercial use.

The 1998 Friends of the Earth book Tomorrow' s World says, "We (the UK) buy over 3.5 million TVs each year, 2.2 million washing machines, 880,000 fridges, 840,000 fridge-freezers and 760,000 freezers. Throwaway attitudes and cheap, shoddy products are factors increasing resource use. People are reluctant even to seek repairs of such products." They propose that the expected lifetime should be marked on durable products.

Friends of the Earth also make the interesting suggestion that there should be an obligation on retailers or manufacturers to offer free extended guarantees for products, covering parts and labour, for example for ten years.

5.6.4. Complementary Components

It is important to design parts for equal lifetimes since failure of a single component often means the whole part or product will be discarded. For example, a laptop computer' s hard disk has a Mean Time Between Failure (MTBF) of 100,000 hours' operation, whereas the backlight for the screen has an MTBF of about 1000 hours.

Compared with desktop machines, laptop computers use 90% less energy, and use 90% less casing materials, so they would seem to be better performers environmentally. However, the lifetime may be shorter due to the lack of complementarity of the components inside. A further factor is that the chipsets inside are about the same as desktop machines and so have similar impacts – the manufacture of a single pentium chip produces about 20kg CO2, 300 litres of waste water and 90g of hazardous waste.

5.6.5. Think Ahead a Long Time

In Southwest England, landowners sometimes plant a stand of willow trees when a daughter is born, to pay for her wedding by being harvested and made into cricket bats. All products are disposable in the end, so firms should always plan for end of life or takeback even if it' ll happen in 20 or 50 years. Alternatively, try to be immortal, like the 800 year old Japanese temple which is regarded as still all

original even though every bit of the building' s fabric has been replaced over the centuries, or like Porsche and Rolls Royce cars, almost all of which are still on the road.

The architects of Jesus College Cambridge over 300 years ago realised that a major oak beam would eventually succumb to rot. When this occurred in the 1980s, the college looked back at the records and realised that the architects had planted a suitable oak tree on college land which was now big enough to replace the original beam.

5.7. Efficient: Less Materials and Energy

5.7.1. Increased Efficiency

Improving efficiency reduces materials or energy costs and is always a good idea. Many environmental innovations fall into this category. Here are just four examples:

- Energy Saver Tyres such as Michelin' s save 5% on fuel use by reducing rolling resistance.
- Window Envelopes that can be resealed and sent back with payment are increasingly popular with energy and water companies, saving an envelope with each bill – probably saving 200 tonnes of paper a year in the UK alone.
- Compact fluorescent light bulbs that draw only 18W gives the same light as 100W incandescent, an 82% saving
- British Telecom' s Residential Phone Book now has 4 columns of text on each page, not 3, due to a layout change and a typeface specially-designed to be legible at smaller sizes.

One way to stimulate design thought is to use a Design Challenge. This approach has been successfully used by Greenpeace, who developed a prototype "SmILE" modified Renault Twingo car, which with a 360cc engine got 75-86 mpg. The idea was to goad the auto industry into coming up with more fuel efficient cars. Five years later, VW launched their Lupo, the diesel version of which does 89 mpg.

5.7.2. Increased Utility

It' s not just about delivering to the customer a chunk of materials in a certain form. What consumers want is light, heat, warmth, entertainment and so on. This utility is the thing to focus on and improve. There may also be other ways to deliver the required utility.

One example of improved utility is the evolution of CPU microprocessors, which have delivered dramatically improved performance for quite small gains in size and energy consumption.

Another way of improving utility to take an existing type of niche product and make it more appealing or useful to a larger audience. For example, motorcycles

are very fuel efficient forms of transport, but they have had a relatively limited uptake in Europe because they are exposed to the elements. The **BMW C1** is a scooter with a roof. You sit with no helmet and a seatbelt and zip around town. Clear benefits are that it's safer than a motorcycle, there's no fuss with helmets, protection from weather, and no need for special clothing or overtrousers, and it only takes up half a lane – reduces congestion and parking pressures. It has a 125 cc 1-cylinder 4-stroke engine, with automatic belt transmission and a three-way catalytic converter. We guess that fuel consumption is about 80 mpg, giving a 58% saving compared with a 33mpg car. BMW have simply recognised that 80% of all journeys are made alone, and come up with a vehicle to serve that need. Dr. Reinhard Loske, of the influential Wuppertal Institut für Klima, Umwelt, Energie, has endorsed the C1, saying, "It allows the individual who wishes to travel from A to B, to do so while moving less mass than the driver of a passenger car, consuming less fuel and occupying less parking space. If the C1 could replace the passenger car in inner-urban traffic to a significant extent, it would make a big contribution towards a sustainable transport system."

5.7.3. Dematerialise

An elegant technique is to simply remove a part of a product. For example, taking out the filler from soap powder gives Concentrated Washing Powders which save up to 40% of packaging and transport impacts.

Lightweighting is a common tool in packaging design – cans and tins are much lighter than a decade ago due to the use of corrugation and spheroidal shaping. J Sainsbury's garlic bread dispensed with the cardboard outer, and no only has a plastic sleeve, saving 80% of packaging. However, watch out for increased product damage rates that may offset any environmental and economic benefits. When SmithKline Beecham looked at reducing the glass content in Lucozade bottles, trial bottles sent by a manufacturer with 33% less glass performed fine in trials. Unfortunately, mass production of the bottles meant quality loss and many bottles broke in transit. More worrying were the bottles that broke in consumers hands as they twisted off the bottle tops. This resulted in 7 million bottles being recalled. SmithKline Beecham have since introduced a reduced glass content bottle that performs satisfactorily.

"Dematerialisation" is the term given to the process of removing mass from a product or eliminating it altogether. BT's **Call Minder** consumer voicemail service effectively dematerialises answerphones by storing messages on the main BT system – although each user accounts for a fraction of the computer and harddisk that makes up the BT switch.

Thinner Copier Paper that is 75gsm instead of the typical 80, 90 or even 100 grammes per square metre means instant savings as the environmental impact of paper manufacture is directly proportional to the mass of paper made. Using less paper by weight (rather than by number of sheets) can make more of a difference to the environment than worrying about the differences between ECF and TCF, for example.

Bagless Vacuum Cleaners such as the Dyson save a bag each time. The container is made of strong plastic and weighs about 1kg, compared with 100g for a paper bag. Assuming a 15-year lifetime, and 6 bags a year, this is an 89% saving.

Eliminating water uses gives a 100% saving for **Waterless urinals** which are cost-effective and don' t smell! Currently in use at the UK Environment Agency' s own offices, as well as tabloid newspaper The Sun and many other sites. Most water-using urinals flush four times an hour, using up to 250,000 litres (65,000 US gallons) a year. If the flushing system is faulty, they can use a lot more. If you have a sensing device then you can save 70% or more – although this will still be the biggest usage of water in an office building.
The developers of Whiff Away, designed by Bee Environmental Ltd, discovered problems with the oil trap technology used by most waterless urinals. Firstly, the oil is just that – a kerosene-based petrochemical, and because it needs to be topped up, it was obviously getting into the drains – something undesirable environmentally and that could require the installation of an expensive oil interceptor to catch it again. They also found that expensive special cleaning materials were needed for washing the bowls out – and that sometimes normal detergents were used by mistake, which of course dispersed the oil away more quickly. Bee Environmental wanted a system that could be cleaned with ordinary soap and water, did not release oil to the environment, and one that was completely "idiot-proof". Rather than using a fragrance which just masks the problem, they use a replaceable paper disk with a compound that reacts with the smell-causing molecule in urine. This mops up any odours and eliminates them, but as people are reassured by ' nice' smell, a hint of lemon fragrance was also added. Apparently, male urine smells more strongly than female urine (just ask the staff at any nursing home), and this is a throwback to primeaval territorial marking as found in cats and dogs. Bee Environmental identified this smell marker molecule and found the right counteractant. The perfume industry was the source of this compound, as there are many unpleasant-smelling ingredients in perfume making that need counteracting. The Whiff Away is widely distributed in the UK through Mc Alpine Plumbing products with the replaceable disks available from Diversey Lever. These retrofitted units cost £10 with a year' s supply of the disks costing around £36.

Inflatable Furniture such as IKEA a.i.r. means an armchair weighs 95% less than a conventional armchair, a wonderful saving on materials. Previous inflatable chairs and sofas used PVC, but these new designs use an olefin plastic which improves on leak performance and has an attractive texture as well.

5.7.4. Every Little Counts

Even if something seems small, it may be worth spending time on if large numbers of units are involved:

Coca Cola at one of their bottling plants found that they were using a lot of plastic film to shrinkwrap loaded pallets. Each pallet, stacked high with boxes of bottles, was wrapped in the film. A team examined the process and found that the overlap

on the film could be reduced by an inch and still stick sufficiently. Because of the volumes involved, this tiny change saved £30,000 a year in packaging materials costs.

McDonald's in the UK reduced the size of their **napkins** by 12%, without informing customers and without any customer reaction. This saves 1000 tonnes of material every year.

Bulk Delivery is a method also used by McDonalds UK. Originally, Coke syrup was delivered in 5 litre polyethylene jugs which were difficult to recycle and usually ended up in landfill. To tackle this, each restaurant now has two 75 gallon steel tanks into which the syrup is pumped from the delivery lorry. This bulk delivery approach removed the need for about 2.8 million jugs each year.

5.7.5. Be More Local
Local sourcing reduces transport impacts and cost. It can also stimulate the local economy, helping local sales of your own products. Many goods are transported remarkable distances, even during processing such as cars which are sent to Italy and back for special features to be added. Another example is "Food Miles", where food either travels a long way, such as from the other side of the world in the case of New Zealand lamb or apples, or it makes seemingly unnecessary round trips, such as from a local farm to the main supermarket distribution centre and back again to a super market only a few miles from where the food was grown.

Remember this as the "proximity principle".

5.7.6. Multifunctionality
Multifunctionality also ensures maximum utility. For example, a multitool is often better than having a specialist tool which is used once a year. PC/TVs and Fax/Scan/Printer/Copiers are other examples.

5.7.7. Exquisitely Fine Control
Exquisitely fine control is found in the metabolism of living systems, and is something which maximises the use of materials. Make systems respond on demand (like the **Ecoflush** toilet with a dial for High, Medium and Low flush volume settings), use senses and feedback loops (like **thermostats**), and make use of everything (like **Chinese cookery** or the printworks which makes birdboxes out of pallets that are beyond repair). A parked Audi's solar-powered fan in the sunroof matches demand automatically as the hotter the day, the more cooling needed and the faster the fan goes.

Presence sensors are used for escalators (in the Vienna Metro), flushes, and lighting, which allows energy and water to be matched exactly with demand.

VW's Ecomatic model of their popular Golf model had an engine which cuts out going downhill! Instantly started again with a tap on the accelerator, this car has revealed that the engine typically can be switched off 30% of the time.

5.7.8. Work with the Seasons
Seasonal variations are inevitable, so work with them. Natural systems are tolerant of flux and have strategies for feast and famine, winter and summer, and so should new products. PCs now **hibernate** when not in use. **Grass roofs** insulate in winter and the plants' transpiration cools in summer.

5.7.9. Biomimicry
Mimick nature's materials, with their elegant solutions to structural problems. Spider's webs, burrs, feathers, mother of pearl, deer antlers and butterfly wings are just a few examples that have inspired important innovations. Nature has been a constant source of inspiration for designers, from the ancient Greek's observations of bird flight and the snail-inspired archimedes screw, to velcro and the famous example of cat's eyes road reflectors.

Biomimicry, also known as biomimetics, is the fusion of the knowledge of engineers and biologists. It has created a wide range of innovations, particularly in the field of materials science. Spider's webs are stronger than steel of the same thickness. Deer antler, one of the toughest types of bone, has been applied to helmet design. Penguin feathers and musk ox fur are being studied to try and capture the secret of their extraordinary insulative properties. High impact joints on racing cars have been inspired by the flexible yet tough nature of hedgehog spines. Jet engine components have been lightweighted by mimicking the 'flaky pastry' structure of mother-of-pearl.

Butterflies are the source for a range of current research. The iridescence created by tiny scales on the wing of the *Morpho* butterfly gives an electric blue colour without using pigment. This phenomenon is being used to develop reflective safety fabrics, car paint substitutes and high-security credit-card markings. A Tufts University team headed by Asst. Professor Peter Wong found the structure of iridescent butterfly wings may reveal a better way to control temperatures while fabricating and using microprocessors. Wong said, "As our team sat down and had lunch one day, we thought about the nice ways in which nature controls heat. We sent students to various departments and one found an interesting example in butterflies." Because they are cold-blooded, the butterflies must constantly adjust their body temperatures, using "thin-film structures" that cling to their wings. Wong's team hopes that by learning how butterflies reflect and absorb radiation they can devise similar techniques to cool microprocessors, an increasing problem with more powerful – and hotter – chip designs.

There are as many biologists as there are management consultants – an untapped solutions resource? Find out who might be of help at your local university, and contact them.

5.8. Fully Sustainable Products: Cyclic, Solar *and* Safe

It is straightforward to innovate in one or two of the Cyclic, Solar, Safe, and Efficient categories. The next step is to achieve high levels in all four parameters at the same time. Here are a few examples analysed in depth:

- The Bioplastic Pen
- The Recycled Plastic Pen
- The Soya Bean Crayon
- The Autonomous House
- The Sustainable Watch

5.8.1. Mater-Bi Corn Starch Pen

Known as "the Green Pen" this pen is a cheery green colour with a bright yellow cap. Except from the ink, nib and ink tube, the Green Pen is made from Mater-Bi, a material derived from cornstarch. Mater-Bi products will disintegrate in about 12 months (similar to wood) when placed in soil, composters, landfills, reedbeds or any system where micro-organisms are active.

Mater-Bi is made by the Italian company Novamont. Other firms also make starch-based plastics, such as the Biopol brand that was developed by ICI (now sold on) and used for potted plant labelling sticks, and also in the Co-Op Bank's non-PVC credit card. These plastified starch materials exhibit mechanical properties similar to conventional plastics such as PP, and are generally resistant to oils and alcohols. However, they degrade when exposed to hot water, and are not formed and moulded in the same equipment as petroleum-based plastics, necessitating new capital investment if a conversion to such plastics is desired.

VERDICT

Cyclic – Yes, but only if it ends up being composted, which may well happen if the user is aware of its properties. If incinerated or landfilled, then it will be converted into CO2 and H2O (with some methane if in landfill) which also will be cyclic but that would be perhaps not as useful as contributing to soil.

Solar – The corn plant's manufacture of the starch molecules is mostly solar (although tractors and fertiliser mean this is definitely not 100%), and the polymerisation process and moulding are not solar.

Safe – I suppose you could eat the barrel and cap of this pen – but I am not sure about the pigments used. The ink and nib and tube would be fairly inert biologically.

Efficiency and Utility – It writes well, and the pen is slightly flexy, which I like but some people don't. I have no data on how long the ink lasts. Not really different to any other pen. They seem to go for about 70p ($1) retail, which is right at the top of the range of prices for disposable, capped, ballpoint pens.

Improvement Suggestions – Sell refills. Make it a bit less clunky (it has a square cross-section). Clearly mark (emboss) on each pen what the user should do at the end of the pen's useful life. Make sure the ink lasts a long time (refills exist which last 4 times longer than a Bic Biro). Use plant-based pigments. Get down to 20p each or 50p with refills at 15p.

5.8.2. The Remarkable Ballpoint Pen

Office audits conducted by the author over the years show that a typical office worker gets through 20 to 30 pens a year. As a typical "Bic" ballpoint pen gives about 1500 metres of ink, that's about 4 or 5 handwritten pages a day – in theory. It seems that a lot of pens go walking, lie unused in drawers, or malfunction in some way. The best way to improve the environmental performance of your pens is to hang on to them and use them all up. However, there are some pens on the market that have superior performance during manufacture as well.

The "Remarkable" brand of pen (made in the UK +44 171 351 4333) is a Bic Biro clone, but with two important differences – the barrel is made of recycled plastic cups, and the ink lasts for 4000 metres (2.67 times longer). It sounds good, but how much of a difference does it make?

Cyclic? – The barrel is 55% of total pen and packaging mass, so I guess we can score it as 55% cyclic – especially as Remarkable tell me they plan to takeback the dead pens in the future. Some people have told me that plastic cups are unnecessary in the first place, so these pens offer no real advantage, but pragmatically they are diverting a real waste stream.

Solar? – Not at all – 0% – although the factory tell me they may consider buying green electrons now as electricity deregulation is happening this year in the UK.

Safe? – No different from a standard ballpoint.

Superior? – Yes – good mileage, and you can have "made from one recycled plastic cup" printed on the barrel if you like that sort of thing.

5.8.3. The Prang Soybean Crayon

Some people use crayons instead of flipchart pens – intuitively they are better as they have no hard plastic to dispose of, and no volatile solvents. The colours come out just fine. However, it seems that it's possible to do even better – by avoiding paraffin wax and going soy-based. In the words of Prang's marketing team: "Why are Prang's new Fun Pro soybean crayons better than the rest? They're better for our planet! They're better for artists! They're the first new kind of crayon in 100 years! They've been in space! And the world's biggest soybean crayon is coming to a city near you!"

Two students at Purdue University came up with the idea while competing in a "New Uses for Soybeans" competition funded by the Indiana Soybean

Development Council. After two years of development this patented idea hit the market.

Cyclic? – It's potentially cyclic – paper with there crayon marks on it would biodegrade – but the whole materials flow of paper is not truly cyclic at the moment. Prang says, "In fact, it's the first and only crayon made from a renewable resource. Prang Fun Pro crayons are 85% soybean oil. That makes them the best choice for the environment. One acre of soybeans can produce 82,368 crayons—year after year after year!"

Solar? – Maybe 50% of total process energy is photosynthetic solar.

Safe? – Well, pretty much. I'm not sure about the byproducts of the pigment manufacture. They are certified Non Toxic by The Art & Creative Materials Institute, Inc. Over at Crayola's web site, there is only an unsubstantiated line, "And of course, every Crayola crayon is non-toxic." Well, kids eat crayons, so let's have a representative from each firm see how many they'd be willing to eat ...

Superior? – Prang say blending and layering colours is better "because you're mixing pigment, not wax!" The initial Purdue researchers found the formula to be comparable in colour transfer and breaking point strength to Crayola crayons. Prang crayons are slightly cheaper than Crayola.

Successful? – The product is sold in Wal-mart, Target, Staples, and other major retailers and amassed $2 million in sales during the 1997 back-to-school season. On November 19, 1997, astronaut Takao Doi from the Japanese Space Agency brought Prang Fun Pro crayons on the Space Shuttle Columbia, making it the first crayon in space.

5.8.4. The Autonomous House

Autonomous houses are self-sufficient in energy, water supply, sewage treatment and waste water disposal, and are connected to no mains services except the telephone, and electricity, so that they can export surplus solar power to the National Grid. They have high thermal mass in the form of thick concrete walls or are partly built in to the ground, preferably south facing and with a large conservatory and a cellar. They need no space heating, thanks to good insulation from triple glazing and passive solar heat input. A heat recovery ventilation system using 12 Volt DC fans and a 70% efficient heat exchanger allow airflow through each house to be maintained as necessary without excessive heat loss.

Water is collected from the roof and greywater is directed back into the garden soil via soakaways. The compost toilets are the ones that go into the basement and which have a small electric fan to continually draw odours down through the toilet, making it less smelly for the next toilet user than conventional water-using WCs.

Materials are sourced locally and are mostly recycled. For example, the Southwell autonomous house excavations were backfilled with broken brick from nearby

demolition sites; rather than with newly-dug stone: the concrete blocks for the cellar were made of waste ash from the local power station; the driveway was made of mining waste; the porch was roofed with recycled slates. The internal woodwork is left unfinished, and lime whitewash is used internally and organic paint externally in place of conventional paints. There is little external woodwork, and that has no preservative but some paint. Mains or Solar PV electricity is used for lighting, hot water supply, cooking and the usual appliance like fridge, microwave, TV and computer.

VERDICT Cyclic? – 70% – Many of the building materials are from secondary sources, but not the bricks, cement or glass. These could easily be recycled at the end of the houses' design life, which is 500 years. The roof insulation is blown cellulose fibre made from waste newsprint treated with a borax fire retardant, which probably could not be made into paper in future but could easily find a closed loop by staying as insulation material.

Solar? – 80 % – Where PV cells are fitted, or electricity is sourced from a renewables utilities company, the energy in use can be entirely solar. However, as the energy use is so low, it means that the embodied energy in the construction materials is relatively more important than usual. Despite this, when amortised over the planned 500 year life, the embodied energy per year becomes very small. The energy for cement manufacture will not have been solar, but the bricks (where not "pre-owned" bricks) for the Southwell house came from a firm which uses landfill gas to fire them. The triple glazing has krypton gas which needs a lot of energy to distil from the air, but as the windows came from Sweden (which has lots of Hydro and Bio) and the volume of Krypton used is quite small, this is not likely to be significant.

Safe? – 80% – By avoiding conventional paints and wood preservatives, the toxics come right down. PV cell toxicity varies, and I' m not able to say much at this stage.

Efficient? – 90% – The Total Energy Consumption is 25.6 kWh/m2/a, nearly a 90% saving on the average UK house which uses 263 kWh/m2/a. Water use is 34 litres/head/day compared with the UK average of 160 litres/head/day.

Superior? – The Designers of the Southwell house are convinced that they can design zero-energy houses that cost about the same as conventional housing – not so impossible as it first sounds as there are no costs for central heating boilers and radiators etc. The benefits for tenants are no worries about utility bills and greater security and autonomy.

5.8.5. The Sustainable Watch

You' d think that something as commonplace as a wristwatch would be an easy thing to get right. Yet surprisingly few manufacturers have addressed environmental issues, despite the overall impact being large – in Europe, we buy the equivalent of about one watch per person per year, and millions of watch batteries are used and disposed of.

A single watch probably weighs less than 50 sheets of paper, or perhaps a day or two' s worth of your food packaging, so it would be easy to say that there are bigger fish to fry. However, every little bit counts, so what would constitute a "sustainable watch"?

The watch is an essential business tool, if only to keep track of when it' s time to go home. But what are the environmental implications of their manufacture, use and disposal? Some of the issues are:

* The advent of the quartz watch has meant that many millions of tiny batteries have been used and disposed of
* Mixtures of metals for decorative and functional purposes make recycling difficult
* Large impacts occur during the extraction and manufacture of metals such as titanium and gold

We' ve looked at current approaches to energy, recycling, toxicity and durability for watches available on the market today. In amongst a sea of indifference, we found some pockets of innovation, but there is still a long way to go before fully sustainable watches will be commonplace.

Cyclic – Only a handful of manufacturers have looked at using recycled materials in their watches. The "Green Piece" by Rewatch has a bezel made from a crushed Heineken can. There is also the "Swiss Cheese Watch" which has a case partly made from a casein protein derived from cheese. But both of these are really gimmick watches. The only truly recycled watches are the Swiss Railway watches made by Mondaine from 100% post consumer recycled brass. They are verified as recycled by a Swiss institute, and come in automatic, quartz and solar models. And what about the end of life of the watch? – watches are not even listed as a waste stream by the upcoming EU WEEE directive on electronic waste. So they mostly end up in landfill or stay in people' s drawers. However, recycling is technically possible, especially the metals, so a metal watch with a metal strap is potentially very recyclable – although normal steel watch cases can contain 15 % nickel and 18.5 % chrome. The batteries remain a problem. Most watch batteries today are lithium, and so no longer have mercury, lead or cadmium in them. However they are still fairly hazardous – they can explode if crushed, and while recycling technologies exist, they are not yet routinely recycled. The rechargeable batteries in solar watches are normally Lithium Ion cells, which are not explosive, and for a watch purchased today, there will probably be recycling facilities available in ten years' time when the battery wears out.

Solar – The amount of energy used by a watch during its life is very small – it' s about the same as the embodied energy that went into making the watch – which means that the choice of materials for the bulk of the watch (the case) is a lot more important than you might first think – it' s different from cars and washing machines, where the energy consumed during use is far greater than manufacturing energy. The overall amount of energy that a watch uses compared with a person' s total energy use (transport, heating, etc.) is tiny – about 1/2000th

of a percent, including manufacturing energy! For starters, some watches use more energy than others. Having big hands, lights, alarms and so on uses a lot more energy than a simple watch with just hours and minutes. Simply choosing a simple watch can mean less batteries being used over the lifetime of a watch. In fact, there are now a few watches that are made with big batteries inside that last for ten or even 15 years without a battery change. Another approach is to have energy-saving features, like Seiko' s Kinetic Auto Relay. If thewatch is unused for three days, it goes into a Power Save mode. The hands stop moving, but the watch continues to keep perfect time internally. If the watch is picked up again anytime within the next 4 years, and shaken a few times, it comes out of the sleep mode, and the hands move to the current time.

Safe – The good old clockwork movements probably still have the lowest environmental impact. They are hand-cranked by a solar-powered person – if we can overlook all the fossil fuels that went into growing and making the food we eat. The automatic self-winders basically scavenge waste energy as we move around. The movements are repairable and are recyclable, mostly ending life being cannibalised for spare parts by watch repairers. Solar watches still have a battery inside, such as a ML2020 Manganese Lithium accumulator, and the lifetime on it is unlikely to be more than 10 years. A conventional digital watch can go for 5 years on one battery change, so the solar watch like the Casio G-Shock Raysman or the 72-model Citizen Eco-Drive range is not really offering a huge performance advantage in terms of reducing battery waste. The Kinetic range by Seiko are quartz automatics that use a tiny dynamo to make electricity from the movement of your wrist. Both the Seiko Kinetic and a Swiss version (variously branded as Autoquartz, Viziomatic or Omegamatic) use a capacitor instead of a battery, which is likely to last a good long time but still is not 100% safe. The safest solution will be the Seiko Kinetic "spring drive" available in 2000, which stores the energy in a spring before releasing it into the microgenerator, rather like the Freeplay clockwork radio.

The nearest thing to a sustainable is the Mondaine Ecomatic, made of recycled materials with its leather strap and 100% post consumer brass case. The automatic movement naturally uses no batteries and is repairable and is potentially recyclable – although at the moment such movements are usually just cannibalised for spare parts. Thus the watch can be almost entirely recycled at the end of its life, albeit with the leather being compostable over 30 years. A score of 80% seems appropriate.

For the solar score, using our rule of thumb that about half the lifetime energy of a watch is used during manufacture, about 20% of energy in Switzerland is from renewable sources, and all the energy that drives the watch is solar via human muscle power. So overall this gives a score of 50+(50*0.2)=60%

The "safe" score does not come out so well. Unfortunately, the Mondaine Ecomatic has a chrome finish, which is a process that will release chromium to the environment, either through the effluent from the plating stage, or simply as the watch surface wears out. Chromium is also likely to be involved during the

tanning process for the leather, although tanning methods that use only plant-based fixatives are available. As there has been no real progress on these fronts since 1990, the Safe score must be zero. On a relative basis compared with a battery, kinetic or solar watch, however, it comes out way ahead, despite the chromium problems.

In terms of efficiency, the watch is quite small, perhaps 15% smaller than the average 1990 watch. This means it has an efficiency score of 17%.

The score is thus 80 | 60 | 0 | 17, or an aggregate score of about 40%, which is not bad. With some thought, great inroads could be made into the toxicity score, and the Mondaine could become over 60% sustainable. If they developed a takeback scheme at the end of life, they could continuously re-use the material and spare parts. They could for example use the "all good things must come to an end" slogan with a picture of the watch run over by a train, and then have a freepost address embossed on the back of the watch for where to send it for remanufacture. The final aspects of toxicity to do with the inks used on the dial, which represent a tiny fraction by weight of the watch, could also be eliminated.

5.9. Desirable But Non-Essential Environmental Criteria

The astute reader will have noticed that there are a few classical environmental criteria that have not been mentioned, such as noise and smell. These have been deliberately excluded because they are not essential to sustainability. Nature is often noisy, smelly and ugly and it still does very well. There is also quite a lot of congestion, although traffic planners could probably learn a lot from watching anthills.

Despite this, noise can be toxic, for example bird nesting patterns near roads show that they are disrupted by high sound level. High noise levels are also bad for workers. Extreme levels of smell can also be overpowering. So any innovation that reduces noise, smell, or visual impact should be pursued, but as a secondary priority to cyclic | solar | safe.

6. Progress Assessment Tools

The goal of sustainable design is simple – to make all products 100% cyclic, solar and safe.

If you are a manufacturer, this means looking at each one of your product lines and making a long-term plan to bring them all up to speed. It you are a service organisation, it means looking at all the things you buy, and making a plan to change their specification and seek out products that are nearer to being 100% environmentally sustainable.

While 100% CSS is the goal, it makes sense to prioritise one' s improvement efforts, and the best way to do this is to see which or a firm' s activities or materials usage takes up the most Ecological Space. Ecological space is the amount of air, land, water and energy taken up by the entire lifecycle of a product. It is broadly proportional to the mass of materials used, and as some materials clearly have more of an environmental impact than others (a tonne of mercury requires more of your attention than a tonne of wood, for example), a scoring system is helpful. The "Rough and Ready Ranking System" is described below in the section *Buying Sustainable Products and Services*, on page [x].

As an example of prioritising impacts, the Union of Concerned Scientists (UCS) did a six-year study on the relative environmental impact of different consumer purchases. Their study found that seven consumer activities account for the vast majority of any one person' s impacts. These are:

- Cars and light trucks
- Meat and poultry
- Household appliances and lighting
- Home heating, hot water, and air conditioning
- Home construction
- Household water and sewage

So making even a small change in one of these areas can have a big impact, such as buying a car that gets 30 miles per gallon vs. 20. "Some consumer decisions, like whether to choose paper or plastic grocery bags, are insignificant," said Dr. Warren Leon, Deputy Director at the Union of Concerned Scientists and co-author of the study. However, if you a manufacturer of plastic bags, then in absolute terms many tonnes of plastic are used, and a more cyclic | solar | safe design is a priority.

UCS developed an economic model to analyse the impact of household spending on the most significant consumer-related environmental problems: air pollution, water pollution, alteration of natural habitats, and global warming. After grouping 134 consumer spending choices into 50 categories (like furnishings, clothing, computers), the authors discovered that cars and light trucks (including minivans and pickups) cause the most environmental damage overall, and are responsible

for nearly half of the toxic air pollution and more than one-quarter of the greenhouse gases traceable to household consumption. Food is second only to transportation as a source of consumer-related environmental problems. Red meat causes especially high amounts of environmental damage for the nutrition it delivers. According to the report, cutting the average household' s meat consumption (both red meat and poultry) in half would reduce food-related land use and common water pollution by 30 and 24 percent, respectively. "Replacing beef with grains and produce, or even chicken, can significantly improve the environment," said Brower.

The UCS report matches very closely a UK National Consumers Council study, which found that the biggest environmental gains to be made from altering current consumption and usage patterns could come from:

- reducing the fuel consumption of cars by over 60 per cent, from 7.7 litres/100 km to a reasonable average of close to 3 litres/100 km and a best of 1 litres/100 km;
- doubling the energy efficiency of the housing stock from a current stock average SAP rating of 34 to a SAP of over 70;
- reducing the energy consumption of domestic appliances with a particular focus on refrigeration, water heaters and electric ovens; and
- reducing water consumption in households through a comprehensive programme to detect and repair leaks, and through changes in installed equipment, particularly toilets.

The NCC report seems to have focused on direct use of energy and water, unlike the UCS study which took a more lifecycle approach. Hence the NCC' s omission of food and construction, whose impacts lie largely upstream.

6.1. The cyclic | solar | safe Scoring System

A product can be scored in two main ways – relative to a baseline product, or in absolute terms. The relative score is easier, and the hardest part is choosing a baseline product. Normally the market leading brand is the best choice for a baseline, but it could also be your the brand you but currently and are wishing to replace, or your existing product line if you are a manufacturer.

Simply use a table like this which shows the main lifecycle stages:

	Raw Materials	**Manufacture, including byproducts and emissions**	**Consumables in Use**	**End of Life**
Cyclicity				
Solarity				
Safety				
Efficiency				

Then compare each stage and give a "+" for better, "0" for same, "-" for worse, and ? for no data.

Auro Paint vs. Normal Paint	**Raw Materials**	**Manufacture, including byproducts and emissions**	**Consumables in Use**	**End of Life**	**TOTAL**
Cyclicity	**+**	**+**	**0**	**+**	
Solarity	**+**	**0**	**0**	**0**	**+**
Safety	**+**	**+**	**0**	**+**	
Efficiency	**-**	**-**	**0**	**0**	**2-**
					5+

If there are 4 or more "?"s then you need to get more data and the overall score is not valid. (although you could also assume pessimistically all the "?"s are "-" and see if that changes the score – if not, then your score is quite robust despite a lack of data.

You might want to try some of these – comparisons as an exercise:

Clockwork Radio vs. Ordinary battery radio
Electric Car vs. Gasoline Car
Ecoflush vs. Usual Cistern
Solar Watch vs. Battery Quartz Watch
Solar Watch vs. Kinetic Spring Drive (no battery/accumulator)
Hardwood windows vs PVC
Paper vs Plastic Bag
Biopol Credit Card vs. PVC

The absolute score is harder to do, but is more useful to see if we are getting near the goal of being 100 | 100 | 100 | 100.

EXAMPLE	**Raw Materials**	**Manufacture**	**Consumables in Use**	**End of Life**	**AVERAGE**
Cyclicity	**100**	**100**	**100**	**100**	**100**
Solarity	**0**	**0**	**0**	**0**	**0**
Safety	**50**	**50**	**50**	**50**	**50**
Efficiency	**10**	**10**	**0**	**20**	**10**
					40%

Overall, this hypothetical product has a score of 100 | 0 | 50 | 10. It is possible to give an Overall Sustainability Index, which in this case would be 40%, but this is a little opaque. It is more transparent to present the four number vital statistic score.

The scores are calculated as follows:

Cyclicity is:

(% materials from recycled source + % materials cycled at end of life) / 2

All organic materials are counted as being from a recycled source, as they are made with recycled Carbon, Hydrogen and Oxygen. Most scrap metal recovery and composted organics count as end of life cycling. Strictly speaking, downcycling does not count as being recycled at end of life, so most paper and plastics recycling would have to be counted as materials life extension, perhaps under efficiency below.

Solarity is:

% kWh of energy that is solar, wind, muscle, photosynthetic, geothermal, hydro, or wave power.

Not all forms of renewable energy are classed as "Solar" as they also have to be cyclic and safe. A large scale hydroelectric dam, for example, can have staggering consequences for the local ecosystem, and in some cases may silt up after only ten or twenty years. However, electrons sourced from dams that already exist can be scored as Solar as the damage they have caused is in the past – generating power now is not making the situation significantly worse. However, new large scale hydro should not be condoned.

Safety is:

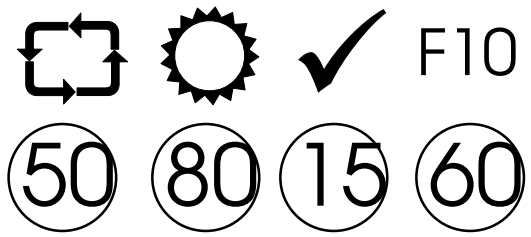
$$(\sum_{1}^{n} 100(1- (Today/1990)/n))$$

where "Today" and "1990" are "release mass per product unit" for each type of release, including X-chemicals (black and grey list) and NOx and SOx but not including CO2 and not counting water, but only the mass of materials dissolved or suspended in it.

Efficiency is the mean efficiency percentage for energy, water and materials usage. The efficiency percentage is based on 100% being a 90% reduction from 1990 levels. The calculation is:

Score = 111- (111(Present Level / 1990 Level))

Here is a worked example for the Frenko Washing Machine, which is marketed under the "Edy" and "Nordland" brands.



It is the only machine to hold the EU Ecolabel, but note that there are several other unlabelled brands that have the same or even slightly better performance, such as Miele, Asko, AEG and Hoover.

The EU Ecolabel sets performance criteria for washing quality, packaging, consumer information, energy and water. For example, the EU ecolabel requires the use of less than or equal to 0.23 kWh of electrical energy and 15 litres of water per kg of washload in a standard 60° C cotton cycle.

How does the Frenko score against the biothinking criteria?

CYCLIC = 50
The machine 85% recyclable and has about 15% recycled material content, so this gives a score of 50.

SOLAR = 80
No solar energy was used in manufacture, but about 80% of total lifecycle energy is consumed during operation. I have rather optimistically assumed that the machine is being used in Sweden or Iceland, and attached to "hot fill", so the water heating (80% of the energy used by a washing machine is for water heating) is geothermal or biomass district heating. The machine could also be being used in the UK by a householder hooked up to a green electricity tariff. Consequently, the machine gets a high score of 80.

SAFE = 15 (estimated)
Frenko have worked on reducing the toxicity of the metal finishes and have a stainless steel drum instead of a chromed one, saving the impact of chromium plating. Because the Safe score covers lifetime toxicity, the Frenko also gets credit for releasing less detergent when in use, as well as causing less releases emissions from energy generation (although most of this is solar, so we mustn' t double count). Getting an accurate score for safety requires more data than was available to the author at the time of writing, so an estimate is used here of about 15%.

EFFICIENT = 60

Efficiency is the mean efficiency percentage for energy, water and materials usage. The efficiency percentage is based on a score of 100% being a 90% reduction from 1990 levels – a Factor 10 improvement. The calculation is:

(Present Level / 1990 Level) / 1.1

Compared with a 1990 average machine, the Frenko uses 30 % less water, 30% less electricity and 30% less detergent, giving a score of about (0.7 / 1.1) = 0.64 or call it 60%. Because energy and materials (inc. water) usage during operation is about 90% of total lifetime materials use, I will exclude manufacturing efficiency for simplicity – remember that the "rucksack" of materials used in ore extraction would skew the figure downwards, something that could be fixed by using more recycled materials.

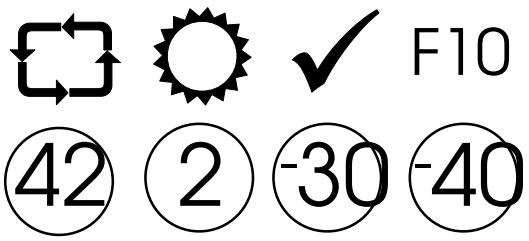
OVERALL

If you wanted to aggregate all four sustainability factors into a single score, you would get: (50+80+15+60)=205 out of a maximum of 400, or 51%.

To get to a completely sustainable 100% score, the manufacturers need to achieve the goals of:

* closed loop appliance recovery and remanufacture;
* recovery and zero toxicity of washing machine effluent;
* effective low temperature washing;
* zero toxicity in manufacture; and
* use of 100% renewable energy in manufacture and use.

What about scoring a whole country? Roughly speaking, the UK would get an overall score of 42|2|-30|-40:



This is based on 1998 figures from the 1999 Waste Strategy of 145 Mt a year waste arisings, of which 31% was recycled and 63% to landfill. This figure has been added to the organic cyclic flows to get a figure of 42%. Renewables are reported by the government to be 2%. The negative scores for Safe and Efficient indicate that more materials are being used and more toxins are being released than in 1990, based on OECD figures which show that chemicals production and general mass turnover are directly proportional to GNP, which has risen to be 40% above the 1990 figure. The figure for Safety is moderated slightly to account for improvements in chemical manufacturing techniques and stricter emissions legislation since 1990.

6.2. Making a Product Sustainability Plan

Once a product has been assessed, the direction for improvement is usually obvious. However, the challenge usually requires a two-pronged approach: an immediate, "low-hanging fruit" approach and a more Blue Sky strategic transition plan.

The experience of Genrikh Altshuller mentioned above proves that innovations usually lie within existing technology and almost always from within the industry that is being considered. However, the task can still be challenging. As the fundamentals of product development are well known and in widespread use, they are beyond the scope of this report – so suffice to say that the development of sustainable products is no different from any other type of product, and that the "8 Ps" apply:

Planning
Prototypes
Patents
Persistence
Production
Promotion
Patience
Payoff

7. Selling Sustainable Products and Services

7.1. Mainstream vs. Premium

The main challenge faced in meeting the goal of 100% sustainability is a marketing one. There are three main marketing strategies when it comes to communicating the environmental performance of a brand or company:

Confident Cool, where environmental performance is not mentioned at all. After all, it would only draw attention to the fact that environment hadn't been addressed in the past, or that other products under the same umbrella were inferior compared with the "greener ones". Brand value is the overriding message communicated. "It's a <famous brand name>, so of course they've sorted out the environmental stuff". This is already what most consumers (mistakenly) think, as the trust they have for the strongest brands means that they might find it hard to believe the companies are being irresponsible in any way. Brands heading this way are Mercedes Benz, Nike and Nokia.

Green Ghetto, where a product is promoted primarily as being "green", overriding any user performance or aesthetic or quality aspects. Often a premium is charged, even when actual costs do not require it. Such products will never be mainstream, even when a major manufacturer brings out a "green" sub-brand. It has to the main brand that becomes more sustainable as that is where both the impacts and the scope for improvement lie. Ghetto brands today include Ecover, Whole Earth, and Tom's.

Integrated Information, where environment is simply one of many aspects of product performance. It is communicated in the same way, as another feature. This is an appropriate approach for a mainstream product that is making improvements. The customers interested in environment will notice the difference, and the indifferent customers won't be put off. User performance and quality and desirability and price remain unchanged. Integrated brands include Volvo, Procter and Gamble, Kyocera, Citizen Watch and J Sainsbury.

7.2. Claims and Labels

Many products that have an improved environmental performance will use a form of claim on their packaging or promotional materials. It's always difficult to communicate a complex issue to a mainstream audience, but when you only a a few words or a square centimetre of packaging in which to do so, the challenge becomes formidable. Furthermore, the public at large have many misconceptions about environment – a UK survey found that 70% of people (incorrectly) think that paper comes from tropical rainforests. Do you pander to such misconceptions or

take the harder route of trying to explain the real facts, at the risk of being misunderstood or ignored?

One way around this problem is to use a widely accepted, third-party verified label. There are national ecolabelling schemes in many countries, including the EU, Germany, Scandinavia, Japan, France, USA, Canada, and South Africa. Some of these have been more successful than others, the main differences arising from the quality of the educational programmes supporting the public's recognition of the labels. Where strong marketing for the label has occurred, and is supported by retailers by means of good signage, as with the Nordic Swan label, then sales have been boosted by the label's presence. In other regions, such as the UK, a prevalence of official-looking "self-labels" dreamed up by the graphic designers of some of the main brands has led to consumer confusion about labels.

Labelling is worth a whole report to itself, so let's leave the topic with this last thought. The German Ecolabel, known as the Blue Angel has a long and impressive list of product categories, and a lot of thinking has gone into the criteria for each product. Simply as a good source of ideas, aspiring designers of sustainable products would do well to get hold of a free copy of the product requirements booklet, "20 Jahre Umweltzeichen" Edition May 1998, published by RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V. It can be ordered over the web at: www.blauer-engel.de

7.3. The Myth of the Green Consumer

The "green consumer" is a mythical beast that goes out and buys "green products". Forget the Green Consumer. Ecolabels are misunderstood by most consumers, and consumers are not going to put themselves out to save the world. Consider food safety – when you go and buy a tub of yoghurt, you don't have to look for a label that says, "safe to eat" – you expect them ALL to be safe to eat. I'm not saying that sustainability should be mandated or legislated – I just think that consumers expect brands they trust to have the environment stuff sorted out. So I'd say DON'T market your products or services on "being green" – it's not the way to gain mainstream acceptance.

In reality, these creatures are rather schizophrenic, buying inconsistently to their ideals, partly because of lack of time to research and partly because of lack of availability of what they want. And their demands are very unlikely to be heard. Retailing guru Sir Terence Conran said in a 1999 interview, "people only buy what they are offered" – so products aren't on shelves because "consumers demand it".

The National Consumer Council's 1997 report *Consumers and the Environment* found that around a third of the British population do make a conscious effort to buy products which are less harmful to the environment when they are shopping. But they end up actually buying very few of these products because they are ill-informed, and because they have difficulty in identifying products which are less harmful to the environment. Also, they are suspicious (and rightly so) about the claims made about many of them.

8. Buying Sustainable Products and Services

Most environmental purchasing programmes concentrate on assessing the management preformance of existing suppliers rather than focusing on product performance. As the whole point of better buying is to locate and purchase better products, this section will not examine such techniques as supplier audits or questionnaires. Instead, it outlines a practical and staightforward system for indentifying the most important product areas on a lifecycle basis.

By analysing the products and services it buys and changing which ones it buys accordingly, any organisation can make a significant difference to its upstream and downstream environmental impacts. Taking it a step further, an environmental sustainability plan can be mapped out.

The first step is data collection, finding out how many tonnes of each type of material flows through the organisation. Then comes an assessment process that ranks these materials flows by the amount of ecological space they take up, showing which ones are the most important. From this an 80:20 plan can be drawn up. This takes the top 20 products that cause 80% of the impacts, and then makes a plan for them to be 80% sustainable by the year 2020, with a view to being 100% sustainable by 2100.

8.1. Data Collection

Getting a picture of a business unit' s environmental impacts is simply a matter of sitting down with a small team and thinking through the materials and items used in a typical year. You can literally draw a picture of materials flows showing the "ins" and "outs".

It is important to include the materials usage of suppliers and contractors. Include everything that you can think of at this stage – if some things turn out to be genuinely insignificant, we can and will exclude them later on, but it is vital to get a complete picture at this stage.

Don't worry too much about the raw materials used by manufacturers – the "upstream" impacts of products and materials, such as the coal and iron ore used to make steel for example, are already included in the data provided below.

Finding good data in any organisation requires persistence. There is usually quite good data on resource use and spend amounts. However, as is typical in service organisations, resources are not managed as closely as they are in the industrial sector, which routinely tracks raw materials usage by quantity, often in real time. Consequently, some data has to be based on estimates that have been derived from financial information. This limits the accuracy and integrity of an assessment, but as long as figures are checked in at least two different ways and use alternative sources of information, the quality of results can be adequate.

In general, getting Materials Data is like doing a Financial Audit and finding that there are no invoices or orders or ledgers! So perseverance is required.

It is also acceptable to take averages per head – for example, every year a typical UK office worker:
- makes 200 kg of waste
- gets through 20 pens
- uses 8000 sheets of A4 paper
- commutes 8 miles each way
- uses 12,000 litres of water

Data sources include:
- Information from Contract Managers and suppliers
- Account Code reports
- Business Plans
- Consultant' s Reports
- Meter Readings
- Educated Guesstimates and model making based on the opinions and experience of managers involved in the activity
- Estimates based on typical expected average consumption per head

For a service organisation, most impacts arise from consumption. In particular, new products purchased carry with them an environmental burden arising from the manufacture of those products – the "upstream" impacts in the flow of materials from "cradle to grave". In many cases, several tonnes of raw materials and much energy is needed by industry to produce one tonne of usable product.

Assessing lifecycle impacts makes use of the fact that the mass of material used is proportional to the environmental impacts arising during its manufacture, use and disposal. For example:
- during extraction of raw materials
- energy used in processing and manufacturing
- waste arising during manufacture
- fuel used in distribution
- packaging needed

8.2. Prioritising Materials and Products

Thus the amount of each material used by a site or Business Unit can be measured, and the amounts adjusted to reflect the different impacts of each type of material – a tonne of steel has more overall environmental impact than a tonne of wood, for example.

The data can then be normalised, based on the impacts of the manufacture of one tonne of steel, to give Tonnes Steel Equivalent, or TSE. Steel is used because its impacts are well known, and the idea that it takes a lot of coal, iron ore and emissions to make a tonne of steel is readily understandable to most people. Here are some examples:

Material	Amount in tonnes	Tonnes of Steel Equivalent (TSE)
Steel	1	1
Wood	1	0.22
Paper	1	1.12
Diesel	1	0.57

Normalising in this way gives an absolute figure for each material flow, allowing comparison with other materials, and the addition of impacts. Working with the full list of TSE Conversion factors can be complex and time consuming, so a simplified form is often used. It is the simpler version that is included in this report as the "Rough and Ready Ranking System".

This system gives either 1, 5, 15, or 50 Bio-Points per tonne for the various materials types:

LOW = 1	Aggregate Asphalt Brick (1t=500 bricks) Cardboard Ceramics Concrete Glass Paper (European-made recycled and Cl-free paper (1t=400reams)) Wood
MEDIUM = 5	Carpet (1t=290m2) Cars (1t=approx. 1 car) Cement Clothes Diesel (1t=1200 litres) Electrical equipment Electricity (1t equiv=5000 kWh) Food (1t=2200 meals) Furniture Gas (1t equiv=16000kWh) Leather Paper from beyond Europe (eg Canada Indonesia or Brazil) Plastics (except PC and PS) Rubber Steel Tyres

HIGH = 15	Aluminium Light bulbs and fluorescent tubes Paint PCs (1t=44 PCs) Polycarbonate Polystyrene Stainless steel
VERY HIGH = 50	Batteries Brass Chromed steel Chromium Copper Gold Nickel Zinc

To calculate the relative environmental importance of the different materials flows in your process, simply multiply the mass in tonnes by 1, 5, 15, or 50 as appropriate. From these figures you can rank the materials flows and then prioritise design efforts.

8.3. Sample Calculations

Use the information provided and the table on the last page to calculate the BioPoints for each of these materials flows that might be used by a small team of 10 people in housing:

Electricity and Gas
From looking at last year' s bills, the team find that the office, which is handily on a separate meter, used 15,000 kWh of Electricity and 30,000 kWh of Gas.

Total BioPoints = ...

Paper
For office use, the team used 160 reams of A4 paper, and during the year, two leaflets were sent out to 23,000 homes, delivered by hand with no envelope. Each leaflet was an A3 sheet folded in two.

Total BioPoints = ...

Computers
The budget approval has finally been given this year to get new PCs for everyone – 10 new PCs.

Total BioPoints = ...

Painting and Decorating
The team' s various projects included painting work which came to a total of £4m. Of this, the team reckons about a tenth of that was spent on materials. To get better detail on this, they have asked one of their contractors to estimate how much paint they used. The team are also trying to work out how many m2 of wall was painted, although this is hard to do and may not be much more accurate than going by spend amounts. On average, paint is about £4 per litre.

Total BioPoints = ...

8.4. Developing an 80:20 Sustainable Product Purchasing Plan

Usually the top 80% of impacts arise from about 10 to 20 product or materials types. For a service organisation, these will typically include the old chestnuts like fuel and paper, but the list will often surprise as well.

Once the priority products have been identified, set up a team for each product area, and have them do a thorough cyclic | solar | safe score on each one. Once a product has been assessed, the direction for improvement is usually obvious. As with 80:20 sustainability for manufacturing, the challenge can require two approaches: an immediate, "low-hanging fruit" approach and a more Blue Sky strategic transition plan.

The product teams can get thinking both short and long term about what product specification would meet the cyclic | solar | safe goals. It could be that a short term target of 30% or 50% cyclic | solar | safe can be set, depending on the product types.

Once the direction is clear, the solutions will present themselves – and so will the barriers! Changing which products are bought or the purchase specifications themselves is a balancing act between price, performance and user perceptions. With care and dedication, these factors can be navigated through, but most of all there needs to be commitment from the top.

The beauty of an 80:20 Product Plan is that it is clear and simple, so that senior executives can understand it and it can be communicated clearly and incorporated into the organisation' s overall business strategy.

9. Training Approaches

The core element of any sustainable product training is the cyclic | solar | safe basics and plenty of product examples.

The cyclic | solar | safe basics can be got across in a text document or by means of exercises or explorations in small groups. Then about 50 product examples can be displayed, quite quickly, with some narration, to give an overview of the breadth of solutions available. After that, groups can be given products on which to practice analysis, with a view to them developing the skill of assessing products or potential design innovations very quickly.

Here is a typical structure for an **SPD Workshop**:

SESSION ONE:

0.00 Welcome and Mandate from Senior Management Representative
0.05 Company' s Progress to date Roundup by Environment Manager
0.15 ... hand over to Edwin or Course Leader
0.15 Workshop Goals and Schedule
0.20 Environment Quiz
0.35 Introduction to SPD talk, including Cyclic, Solar, Safe and Efficient (CSSE)
0.55 Materials ranking exercise in groups of 5
1.15 Product Examples Slide Show
1.40 CSSE Exercise – Existing greener product compared with mainstream brand in groups of 5
2.00 SPD Toolkit Introduction
2.10 BREAK
2.30 CSSE Exercise – Improving an Existing Product using SPD Toolkit in groups
3.05 Solutions Brainstorm in Groups
3.15 Compiling and Ranking Ideas from "blue sky" to "do it tomorrow"
3.40 Assigning ideas for further development and research to teams
3.50 "Golden nugget" summary (each participant' s most useful thing learnt)
4.00 Finish

6 WEEK INTERVAL

Teams research feasibility and desirability of the ideas assigned to them, working at their own schedule but using hours formally assigned by their managers.

About 7 manhours per idea.

SESSION TWO:

(About 2hours max.)

Feedback from each group on research and progress on their assigned ideas

Edwin and Environment Manager's views on quality and accuracy of environmental aspects

Group gives feedback of technical / practical / financial / marketing aspects

More refined CSSE examples and slides as necessary to develop skills and understanding

Voting process to eliminate unworkable ideas (it is inevitable and desirable that some ideas will turn out to be not worth progressing – all part of the evolutionary process)

Most promising "immediate" ideas become Projects

Most promising "blue sky ideas" get put forward to Board for Strategic Assessment

Good sources of **product examples** are:

- Edwin's website - www.greenerbydesign.com
- Several links from there, including the Global Futures Foundation (www.globalff.org) and the O2 Global Network (www.o2.org)
- Edwin's free email which examines a product each week *The BioThinker*
- Magazines that feature new technologies
- Design awards
- Consumer-focused environmental magazines

Books that are recommended background reading include:

- *Industrial Ecology and Global Change* by R. Socolow (Ed.) Cambridge University Press, ISBN 0-521-57783-7
- *Charging Ahead: The Business of Renewable Energy and What it Means for America* by John J Berger, California University Press ISBN 0-520-21614-8
- *Chemicals in the European Environment: Low Doses, High Stakes?* European Environment Agency, GE.98-03845-Septembre 1998-10,000 UNEP/ROE/97/16
- *Factor Four* by Ernst von Weizsacker and Amory Lovins, Earthscan, London
- *Natural Capitalism* by Amory Lovins, Hunter Lovins and Paul Hawken, Little & Brown, 1999
- *The Circle of Innovation* by Tom Peters, Hodder & Stoughton ISBN 0 340 71720 3
- *Breakthroughs* or *Upsizing*, both by Gunter Pauli, ISBN: 1 900 820 005
- *Design for the Real World* by Victor Papanek

Sustainable Product Lunches are learning lunches where a team of people get together every week to discuss a product. One member of the team selects a product and prepares in advance by getting hold of a sample or a photo and some data, and they run the session. The group analyse the product following the cyclic | solar | safe | efficient framework, with perhaps a few other criteria thrown in, like "effectiveness", "value for money", "likely success in the marketplace", "aesthetics", and so on. The following week another member of the team will present and lead the discussion. Rather than trying to give an absolute score, it is often easier to choose a baseline product to compare a new product with. The market leader is usually a good choice. The human brain is very good at spotting differences, so it is much quicker and easier to say a product is "more cyclic" or

"less safe" than another, as opposed to giving an absolute score of "[x]% cyclic", which would require more research.

It is also possible to "**sloganise**" cyclic | solar | safe into a more populist format, something along the lines of:

> *"If it' s grown on a farm it goes back to a farm"*
> *"Only mine from above the ground and recycle all inorganic waste"*
> *"Use no nuclear power, fossil fuels or big new hydroelectric dams"*
> *"Only emit food and keep plenty of land for wild things"*
> *"Do thrice as much using a third of the stuff"*

10. Conclusion

cyclic | solar | safe is the best tool for understanding products and how they can become more environmentally sustainable. It is fast and easy to use, whether you are designing a product or considering buying it.

Becoming 100% sustainable is not only possible, it can be achieved by the year 2100. By moving away from the "how can we be less bad?" mentality to the "how can we be 100% good?" mindset, we give ourselves the capability of redesigning every product to be 100% cyclic, solar and safe.

11. About the Author and BioThinking International

Edwin Datschefski is Founder of BioThinking International, a nonprofit organisation that aims to train a million people in sustainable product design.

In the past 5 years, Edwin has trained over 5000 people and acted as a consultant to some of the world' s leading organisations, including Blue Circle Cement, BP Exploration, BT, British Airways, The Environment Agency, IBM, Interface, J Sainsbury and Westminster City Council.

He spent 8 years as a Senior Manager at The Environment Council, and is a member of the BSI committee that wrote BS7750. Edwin has given talks all over the UK, as well as in France, USA, Japan, Sweden, Denmark, Luxembourg, Malta, Belgium, Italy and The Netherlands. He is a founder member of the Professional Speakers Association.

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