FUTURIZON

Sustaining the Earth

A Futurizon Report

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Author: Ian Pearson BSc DSc(hc) CITP FBCS FWAAS FRSA FIN FWIF

Author contact details: idpearson@gmail.com

INTRODUCTION– SUSTAINABILITY VIA INTELLIGENCE

As world population grows and the BRIC regions develop, we are increasingly aware that the world's natural resources are finite and that humans can have a very significant impact on many aspects of the environment. Care is needed to avoid the environment being severely damaged. But if we do it right, and I think we can, then we could all live prosperous fulfilled lives and still keep the Earth healthy. Sustainability is a fashionable term right now, and people define it differently, but to me it simply means that we must ensure that we and our descendants can live without jeopardising the ability of future generations also to live. Some people argue that our lives today are highly unsustainable, and I read a lot of prophecies of doom, but I don't think they are sound. Optimism is justified by the changes I see ahead, though there are problems to fix and complacency will get us nowhere. Sustainability doesn't necessarily require that each generation hands the world over to the next totally unharmed (though that is a nice goal), but it does mean that we should at the very least be confident that future generations will still be able to lead decent lives in the world we leave them. If we do well, they will be able to lead even better lives, and I think we all want that.

The developed world has a healthier environment now than in the middle of the industrial revolution. I was taught in school how Dublin's river once caught fire because it was so polluted. Analysis of my local river was my first ever environmental project and I found it greatly polluted, but several years later, it had been cleaned up and fish were reintroduced. It is now a major leisure resource that provides happiness for many people and a thriving ecosystem. This shows that future generations can sometimes undo damage done by earlier ones, and that is important to factor in when looking at sustainability. So is the recognition that we have only reached the cleaner technology of today by going through the earlier, dirtier stages of the industrial revolution. Without that, we couldn't possibly have sustainability with today's population let alone tomorrow's.

We must go through early stages of development to get to more advanced ones and sometimes those stages can create some damage. Some of it might be completely repairable; some might remain as lasting scars but still not threaten sustainability. Achieving the best overall solution may still incur permanent penalties.

As an engineer keen to apply science and engineering to help the environment, I have often been frustrated by the dominance of emotion over rational thinking in some environmental circles and what is sometimes a quite destructive contempt for science. I was once told strongly by one of leaders of the green movement that 'the last thing we need is more science'. That is a very damaging attitude indeed that is as likely to harm the environment more than to help it. There is abundant evidence that because of this attitude, the 'green movement' has resulted in a great deal of environmental damage already in spite of achieving some good results. Randomly creating good or bad outcomes, it isn't even certain that it has been beneficial overall. How can we possibly protect something if we can't make informed decisions on what needs to be done to help? Emotions certainly have a place in making people want to look after the Earth, but science is the only way we can determine what will actually work. Wanting to do something is of no use in telling you what to do.

Thirty years of engineering has taught me that newer technologies usually deliver healthier environmental impact in the long term, even if some early stages of development can be messy. It is quite rare for a more advanced technology to be more environmentally damaging than its predecessors. Technology doesn't always get better but it usually does.

But technology isn't the only issue. We also need to look at the design of human social and political systems, infrastructure and service provision and many aspects of cultures - even religions, all of which can have big effects on the environment too. I can't address all these areas here, and there are many excellent works by other people covering such issues. My personal expertise is in technology, so I will focus mainly on that in this report, but I'll also look at a few other areas from a systems engineering angle as I feel appropriate.

THE KEYS TO SUSTAINABILITY

There are a few key principles to keep in mind when looking at sustainability. Most are uncontroversial. A few run contrary to conventional environmental opinion, but I think they stand nonetheless.

1 Resources are finite, but new technology or better design can often deliver similar function with less resource use. Reduce, re-use, recycle remains a useful principle. More advanced technology can help the environment. Holding technology development back prevents this gain and may damage the environment.

2 Greater wealth makes it easier to protect the environment as well as creating extra demands on resources.

A key factor in looking after the environment is that increasing wealth can help too. Wealth does not inherently cause environmental damage. Quality of life depends in part on quality of environment, and people are prepared to pay for a better environment if they can afford to, both individually and collectively. Price is a factor that often causes people and governments to use less environmentally solutions. Reducing costs and increasing wealth both reduce this as a barrier.

3 If we want a world where everyone can have a good lifestyle, we need to accept and even encourage rapid obsolescence, driving the technology quickly towards low environmental impact.

Although wealthier people still want a nice environment, they tend to consume more, so the technology development rate needs to keep up with spending power and lifestyle expectations, or environmental impact overall increases. But the evidence is good that it can and does. A modern smartphone using 150g of resources easily replaces 600kg of 1990 IT, with a corresponding drop in energy demand. Someone poor who is forced to make their old kit last longer inevitably makes a worse impact than they may wish. Some environmentalists have worked hard to fight rapid obsolescence, but actually it is a very important contributor towards sustainability. We really want that 150g of resource use rather than 600kg. If technology is allowed to progress, even that 150g will fall much further.

4 We need to consider the whole system and whole life cycle, not just bits of it.

The environment doesn't stand separate from humanity. Some processes are governed mainly by the laws of nature, but some are affected strongly by human activity too. To achieve long term sustainability, we need to look at the entire system for the whole lifecycle, not just bits of it or one part of the production cycle, both natural and human impacts, with all the complex interactions and feedbacks. This is impossibly difficult and no existing Earth model comes anywhere near modelling the whole system, but a good starting point is not to worry about precision in one area if a much larger factor is being ignored. System-wide thinking is where much environmental dogma fails because it tends to be superficial and simplistic and based on primal emotional urges rather than deep thinking. As an example, the Stern Review a few years back looked at great length at some areas, but took far too little account of long term technology change, and in spite of being produced by an economist, missed what should have been obvious human responses to recommendations. It recommended biofuels and carbon trading, but ignored the obvious fact that this would incentives people to drain bogs and burn forests to build palm oil plantations and divert land from production of food to biofuels, both of which resulted enormous human and natural damage. Human responses to stimuli must be factored in much better when working out environmental policy.

Natural feedbacks need to be accounted far better too. We still don't understand a lot of environmental factors even reasonably well. In climate modelling, some factors such as the interaction of cosmic rays in cloud formation, (mediated by solar activity), were denied by many researchers so left out of models, and even now arguments are raging over the likely mechanisms and magnitudes. CERN's study also proved that assumed atmospheric chemistry is incorrect. Similar lack of understanding is found in most environmental areas. The environment is just too complex, the science is too young and the data too sparse or too open to interpretation. In particular, it is very easy to confuse correlation with causality. If important factors are left out of models or modelled wrongly, their predictive value will be poor. We need better understanding to make the right decisions. And that brings us nicely to the next principle.

5 Short term harm may be an acceptable price to pay for a longer term benefit

This is essentially just another side of principle 4. Just like investing money makes a short term hit on your bank account but hopefully pays off nicely later, environmental care can work the same way. We should not worry unduly about short term damage, but should focus on the longer term balance. Digging a mine is unsightly but may yield minerals that increase wealth and enable investment in a better environment. It doesn't matter how complex the route is either. The environment is pretty resilient and has a lot of built in buffers, so can cope happily with a large amount of short term damage. Sustainability doesn't need us to avoid harm, just to make sure it doesn't become too large to prevent later recovery.

6 Panic isn't a good strategy

Sustainability is a long term issue, but the greatest alarm at the moment is probably in the debate around human impacts on climate change. Everyone agrees that the climate is changing, it always has. As to whether and to what extent we are in danger because of human impacts, there isn't a single sentence I could write here that someone wouldn't passionately disagree with. Opinion is highly polarised. But to offer as little controversy as is probably possible, the evidence does seem that we have more time than was thought to deal with any problems we may be causing, and that means more time to develop new technology and lifestyles to fix it or adapt to it. Amusingly, with Durban, yet another 'last chance to save the world' has passed with appointments made for the next one.

However, with poor agreement on climate science, (even though some claim it is all settled) we are like a guy standing on the edge of a cliff, wearing a blindfold. Lots of people are screaming at us, telling us to do something because we are in grave danger. But if we move before we can see the direction of the drop, we are as likely to die as to survive. By far the best course of action is to remove the blindfold before we do anything else. Better science is essential. Much good science has already been done, but it is badly polluted by much that has been conspicuously corrupted. The field needs tidied up, weeded out and repaired.

Proof enough of the potential for doing more harm than good is that some climate scientists a few decades ago were panicking about us going into a new ice age, and advocating spraying carbon onto the poles to absorb more sunlight. Today, they would mostly argue the opposite. Actually, at the moment, it could go either way. We may be seeing a new Maunder minimum and decades of cooling, or we may just have seen 13 years of stalled global warming suddenly catching up with us. I wouldn't want to gamble the future of life on earth on the flip of a coin, just to be able to say I did something.

7 Science is the best system for development of useful knowledge

The environment tends to bring out the emotional side in people. None of us wants to see environmental damage. To some people, that does make them want to do something, but as I just wrote, panic isn't a good strategy. Unfortunately, it also tends to be a religion substitute for some people, pressing the same reward buttons in the brain and creating notional moral high ground that can be occupied by opposing views at the same time, just as different religions insist they have the right god. That biases judgement and can result in bad decisions. Where it infiltrates science or policy making, the religious or superstitious side of environmentalism is highly dangerous, and by holding back the pursuit of the scientific truth, it can delay deployment of the best solutions, and hence damage to the environment too. Unfortunately, the laws of nature don't depend on whether you believe them or not. They will still behave the same regardless of your intention or faith. There really is no substitute for good, uncorrupted science. Sadly in environmental science it is often hard to tell which is which and that is definitely bad for the environment and achieving sustainability.

8 Not all resources are equal

If you take any particular element, there is more or less the same amount on the planet as there was before humans arrived. A small amount of natural leakage and accumulations from space has occurred since and a tiny amount has been dispatched into space as spacecraft or rocket fuel. What humans have changed is the availability of various chemical combinations they were available in, and the distribution. That is really either a matter of energy to recreate them, or more often, finding substitutes via technology development. If we start to really run out of something, then we can mine rubbish tips or even asteroids to make up the difference. I am not especially concerned about the quantity of such resources, though we need to consider the environmental damage that might be done extracting them versus recycling or substituting them. Sustainability doesn't really depend on us protecting physical resources. We are simply not likely to make any real impact on levels in any timeframe where they can't be replaced. On the other hand, we shouldn't waste stuff either, and should try to do more with less.

A much larger concern is the organic environment. Some day we will master genetic technology and be able to design and recreate organisms (we're making progress on DNA banks for familiar and human-significant organisms), but even then, recreating a rain forest would be a big job. It is far better that we protect the ecosystem from destruction in the first place. We also don't know what resources there are for new medicines or materials that haven't been discovered yet, and very many species don't feature in the DNA banks yet because they haven't even been discovered. Over-fishing of the seas and destruction of land habitats are probably the biggest concerns, leading to severe depletion or even extinctions or some species. We should put more effort into protecting the ecosystem, not just because it is emotionally more important than minerals, but pragmatically because it is much harder to replace.

9 Recognise the importance of cultural sustainability too

Human happiness is important and should not be neglected when we look at sustainability. We should therefore properly weigh up the consequences of environmental policy against human impact. A healthy environment is an important factor in human happiness, but protecting the environment should not always win when it competes with human interests. Other factors may sometimes be more important.

10 We should be optimistic for our grandchildren

Taking all these principle together, we need better science, and with that we can understand the whole system better and make better solutions. In parallel, that same scientific progress will lead to better technology across the board, making more efficient use of resources, greater wealth and better treatment of the rest of the environment. It is possible to live in a much nicer and healthier world, with much better lifestyles, for all.

There are plenty of doom-mongers who advocate an impoverished future, full of regulation and punitive taxes on consumption, because they see sustainability in terms of humans simply doing less, consuming less, living less well. I don't share their prophecies of doom, nor their solutions even if they were right. Environmental doom-mongers are usually wrong, and I don't see any evidence that the current batch is any better. There are certainly some biggish environmental problems that do need to be dealt with, but nothing we can't handle with willingness to act and appropriate use of science and technology. Emotions should drive us, values should be given appropriate weightings, and then rationality should tell us how to achieve what we want in the best way.

I would prefer a high tech, high prosperity, high happiness and restored environment solution instead any day. It is perfectly possible as long as we can just stop the loonies taking over the asylum.

So rather than doom, I predict that once the world economy is back on track, we will race towards a prosperous future for both our descendants and nature.

POPULATION GROWTH

World population is growing rapidly, and will continue till it levels off around 9.5 billion by about 2050, after which it will start to fall. (9.5 billion is a lot of people, but let's not treat it as if it will be a major catastrophe. Some doom-mongers are already predicting mass starvation, riots and so on, but the numbers need put in perspective. I live in the South of England. I can easily go on a walk and meet few people on the way; mostly it will be empty countryside and most of the time we won't be able to see a single building or road. I do not feel it is terribly overpopulated here yet, even with the second highest population density on Earth, at 470 people per square kilometre. Other countries with massive populations are actually less densely populated. India only has 345 people per square kilometre, even with its massive population. China has even less at only 140, while Indonesia has 117, Brazil just 22, and Russia a mere 7.4 people per square kilometre. Yet these are the world's biggest populations today. So there is plenty of room for expansion perhaps. If all the inhabitable land in the world were to be occupied at average English density, the world can actually hold 75Bn people. There would still be loads of open countryside, still only 1 or 2% covered in concrete and tarmac. So let's stop first of all from imagining that we are running out of space any time soon. We just aren't! We panic in the UK because we see the extreme inequality of distribution of people, but that will self limit. If it becomes too dense, people will stop immigrating.

Secondly, westerners' (i.e. relatively wealthy people's) houses typically provide 5 or 6m deep of living space. They live on top of 6000km deep of materials, a million times more, and much denser. So do their neighbours. Not all of it is useful, but it is really hard to see why there is so much panic about physical resources when they lie so deep under our feet. When we discard them, they are still there, just repositioned. If you buy stuff, your house quickly fills up and you have to throw something out to make space before you buy more. It gets recycled or thrown on landfill, which may become a future mine if materials ever did become scarce enough. A

few spacecraft have left the earth forever over the years, but space dust occasionally lands too, so actually there are more physical resources on Earth than there were before people came into being. Asteroid mining will also come into use in a few decades, bringing us any essential materials that are in short supply. Organic resources such as forests and fisheries are a different matter, but they can be managed and farmed sustainably.

But of course, all other things remaining the same, if everyone wants to live to westerns standards, the demands on the environment will grow as the poor become richer and able to afford more. If we try to carry on with existing technology, or worse, with yesterday's, we will not find it easy. Those environmental activists who preach that technology and economic growth are enemies of the environment, and who therefore want to lock us into today's or yesterday's technology, would condemn not only billions of people to poverty and misery but also force those extra people to destroy the environment to try to survive. Poverty is one of the greatest causes of environmental destruction. The result would be miserable future for humanity and a wrecked environment. Those people are the true enemies of the earth, and of humanity. Thankfully, most environmentalists are not so extreme. If we ignore such lunacy as we should, and allow progress to continue, we will see steady global economic growth that will result in a higher average income per capita in 2050 with 9.5Bn people than we have today with only 7Bn. The technology meanwhile will develop so much that the same standard of living can be achieved with far less environmental impact. Before modern engineering, structures had to use far more resources than today's, but now we can make materials with known and consistent strength, and can model the forces precisely, so we need far less material to do the same job. With nanotechnology and improved materials, we will need even less in future. The environmental footprint of each person will be far lower in the far future if we encourage technology development than it would be if we restrict growth and technology development. It will almost certainly be less even than today's, even though our future lifestyles would be far better.

Take TVs as an example. TVs used to be hugely heavy and bulky glass monsters that took up half the living room, used lots of electricity, but offered relatively small displays to show a few channels. Today, thin LCD/LED displays use far less material, consume much less power, take up far less space and offer bigger and better displays offering access to thousands of channels via satellites and web links. So as far as TV-based entertainment goes, we have a higher standard of living with lower environmental impact. The same is true for our phones, computers, networks, cars, fridges, washing machines, and most other tools. Better materials enable lower use. New science and technology has enabled new kinds of materials that can substitute for scarce physical resources. Copper was once in danger of running out imminently. Now you can build a national fibre telecommunication network with a few bucketfuls of sand and some plastic. And we have plastic pipes and water tanks too, so we don’t really need copper for plumbing either. Aluminium makes reasonable cables, and future materials will make even better cables, still with no copper use. There are few things that can’t be done with alternative materials, especially as quantum materials can be designed to echo the behaviour of many chemicals.

Oil will be much the same story. To believe the doom-mongers, our use of oil will continue to grow exponentially until one day there is none left and then we will all be in big trouble, or dead, breathing in 20% CO2 by then of course. Again, this will prove nonsense. By 2030, oil will be considered a messy and expensive way of getting energy, and most will be left in the ground. The 6Gjoules of energy a barrel of oil contains could be made for $30 using solar panels in the deserts, and electricity is clean. This solar energy can be generated in deserts, where it is actually sunny, where land is cheap, because it isn't much use for anything else. The energy will get to us via superconducting cables. Sure, the technology doesn't yet exist, but it will. Oil will only cost $30 a barrel because no-one will want to pay more than that for what will be seen as an inferior means of energy production.

By 2050, fusion power should be up and running, alongside efficient solar power, thorium-based nuclear, shale gas power generation, and various other forms of energy production, proving a huge energy glut that will help with water supply and food production as well as our other energy needs. Our technologies will be so advanced by then that we will be able to control climate better too. We will have environmental models based on science, so we will know what we're doing rather than acting on guesswork and old-wives' tales. We will have excellent understanding of genetics and biotech and be able to make far superior crops and animals, so will be able to make foods to feed everyone. While today's crops deliver about 2% of the solar energy landing on their fields to us as food, we will be able to make foods in labs far more efficiently, and will have crops that are also far more efficient. In the long term, there is absolutely no need to worry about feeding everyone. And no need to worry about the impact on the environment either, because we can make more food with far less space. No-one needs to be hungry, and with steady economic growth, everyone can afford food too. This is no fanciful techno-utopia. It is entirely deliverable and even expectable.

And how can we be sure it will be developed? Well, for one thing, there will be more people. That means more brains. Those people will be richer; they will be better educated; many will be scientists and engineers; many will have been born in countries that value engineers and scientists greatly, and will have lot of backing, so will get results. And some will be in IT, and will have developed

computer intelligence to add to the human effort, and provided better, cheaper and fast tools for scientists and engineers in every field to use. The total intellectual resources available to solve problems will be far greater than they are today. So we can be absolutely certain that technological progress will continue to accelerate. And as it does, the environment will become cleaner, healthier, because we will choose to make it so. We will restore nature. Rivers today in the UK are cleaner than 100 years ago. The air is cleaner too. We look after nature better, because that's what people do when they are affluent and well educated. In the far future, when far more people are wealthy, we will see that care being even more widespread. The rainforests will be flourishing, species will be being resurrected from extinction via DNA banks. People will be well fed. Water supply will be adequate. But it can only happen if we stop following the advice of doom mongers who want to take us backwards.

And that is really key: more people means more brain power, more solutions, better technology. And for the last million years, that has meant steady improvement of our lot. In the un-technological world of the cavemen hunter-gatherers, the world was capable of supporting maybe 60 million people. If we try to restrict technology development now, it will be a death sentence for humanity and nature. People and the environment would both suffer. No-one wins if we stop progress. That is the fallacy of environmental dogma shouted at us by doom mongers. They would go back to yesterday, rejecting technology, living on nature and punishing everyone who disagrees with them. They can indulge such stupidity when there are only a few of them, and the rest of us make their lifestyles possible, but we can't all live like that. Again, without technology, the world can only support 60 million. Not 6 billion or 7 billion or 75 billion. There simply aren't enough nice fields and forests for us all to live that way. It is a simple choice. We could have 60 million miserable post-environmentalists living in a post eco-catastrophe world where nature has been devastated by the results of stupid environmental policies invented by environmentalists with contempt for science. Or we can stop the nonsense, get on with our ongoing development, and live in a richer, nicer world where 9.5Bn people (or even far more if we want) can be happy, well fed, well educated, with a good standard of living, living side by side with a flourishing environment, where our main impacts on the environment are positive. Technology won't solve every problem, and will even create some, but without a shadow of a doubt, technology is by far nature's best friend. And ours. Not the 'environmentalists', many of whom are actually among the environment's worst enemies, at best well meaning fools.

And there is one final point hat is always overlooked in this debate. Every new person that is born is another life, living, breathing, loving, hopefully having fun, enjoying life and being happy. Life is a good thing, to be celebrated, not extinguished or prevented from coming into existence just because someone else has no imagination. Thanks to the positive feedbacks in the development loops, 50% more people means probably 100% more total joy and happiness. Population growth is good, we just have to be more creative, but that's what we do all the time. Now let's get on with making it work.

ENVIRONMENTAL POLICY

We don't have to wait for new technology to make a start. Some things can be changed now. For example, local authority, corporate and government environmental policies can have a rage impact on sustainability but are often poorly thought through, taking too simplistic an approach and ignoring secondary impacts of superficially promising ideas. There are many areas where policy could usefully be considered on a more system-wide, full life-cycle basis. A few to start with:

Rubbish taxation is sometimes advocated to reduce waste production, but it may result in increased water demand and increased pollution through use of water to wash cans, and flushing of organic waste instead of putting it in bins. Also, flushing waste at the point of creation reduces the potential for central biomass power if the waste were instead collected. It additionally increases resource use by stimulating the market for waste disposal units. The use of more hot water and dishwashers compounds the problem still further. Even though it obviously makes it easier for recycling depots to push work onto the household, people should not be asked not to wash out containers before collection. Centralised washing is better because it creates less pollution, uses less resource and better enables use of the organic waste for power generation or composting.

Encouraging home composting can increase methane levels, especially since most people are far from expert at composting. Centralised composting may be better, since methane can be tapped and used.

Privately owned bus companies may generate more CO_2 than publicly owned services, because the need to generate profits leads to practices such as using meandering routes to fill the buses. Increased journey length obviously needs more fuel, even though it is shared among more passengers. Worse, it deters many people from using them by increasing journey time and so increases uses of private cars. More complex models should be used when designing routes to factor in environmental damage.

Taxis generate more CO_2 per passenger journey than private cars (a taxi often has to make the trip in one direction empty) so classification as public transport should be reconsidered and their use should be discouraged. However, the maths will change substantially when the taxis are replaced by self driving pods in a decade or two.

Bicycles not using cycle lanes can cause many other vehicles to brake and accelerate, thereby increasing overall system wide CO_2 production and energy use, and having secondary impacts via time wastage, wear and tear etc. Although beneficial when used sensibly, bikes should be discouraged from using busy roads at peak times except on cycle paths. Of course, if linear induction mats are used, this would be less of a problem (see below).

Use of biodegradable plastics has some merit but can prevent recycling by contaminating plastic recycling batches.

It also may prevent carbon sequestration via carbon reefs, see below.

Use of biofuels is of highly dubious merit. Though new techniques are constantly being developed to use bio-waste, these need to be modelled properly against the use of that waste in power generation, composting or ploughing back into the ground to maintain soil structure, carbon sequestration and other secondary impacts on the ecosystem. Soil structure and chemistry in particular is an area that needs more attention in climate models and obviously in overall ecosystem maintenance. It is far from fully understood.

The production and erosion of topsoil, which is a very significant climate change factor, is strongly affected by a range of other decisions, such as the use of biomass for power production. Greater coordination and much more system-wide, full lifecycle thinking is required.

Use of agricultural land to grow biofuels is certainly counter-productive, via a range of mechanisms. It causes great harm to both people and the environment.

Carbon trading is too much associated with fraud and other crimes and creates perverse incentives for environmental destruction. Although it is agreed that CO2 contributes to warming, other natural factors seem much stronger, (there is some evidence that we may even be heading into a few decades of cooling), and it is certainly by no means agreed that CO2 production is a grave danger that requires solutions with such heavy socio-economic impacts across the board. At the very least, the whole global carbon trading system needs a major rethink and overhaul.

So much for local and national policy. At a global level, some environmental policy could use some tweaking too. The whole global environment is intricately interconnected, and the environmental doctrine of ‘think globally and act locally’ applies well, but we still need to do some global thinking too.

Land Use

The Earth provides a diverse range of climates and terrains. Some land is particularly suited to growing crops, rearing animals, human habitation, or extraction of minerals. Some offers little except sunshine, but even that has uses. Some is beautiful and needs preserved in its own right. A sustainable world will need people to organise things that affect land use globally as well as locally. It is easy for countries to have too much inward focus when looking at environmental use. It is hard for most people to understand land being left idle because of local market gluts when other parts of the world are short of food, forcing them to destroy their local environment to provide food for their families, which eventually feeds back into global environmental changes. Economic excuses might be valid today, but that really only suggests that the economy needs to be fixed – people should not be starving when there is plenty of room to grow food to feed them. More coordination is needed. It makes little sense to use arable land to grow bio-fuel for example. It should be used for food production. There are plenty of alternative fuel supplies today and in the future, energy can be produced using solar energy in deserts. If we use deserts to make energy for machines, we can use arable land to make energy for humans and animals. A small proportion of land everywhere needs to be sacrificed for housing and industry. This could be optimised better too, but the benefits would actually be quite small, since only 2% of land area is covered in buildings or roads even in densely populated countries such as the UK. As for getting minerals, we just have to put up with where nature has placed them.

TECHNOLOGY DEVELOPMENT

Linear Induction Bike Lanes

Electronic bicycle lanes could also be constructed to incentivise cycling. A linear induction motor, laid into or on the cycle lane surface could pull cyclists along if they wanted assistance. Mechanical energy is very cheap, whereas the effort required to cycle long

distances or up hills is a strong deterrent to many potential cyclists – they are not all super fit! This linear induction drive would only require a small modification to the bicycle (a simple metal plate affixed to the front forks would probably do), and could easily be switched on and off, could offer variable speeds for individual cyclists. Bikes would be pulled along by the magnetic field. It is quite easy to engineer in various safety precautions to prevent misuse and also to enable charging to make commercial ones viable. With no moving parts, and therefore nothing to clog up, it could be extremely reliable. Tracks could be laid either into the surface, or made as rolls that could be quickly laid out on hills to give extra assistance where it is needed. Of course other technologies such as RFID chips could enable highly personalized control (and payment) systems. Apart from encouraging more bicycle use, it could also be used to increase bicycle speed, which both improves journey time for the cyclist, and reduces the congestion bicycles can cause in other traffic. Making it easier to use bikes, and enabling people to use them to commute without needing a shower as soon as they arrive, would yield system wide benefits through extra bicycle use and increased fitness and because speeds would be higher, they wouldn't slow down other transport as much or cause so many accidents.

Self-driven Pods

New transport solutions based on electronically driven cars and electronic highways could be developed quickly. The basic technologies are all proven now. Cars in the far future will simply drive themselves. These could dramatically improve personal mobility and social inclusivity, and greatly reduce congestion. People would most likely abandon car ownership if this is done well. If personal driving style is eliminated by electronic overrides, there is far less incentive to personally own a car, and at the same time it will become much easier to implement and manage large fleets of shared cars. Fleets give economy of scale and also far better economy of resource. A car would not spend most of its life idle, but could be in use most of the time. A modest number of cars could cater for a large population, especially since the exact locations of all the cars is known, as well as the destinations and likely arrival times of cars in transit. There are already several instances of car rental systems that allow people to just pick up and drop cars as they wish. This will become much more attractive an option with future technology.

So we may well see large fleets of shared cars, owned by companies, government or social groups. With cars linked electronically into a 'road train' for acceleration and braking, they could drive closer together, increasing road occupancy, reducing drag and making road travel more energy efficient. With computers driving the cars, they could be much closer together sideways as well as lengthwise, squeezing more lanes onto the same road area, so it may be possible to increase the number of cars on a stretch of road. Given smaller pods instead of large cars, narrower lanes and closer distancing, it should easily be possible to achieve a factor of 5 in the number on a stretch and since they could all be moving well, overall capacity would improve even more. It also makes it more feasible to run roads with lane direction determined by time of day, with some lanes carrying cars one way in the morning rush, and the other way in the afternoon.

Obviously, lorries need more road space but this can easily be accounted and flow still optimised by a computer driven system. Lorries are already being developed that can work in road trains to save drag and driver fatigue.

Such an electronically controlled system could have a mixture of public and private (large fleet company) ownership. The key feature is that it will have all the flexibility of private transport but be more socially inclusive than current public transport, since older people wouldn't have to walk to a distant bus stop. All they would do is ask their computer to get them a car.

Car batteries are an obvious storage solution for intermittent energy supplies such as wind or solar energy. However, if direct power pickup from road surfaces is implements, and it is likely, then batteries would not need to be very high capacity, since they would only need relatively short local reach. Using smaller batteries would greatly reduce the need for lithium and other materials, making cars cheaper, lighter and safer.

Buses would be a big spoiler for such a system. Since they have to stop frequently to let people on and off, it would be far better to replace them with individual pods. Each person would get personal service door to door and the reduced size makes it far easier for computers to organise flow around them as they stop. In fact, they may even be small enough to simply use pavement. Few people would miss slow and dirty buses or the risk of having a drunk sit next to you, when faced with the option for comfortable end to end service at probably lower cost.

A public transport system like this would require far less resource than today's, because far fewer vehicles would be needed, and they would be lighter so need less raw material, and drag would be much lower, so they would use less energy. It would also be safer, cheaper and more socially inclusive by far than what we have today.

Rail use - pod trains

There is really no reason why these self-driven pods or road train technology could not be implemented on the railways too. Rail occupancy can be as low as 0.4% on regional railways. Performance analysis shows that packet switched networks can be safely loaded to 80% occupancy before statistics cause significant performance degradation. So there is clearly a huge opportunity for improving the capacity of railways, perhaps 100-fold, if packet switching based solutions were to be implemented instead of the current system, which allocates a very long stretch of track exclusively to each train because of the safety limits required by the obsolete signalling and control technologies that current railways use. Suppose that electronically driven cars and buses could be taken onto the railways, and interleaved with vans and small rail carriages that spend all their time on railways. For example, cars could be made with dual wheels, as some buses are today. Once on rail, no steering is needed and with the vehicles talking electronically to each other to coordinate braking and acceleration, the driver could do other things while the car drives itself to the destination station, whereupon it would leave the track and use its other wheels to get to its final destination. The cars could be driven very closely, and of course the drag and friction costs would be very low. Furthermore, since most of the journey could be on rail with electric energy easily provided, the car could use an electric motor. Instead of using petrol or diesel, or even fuel cells, it could make very long journeys just on batteries, since the batteries could be recharged during the rail journey. Since railways are simple one-dimensional systems, this would be far less demanding in terms of control systems than the equivalent on the roads. So whereas electronic highways will take some more years to become feasible, rail based systems could be implemented much more quickly, given the will.

Nuclear energy - Thorium

Many environmentalists are in favour of nuclear power compared to a few years ago. Nuclear power has always been a scary option to many people because of the waste disposal problem, and the potential use of some kinds of nuclear power stations to generate material for bombs. Nevertheless, if it does turn out that CO2 emissions are a problem, then it offers an obvious way of reducing them while providing much more stable power than that available from wind, wave or solar.

Today's nuclear stations mainly use uranium, a few use plutonium, but tomorrow we will probably have many that use thorium, a relatively common element that is cheaper and more readily available than uranium, and produces much less dangerous by products as it decays. The Chinese are currently trying to develop thorium reactors and are likely to succeed. If so, this will provide a great deal of help in achieving a sustainable world that still has enough energy for us all to lead comfortable lives.

In the longer term, fusion based energy is inevitable too, but no-one knows when this is really likely to become reality. The very far future has a glut of potential energy supplies, so it is only the short and medium terms that are threatened with shortages. Long term sustainability is not a problem as far as energy goes.

Nuclear waste disposal

Uranium comes from mines. It is extracted, concentrated, used until it isn't radioactive enough any more and then we lock it in secure dumps until we figure out what to do with it. One option seems obvious when you remember that it came from a mine originally. If the nuclear waste it replaces were to be extremely diluted by mixing with the refuse from the uranium mine, (or indeed with any other rubbish if it is being used for landfill), then it could all be dumped back in the hole it originally came from, and that would result is a slightly less radioactive mine than the original.

A longer term option lies in the space elevator. Nuclear waste could be flung into the sun, which of course is just a nuclear reactor anyway. It could be an expensive solution compared to burying it or using it up in a thorium reactor, but who knows?

Wind energy

If there is one perfect example of the triumph of green dogma over scientific sense, it would be wind farms. Wind farms can harness superficially free energy but are an eyesore, cause noise and stress, disrupt breeding cycles and kill birds, and may even sap enough of the wind to disturb natural weather patterns. They are ludicrously expensive to build, with little scope for cost reduction requiring heavy subsidies. Because wind doesn't always blow, they still need other power generation capacity to be provided alongside, and this also needs to be subsidised if the generator companies can't sell their power all the time. Overall, wind farms as they currently stand are anything but green and should really be a last resort.

There are a few developments that will make wind energy slightly less awful though. One is the use of different kinds of turbines according to the deployment circumstances. Vertical axis turbines may be better in turbulent environments such as housing areas, whereas conventional fans cannot harvest efficiently when the wind direction changes frequently.

Super-capacitors made of novel materials such as graphene offer the prospect of being able to store energy more easily, solving one of the big problems with intermittent energy use.

Plastic capacitor sails

Also on the capacitor side, plastic capacitors change their capacitance as they deform. Wind energy harvesters can be made using large sails covered in millions of tiny plastic capacitors that spin in the wind, deforming and springing back every time they make a rotation. The sails would lie on the surface of the sea, and only become visible when the wind fills the sail. There would be no visible movement from any distance away because of the small size of the capacitors, so this would doubly help visual disturbance. Since the energy would be converted more directly into electricity, there would be no need for a large central generator, no need for heavy engineering. The costs of plastic capacitors today make sail solutions even more expensive than conventional turbines, but materials science often follows Moore's law cost reductions, whereas mechanical systems don't. This means that in a few years it may be cheaper to use sails, and the cost benefits would continue to improve thereafter.

Whether such advances will ever make wind energy a good solution is uncertain, but it could be less bad.

Solar farms

Solar farms in equatorial regions are likely to spread, contributing enormously to energy supply, but affecting wealth distribution and already associated with crime and forced people movement. Short term costs are very high but inevitably will fall. They also increase absorption of sun's energy relative to bare ground. So solar farms would produce a great deal of energy and could be cheap as Moore's law brings down the costs and increases efficiency of photovoltaics, but it isn't the clean solution sometimes imagined.

Graphene

Graphene is the new wonder material. Like carbon nanotubes, it is just another form of carbon, the atoms just laid out differently. Having said that, it is far stronger and lighter than steel, is a superb conductor, it can be used as a substrate for electronic circuits, and it is made of carbon, an extremely common element. Its importance in sustainability will come from many angles. To list just a few, it will enable substitution for other materials that are in short supply, expensive or dangerous or resource-consuming to make. It will allow super-capacitors that can replace batteries and store power from intermittent energy supplies. It will make ultrafast computers, better sensors, and many other things we haven't even imagined yet. Engineers are very excited about its potential and it is impossible to know just how much impact it will eventually have, but it is likely to be huge. As a key pillar in future sustainability, graphene is certainly in there.

AI (artificial intelligence)

If we could produce intelligence synthetically, and therefore provide extra thinking capability to solve problems, this could have a profound effect on technology development rate, in every field. Since it is likely that this will be achieved in the next few decades, AI is a very important sustainability tool, with its enormous potential to invent solutions, increase understanding of the environment, and accelerate research development, but it is rarely mentioned in environment debates. Clearly, smart machines might be used to design smarter machines, which will design smarter ones still, leading exponentially quickly to vastly superhuman intelligence that may well solve many of the problems for us, with new energy technology, and new environmental clean-up and management technology.

We should not rely on AI to save us, but we may reasonably expect that it will, even if some man-made solutions fail. It gives us hope, but not enough certainty to avoid us using other approaches in parallel.

Active contact lens

My own invention in 1991, the active contact lens is a tiny display device that is worn as a contact lens, and contains circuits to project images directly onto the retina. It has already been prototyped in primitive form but in the far future it will offer ultra-high resolution fully immersive 3d images, and will make all other display devices unnecessary (though we may still have some anyway). Any kind of other display could be mimicked as a portion of the active contact lens display area. It is possible therefore to save all the resources and pollution involved in all the others. Given the number of TVs, mobiles, PCs, tablets and so on that could be replaced, the active contact lens can be a significant contributor directly to sustainable resource use.

In addition to replacing other displays, it can also be used for new services such as augmented reality. This allows even a basic environment to be enhanced virtually, and if the display quality is sufficient, it would be indistinguishable from the real thing.

Digital Jewellery

A person wearing a few grammes of digital jewellery in the 2020s will have far more IT capability than someone today with a laptop, phone, PDA, MP3 player, digital camera, GPS navigation system, security alarm, identity card, electronic cash cards, credit cards, voice recorder, video camera, memory sticks, radio, portable TV, a book, magazine, games console and many other gadgets that haven't even been invented yet. Furthermore, by 2020, billions more people will be able to afford these sorts of things. These can also be the basis for a distributed cloud platform, requiring far less server farm provision and requiring far less power than today's server farms. It is important that we get greater miniaturisation and lower energy use if everyone in the world is to have access to all the benefits of IT sustainably. Digital jewellery will be key.

Biomimetics

Biomimetics is simply using nature as stimulation in engineering design. Three billion years of natural evolution has come up with some great ideas, still being discovered. Engineers draw inspiration from these. Sometimes natural techniques and designs can be mimicked almost exactly, sometimes a bit of human tweaking is a good idea, but nature-inspired design is often lighter, stronger, faster, or better in some other way than alternatives. Biomimetics is another great sustainability tool. There are some purists in the field who like to stay true to nature, but as far as sustainability goes, it is great to get ideas wherever they come from, and nature is a big source. Even if the end product looks nothing like nature, its initial inspiration can be important.

Biomimetic architecture has been around quite a while, enabling low power air conditioning systems for example, or skyscrapers that can be lighter weight, or use lower drag materials to reduce wind pressure. There are very many opportunities here.

Synthetic Biology

Synthetic biology can be seen as a major derivative or biomimetics. Engineers and scientists have been discovering how nature works at microcellular and even molecular levels, and are now copying and using even genetic tools. At first, the major headlines are in modifying DNA slightly or assembling genomes from off-the-shelf chemicals to create synthetic bacteria, but it will undoubtedly progress to designing whole new classes of proteins, genes, and different types of synthetic organisms. It will also allow us to modify and enhance existing ones. Proteins are nature's machines, and by understanding how to design and build them for our own purposes, this will be a rich seam for future development.

However, it is not without risk. Messing with nature will allow us to fix a lot of environmental problems. But as it becomes better and eventually commoditised, it is also a tool that lends itself well to the military, terrorists and mad scientists. I would say synthetic biology is in the top three tools when it comes to achieving sustainability, but I'd also put it in the top three risk to life on earth. If we can harness its potential while protecting against its threats, we will have a much better world for sure, but that is no easy task.

Bacterial mining

One example already under way is bacterial mining, designing bacteria to break transform a fixed resource (coal in this case) into a gaseous one (methane) so that it can be extracted more easily. Methane also produces less CO2 than coal for a given amount of energy. This clearly would help sustainability, as would many other custom bacteria. Other roles may be mining rubbish tips to recover useful elements from them, extracting resources without digging big holes and ruining ecosystems; processing waste; fixing carbon; making algae fuels; changing the earth's albedo and many others. Again, the dangers are possible harmful but unexpected interactions with the environment (and it certainly wouldn't be the first time we have had unexpected reactions), or commoditised advanced uses being perverted for destruction.

Restoration of the environment to health via genetic technology, desert greening programs, weather control technology and so on, are all highly likely to be developed over the next several decades. Synthetic biology could also yield tools to rescue life on earth after environmental catastrophe, by eventually enabling wholesale redesigning of the ecosystem from the ground up.

Carbon Reefs

Most UK householders are already encouraged to separate plastic waste for recycling, and when it reaches the recycling centres, it is usually compressed into blocks for easier handling, which sadly is often done in China. If these blocks were instead to be dumped in the sea and suitably contained, just off the Norfolk coast for example, transport and processing would produce far less CO_2, carbon would be locked up, coastal erosion would be reduced, land would be reclaimed, and landfill would fill up more slowly. The plastic would effectively become a plastic reef and later, reclaimed land. This approach would be carbon negative, while recycling is at best

carbon neutral. One of the obstacles to this solution is the move towards biodegradable plastic, which of course returns carbon to the atmosphere, and ironically, was developed to help the environment. Another is EU law which prohibits dumping plastic in the sea. Another obstacle is environmental groups who argue that we shouldn't try to resist erosion because it will then happen elsewhere, but that is a rather defeatist attitude. Put some of the blocks there too.

The much levied criticism of conventional plastics, that they will stay around in the environment for thousands of years, actually makes them ideal for a carbon sink. Bio-degradable plastic, and current laws that prevent plastics from being dumped in the sea could turn out to be environmentally damaging, by preventing such solutions.

Some other waste could be mixed in too. For example, glass is borderline recyclable, yielding a environmental benefit when recycling it rather than producing it from scratch, but since this full-life benefit is actually quite small, perhaps it could also be included with the plastic, giving extra density to the waste.

Even organic waste could be processed by heating with reduced oxygen so that it carbonises, giving off natural gas in the process that could be used as fuel. The carbon could be added to the plastic reef to help absorb toxins from the seawater, cleaning it up a bit too.

Fabric Technology

New fabrics that don't need to be washed are making their way onto markets already. It is the norm for clothes to be washed of course, and not everyone will be happy wearing clothes without ever washing them, but gradually acceptance is likely to grow. Washing machines that require far less water and detergent, and wash at lower temperatures are of course already here, and we will see their penetration increase too. All of these are useful tools in the battle for sustainability.

One of the first fabrics to be released is treated cotton. This is quite ironic, since cotton production is extremely water intensive and polluting. But it is still a start.

We can expect more and better synthetic fabrics in the future of course as well as treatments for natural fibres. Some of these will reduce environmental footprints by keeping us warm and dry and clean while reducing consumption of raw materials, water and energy use. Genetic engineering is likely to improve natural fibres too or make them easier to produce without so much water.

Carbon sequestration

Solutions for carbon sequestration can be developed quickly if we need them. As yet, we don't really know if we do and this could be money wasted.

Farming

Organic farming generally produces less food per hectare of land, which decreases global food production capacity, which increases prices and makes it harder for poor people to survive, forcing them to have more children, which creates a greater population, greater need for aid and so on. It is a Western luxury that is paid for elsewhere.

Organic farming products are often delivered by a different distribution system, which has different impacts and these also need to be accounted. Additionally, marketing for organic produce tends to reinforce other aspects of lifestyle and attitudes that affect the system in many more subtle ways. For example, as well as consuming 'organic' food, the same people are likely to prefer natural fibres instead of synthetic substitutes. This increases demand for cotton. Cotton is becoming a hot environmental topic in itself, producing pollution and water stress among many other socioeconomic problems. Again, the transport, CO_2, energy demand and social impact is very different across the whole system and whole lifecycle from synthetic clothing.

Planes and alternatives

Cheap air travel is a strong focal point for environmental hostility, but it is generally better to solve the actual problem than just tackling a few of the symptoms. The real issue isn't travel, it is the environmental impact of the travel. Future technology can even provide alternatives to planes if need be. And ultimately, there is no law of physics that says that travel has to use any energy. The whole planet travels 1.5 million miles every day without using any energy at all!

The airline industry is currently researching the potential for both battery powered and hydrogen powered planes. If the hydrogen is produced in an environmentally friendly way, then that would certainly be one solution that would keep air travel going without

creating major environmental problems. More interestingly, taking futurology back 100 years, we find ideas that may just have been ahead of their time. At the turn of the 20th century, futurologists were suggesting long tubes through which people could be propelled in vehicles by compressed air. That idea is now making a comeback, with long tubes that use vacuums and magnetic propulsion instead of compressed air. De-pressurising the tubes reduces air resistance. Superconductivity will make these far better than is possible today. We do not yet posses the tunnelling technology to make such solutions viable on a widespread basis, but they may become viable for high speed city links in the not too far future. For overseas journeys, large plastic tubes might even work, suspended not too far below the surface. Again, once an object is moving, in the absence of friction, it will continue doing so with no power consumption. This could be a very low energy transport solution one day, or perhaps it will be still a curiosity in another 100 years.

Yet another novelty is the idea of using super-cavitation to allow supersonic submarines. It has apparently been demonstrated that high speed travel through water can be done with less resistance than through air. This effect has already been used for torpedo technology.

Virtual existence

Estimates of future population generally only include humans, but we won't be the only intelligent beings on the planet much longer. Advances in AI promise to make sentient AIs in a decade or two and by the end of this century there will be millions or even billions of them, with a wide range of intelligence levels and characteristics. They will not only exist to serve people. Some will have a purposeful existence of their own, just as we do. They will have their own culture, and we will interwork with them. AI's are potentially very diverse in nature, just as organic life is. We shouldn't assume that they will all sit in rooms looking like computers, or even walk around as robots. Some will, some won't. Some AIs will stay in the same place. But that 'place' could be the entire global network and any associated computer. They may roam electronically. They may also consume resources just like we do, for entertainment, research, building, arts, even growing gardens. We should not preclude AIs necessarily from sharing at least some human interests, as well as many we don't have. But we can reasonable assume that many or even most AIs are produced to serve human interests. They may help a great deal with science and technology development, so may be extremely valuable in the fight to achieve sustainability. But there are some other lines of thought worth listing before moving on.

Science fiction generally presents robots as having their 'brain' on board. With cloud working today, this already looks dated. It is highly likely that robots will have a mixture of on-board and remote capability for processing, sensing, storage and communication. Some robots will essentially be empty husks waiting for occupation by any AI that is capable of occupying them. Or human mind for that matter, once our technology is up to the job. Direct links to the brain are extremely embryonic today, but by 2050, remotely occupying a robot and feeling senses as if you were present in it should be feasible, and if not by then, certainly not long after. This is an important factor for sustainability. It opens the possibility that people could carry on in machine form after their biological bodies die, or even have multiple parallel existences in different forms. It also allows an alternative for of travel, where you simply hire a robot at the destination and use remote presence to be there. There is little point in detail here since these technologies are too far away and will happen in a very different world from ours. It is enough just to mention them and move on, as I will now.

DANGERS FROM TECHNOLOGY PROGRESS

I am very enthusiastic about technology and its potential not just to make our lives better, but also to protect and even restore the environment. However, although I disagree strongly with doom-mongers most of the time, I am far from a utopianist and am quite capable of seeing potential horrors ahead too. The key word is potential. I don't think they will likely happen, because I hope we will find ways of avoiding them. However, there were only a few ways that life on earth could be extinguished a century ago, and now there are quite a few. Nature gives us plagues, super-volcanoes, asteroid and comet strikes, supernovas and even solar events in the list of possible extinction-level events. To this we added nuclear oblivion in the 1940s. Not long after, research into bio-weapons came up with viruses and bacteria that could wipe out almost all of humanity as well as hydrogen bombs. Now, we can add a much wider range of nuclear, chemical and biological weapons or mass destruction, particle accelerator accidents, asteroid steering, and can already see potential accidents or weapons arising from solar wind deflection, zombie viruses, genetic modification accidents, nanobot infestations, grey goo scenarios and many more. If you plot a timeline of all these on a graph, it makes quite a neat exponential curve, with the number of ways we could kill everyone rising to about 100 by 2050 and carrying on rising exponentially even after that. Assessing the probability of such things actually happening is difficult, but starting with a familiar one, most of us think a global nuclear war is unlikely in any particular year, but also worry that it may happen one day. If we are in optimistic mood, we might estimate the probability of a nuclear war as 1 in 10,000 in any particular year. When trouble rises in North Korea, Pakistan, or Iran, we might be less optimistic. There are also plenty of mad scientists and terrorist groups as well as malicious governments,

mad dictators and religious extremists who want to make an impression on history, not to mention that any of the events might also happen entirely by accident. Additionally, technology has a habit of becoming commoditised over time, so that more people get access to it. Imagine a far future where every depressed student effectively has access to a big red button labelled as 'destroy the world'! Taking the 1 in 10,000 chance as an averagely optimistic probability for any of the scenarios (remember), the 100 mechanisms in 2050 would give a one percent chance of an extinction level events happening that year. The one percent would rise every year thereafter. It is therefore easy to estimate that the expectation date for extinction is around 2085 based on this argument and these estimates of probability.

There is little point in worrying about other longer term sustainability issues if we are going to wipe ourselves out along with most of the rest of life on the planet. Therefore, finding ways to prevent technology-enabled disasters is very key to sustainability. In this direction, The Lifeboat Foundation started up some years ago and many benign and fine minds work to finding potential solutions to all the disaster scenarios. This work should be considered absolutely essential but sadly is poorly funded, even compared to far more trivial environmental issues. We can't prevent nutters and nasty people from existing, but we can certainly find ways of limiting the damage they can cause.

QUALITY OF LIFE SUSTAINABILITY

Some people have a very luxurious lifestyle, others live in total poverty and misery. I don't think it is possible for everyone to be happy, but we should be able to make it possible for everyone to have a good chance of happiness and certainly we should be able to make enough food and clothes, shelter and clean water available to everyone. Sustainability of quality of life is important too. We should try hard to achieve environmental sustainability without damaging people's ability to live happily.

Scientific surveys occasionally highlight the things that contribute to happiness, and these can be aggregated to a fairly short list: Peace, health, family and friends, social and political inclusion, a nice environment, justice, education, wealth and respect for human rights. Although these are listed in no particular order wealth is actually a fairly poor indicator of happiness, so making quality of life sustainable does not mean everyone has to be wealthy.

CLOSING COMMENTS

Sadly, both dogma and poor thinking are all too commonplace in environmental debate and this one the biggest barriers to protecting the environment, especially when it is coupled with sanctimony and a contempt for science and technology. By enforcing misguided policies, society is prevented from adopting solutions that could actually protect the environment. With the right incentives and leadership, the science and engineering community could produce far better solutions. Technology can and should bale us out of our sustainability problem. Science and technology can offer real solutions that will work without reducing quality of life. This is surely a far better prospect than attempting to solve the problem by constraining people's lifestyles. We need to achieve sustainability by applying intelligence.

ABOUT THE AUTHOR

Ian Pearson is a full time futurologist, tracking and predicting developments across a wide range of technology, business, society, politics and the environment. He is a Maths and Physics graduate and has worked in numerous branches of engineering, from aeronautics to cybernetics, sustainable transport to electronic cosmetics. His inventions include text messaging and the active contact lens. He was BT's full-time futurologist from 1991 to 2007 and now works for Futurizon, a small futures institute. He writes, lectures and consults globally on all aspects of the technology-driven future. He has written several books and made over 450 TV and radio appearances. He is a Chartered Fellow of the British Computer Society, the World Academy of Art and Science, the Royal Society of Arts, the Institute of Nanotechnology, and the World Innovation Foundation. He holds a Doctor of Science degree from the University of Westminster and an Award for Excellence from the US Army.