FUTURIZON

Carbon

Achieving CO_2 reductions in the UK by using technology instead of muddled thinking

A Futurizon Report

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EXECUTIVE SUMMARY – SUSTAINABILITY VIA INTELLIGENCE

After four decades of warnings by scientists, climate change is at last getting a lot of attention globally. It certainly is a problem that needs to be addressed before it is too late. However, panic is rarely an effective response and it is frustrating to see how much suggested remedial action is based on out-of-date technology or poor thinking. Firstly, one of the main problems is the lack of clear, system wide, full lifecycle thinking in the environment space. This report highlights some of the very significant policy errors that result. Secondly, with rapid technological development, it is better to look at the problem from scratch and see what can be done using the mechanisms and technologies available to us now and in the future instead of looking to yesterday for solutions. By considering this future technology potential, this report challenges much of the current thinking and highlights the potential of technology to solve climate change in the long term. Although some of the content of this report applies specifically to the UK, much of it applies globally. Consequently, provided that reasonably sensible policies are deployed in the short term to prevent runaway effects from taking hold, climate change will be reduced to a short and medium term problem, entirely soluble in the longer term. Realisation of this certainly justifies action but certainly not panic.

Most importantly, the report aims to show that an environmentally healthy future does not have to be based on going back to yesterday. The key to sustainability is not to prevent people from doing what they want to do, but to use intelligence to develop more environmentally friendly solutions. i.e. sustainability via intelligence.

PROBLEMS

Problems identified include

Local authority, corporate and government environmental policies are often poorly thought through.

In particular, eco-towns, over-emphasis on public transport, use of biofuels, and carbon trading are of dubious merit.

Interactions between many social and cultural factors with the environment and environmental behaviour are highly complex and often ignored, leading to inaccuracies in climate predictions.

Being seen to be doing something is often more important to people and companies than helping the environment.

There is far too much use of decades-old environmental polices that are now out of date and counter-productive.

Use of agricultural land to grow biofuels is counter-productive. Carbon taxes may well also prove to be counterproductive.

Use of biodegradable plastics will prevent carbon sequestration via carbon reefs.

Encouraging home composting will increase methane levels.

Rubbish taxation will increase water demand and increase pollution through use of water to wash cans, and flushing of organic waste, also reducing the potential for biomass power, while increasing resource use even further by stimulating rapid expansion of the market for waste disposal units. Use of hot water and dishwashers compounds the problem still further. People should be asked not to wash out containers before collection.

Privately owned bus companies will on average generate more CO_2 than publicly owned services, because the need to generate profits generates practices such as using indirect routes to fill the buses, that deter people from using them and increase journey length.

Taxis generate far more CO_2 per passenger journey than private cars so should no longer be classified as public transport and their use should be discouraged.

Bicycles not using cycle lanes can cause many other vehicles to brake and accelerate, thereby increasing overall system wide CO_2 production. Although beneficial when used sensibly, they should be discouraged from using busy roads at peak times.

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

Consumption of bottled water should be discouraged.

SOLUTIONS

Rapid technology obsolescence is an essential tool in reducing environmental footprint.

Solutions for carbon sequestration, nuclear waste disposal, and restoration of the environment to health are all highly likely to be developed over the next several decades, ensuring that climate change is only a short and medium term problem, but not a long term one.

Solar farms in equatorial regions are likely, contributing enormously to energy supply, but affecting wealth distribution.

New transport solutions based on electronically driven cars and electronic highways could be developed quickly which could dramatically improve CO_2 production, personal mobility and social inclusivity, while reducing congestion.

AI will be a very strong contributor to dealing with climate change. AI will dramatically accelerate scientific and technological progress across the board and expedite solutions.

Technology such as linear induction motors could be applied well to cycle lanes to provide extra power to cyclists on hills or to increase average speed and reduce travel times, with system wide carbon benefits through extra bicycle use and increased fitness and reduced adverse carbon effects on other transport.

RECOMMENDATIONS

It is recommended that a more thorough analysis of full system wide impacts and interactions is undertaken before environmental policies are established.

Climate change and other environmental policies should consider complex socio-economic impacts and their complex higher order interactions. There is a need for better public research on environmental issues so that proper scientifically based advice can be made available to government, business, individuals and society.

In particular, impacts on corporate efficiency, output and the support of staff for other environmental programmes should be considered better when deciding on corporate policies. Depending on how well these policies are prepared, a local saving of CO2 production could easily come at the expense of a much greater global, full system production.

It is important that companies use scientifically based recommendations as the basis of their policies rather than inputs from green groups that may have a disregard for science or politically motivated agendas. Caution is also needed to prevent environmental management roles being hijacked to indulge and leverage personal views.

CAUSES OF WATER VAPOUR AT ALL LEVELS OF THE ATMOSPHERE SHOULD BE CONSIDERED MORE, AS SHOULD THE IMPACTS OF SOIL MANAGEMENT AND OTHER FARMING PRACTICES,

WHICH ARE DEEPLY INTERWOVEN WITH OTHER ENVIRONMENTAL POLICIES.

INTRODUCTION

Until a few years ago, there was still significant scientific scepticism about the reality of climate change. Today, it is generally accepted as fact and as a serious problem by the scientific community, with only one or two doubters.

The recent Stern Review suggests that we may only have a decade left to start taking serious action to avoid massive costs later. Having left it too late to commission properly funded research to gather all the appropriate facts, we are inevitably acting blind to some degree, and government is likely to recommend drastic solutions. We still don't have all the information yet on how the environment works, and climate models often produce wildly differing predictions of the magnitude and nature of the problem. Complicating the problem even more, we also don't have reliable models of global society and the global economy, nor their interactions with the environment. We need good models of how the environment works and how it interacts with human society before we can make the right decisions on how to act. We need more and better science. Acting without fully understanding system dynamics inevitably involves risk, but the level of risk can be reduced by increasing knowledge, and ensuring that solution design is unimpeded by dogma and poor thinking.

An interesting analogy to our current position is a blindfolded man standing on the edge of a cliff. Concerned passers by might yell at him to move because he is in serious danger and needs to take action, but unless he takes the time to remove the blindfold to do basic research on which direction to move, he is as likely to fall off as to move to safe ground. Unfortunately, although the current advice from environmental pressure groups is based on a very commendable desire to do something, it is not always scientifically informed, and consequently is in some cases as likely to be harmful as beneficial. Some greens actually see science as part of the problem, but without science, how can we know what to do? Science is the only reliable way we have of figuring out how things work and predicting the impact of an action.

Of course, the UK holds only 1% of the world's population and the big global impacts are elsewhere, but each region must do what it can to reduce its own emissions, and if possible, to export better solutions. In any case, much of the content of this report would apply to other regions too.

DOGMA IN THE WAY

Some conventional environmental thinking is little more than dogma, ideas and beliefs held almost religiously in spite of contrary scientific evidence or in spite of significant change in the situation . Environmentalism is also clearly one of a number of ideologies that comprise 21st century piety, other obvious ones being vegetarianism, obsession with health foods, organic produce and bottled water, anti-capitalism and new ageism. They appeal to many people's natural desire to be seen as 'good people', and since mainstream religion, the historic foundation of holiness, is now unfashionable, these often act as easy secular substitutes. When this happens, the perfectly rational desire to protect the environment can be subjugated by other political and ideological goals and behaviours that also contribute to that person's piety. Sadly, the personal feeling of being 'good' and to be seen as being good, is often stronger than the need to be well informed, and environmentalists can often become sanctimonious and damage the environment by applying poorly thought through practices and trying to force others to do so.

Since there has been so much change in the techno-social situation since environmentalism began, it is time to reassess common environmental beliefs against good science, so that dogma doesn't get in the way of doing the right things, or we may be making the problem worse.

Apart from adherence to out-of-date dogma, and corruption of thinking by 21st century piety, other causes of poor thinking that frequently affect the climate change debate include:

- lots of things that were true 30 years ago are no longer true today because the situation is different;
- common sense is often wrong;
- people are notoriously extremely bad at weighing up risks and rewards;
- most people have little intuitive understanding of exponential or other non-linear change, even many scientists;
- some things that look good at first, look bad once second and third order effects are taken into consideration.

Together, these problems have resulted in a set of environmental policies that might have been good ideas once upon a time, but which do not bear up to proper scientific analysis now. For example, anti-nuclear lobbying was extremely successful at restricting the use of nuclear power, when there was clearly no economically feasible substitute other than to use fossil fuels. The consequently greater production of CO_2 emissions has contributed significantly to the climate change problem. Although some green groups still strongly oppose any return to nuclear power, many other environmentalists now see nuclear power as the lesser of two evils, and some governments are seriously considering returning to nuclear power, while also investing heavily in development of renewable energy production. This latter approach seems entirely sensible given the current situation.

One thing that is certainly not wrong is the passion that many people share to protect and nurture the environment. Whatever minor criticisms of green groups may be made, they still have a very important part to play, having won the hearts and minds of many environmental supporters. One of the strongest weapons they hold is that they are not geographically constrained, so are not under control of any particular government or culture, so are in a strong position to continue to lead environmentalists. They should be encouraged to carry on campaigning for environmental protection and for remedial action. But making sure that their decisions and campaigns are properly informed and scientifically valid is essential if the environment is to benefit. The wider scientific community needs to be much more actively involved in informed decision making to make sure we do the right things.

In short, if we want to defend and repair the environment, rather than just to feel good about 'doing something', we need more scientifically informed environmentalism.

ECO-TOWNS

Ecotowns are obviously intended to provide environmentally friendly accommodation. While this in itself might be a good idea, unfortunately, the plans often focus on old-fashioned environmental solutions and therefore are in danger of locking in out-of date technologies. Since technology progress is already rapid and accelerating, preventing the adoption of new environmentally friendly solutions by locking in old and even obsolete ones does not seem wise.

For example, current environmental dogma says that cars are bad a public transport is good. As this report argues, actually quite the reverse is true in the long term, and to use 1990s solutions such as guided bus-ways is severely misguided. It would be far better to implement pilot schemes such as electronic routes and electronic vehicles. If a whole town is being built, given that most journeys are local, there is a perfect opportunity for genuine eco-towns to trial such new technologies, that are far more environmentally friendly than any bus-based system, while allowing un-restricted travel, and allowing full social inclusivity for an ageing population.

Similarly, rolling out 1990s energy solutions such as CHP plants will increase infrastructure costs and prevent the adoption of newer solutions arising in the next couple of decades. Arguments for extra infrastructure investment that pay net environmental dividends only over the long term should be abandoned. The fact is that the net value of benefits in the longer term is much lower than in the first years, due to the inevitable availability of much better

alternatives in the longer term. A heavily discounted weighting of far-future benefits should be applied, and when this is done, many supposedly beneficial solutions look very much worse. It will often be far better to use an inefficient interim solution and wait for better solutions to arrive than to implement and inefficient and long-lived solution now. This stands in stark contrast with the all-too-common philosophy that we have to act now and can't afford to wait for new technology to arrive. If the purpose is to benefit the environment, then a full lifetime, full system cost-benefit analysis needs to be done, and this often will mean waiting a while before doing anything. It is simply nonsense to assume that acting soonest will always reap the best benefits overall.

CARBON TRADING

The underlying principle of trading CO_2 allowances is that the use of market forces will cause reduction in CO_2 production. It fails because it relies on the good will and cooperation of many diverse people, and on their willingness to put the environment ahead of their own desire for wealth and also because it is very difficult to verify that carbon is actually being offset by people selling allowances. Like any system that depends on people acting for the common good, it is vulnerable to those who do not share the same ideals. It is already clear that the system has been poorly conceived, too vulnerable to abuse, fraud and incompetence. Some offset schemes are badly managed and trees die. People buying offsets often don't check whether the trees they are supposedly having planted would have been planted anyway as part of already existing commercial forestry business, or whether they have already been sold many times, or whether they are left to die and then replaced by new ones sold afresh on the same site. Large scale alleged abuses recently in the media include Indonesia draining its bogs, releasing huge CO_2 additions, and then offering to stop if paid. This is feasible because the treaty on CO_2 limitation did not cover Indonesia (or many other countries). Such practices border on blackmail. Deliberately increasing emissions of CO_2 to create a market for reduction certainly are not intended consequences of developing a carbon trading market, any more than simply re-labelling existing activities so as to become eligible for payment. But it is obvious that where large amounts of money are made available, with little protection against abuse, people will be highly creative in taking full advantage. Carbon trading seems to be more of a system for dubious wealth redistribution than an effective way of limiting CO_2 production.

CORPORATE ENVIRONMENTAL POLICIES: GREEN BIAS AND GREENWASH

Corporations have a great deal of influence on global CO_2 production, and it is important that their environmental policy managers are not only properly informed, but also properly motivated. However, it seems reasonable to assume that many of those give responsibility for environmental policies are those that have shown interest in them and many of these will have some affiliation with green groups. Given the poor respect given to science and technology by green groups, putting people in charge who have a green bias, and are likely to leverage corporate policy to indulge their own views, seems inevitably to generate an overall corporate bias towards greens instead of legitimate science based policy.

This inbuilt corporate bias will make it more difficult to achieve environmental benefits by creating a barrier to scientifically based policies.

On the other hand, environmentalism often fits in corporation in close proximity with corporate social responsibility, branding and marketing. These are inextricably linked of course, given the strong media attention to environmental concerns and corporate behaviour. Many blue chip companies have already discovered how to use environmental policy to generate favourable brand impact. Companies of course want to demonstrate their support for environmental initiatives. Sadly, it is much better from a short term brand viewpoint, to do things that demonstrate conformance to current popular environmental wisdom, as featured in popular media and green figures, which as this report argues strongly, is often badly misinformed.

By amplifying the impacts of personal green bias and fashion at the expense of good science, corporate environmentalism can do far more harm than good. It is often much more interested in doing something than in doing the right thing. It takes a brave environmental policy director and indeed a brave brand director to risk angering greens by doing the right thing instead of following misguided dogma. All too many fall foul and simply roll out obsolete or misguided directives.

The other area of concern in corporations is that they have a tendency knowingly to misrepresent activity so that it looks much more environmentally responsible than it is. Corporate spin is nothing new of course, but the enormous media and brand value of 'being seen to be green' has generated a high degree of corporate greenwash, putting a green spin on something that sometimes is anything but green. Fortunately, the media provides a very useful deterrent, happy to unveil corporate green hypocrisy when they find it.

TECHNOLOGY OBSOLESCENCE: ENVIRONMENTAL FRIEND OR FOE?

Technology change is accelerating and many environmentalists have expressed strong concern that high tech gadgets such as phones, computers and MP3 players become obsolete very quickly and end up on landfill while they still have years of useful potential life left. Some companies that consider themselves environmentally responsible have initiated programmes to tackle obsolescence.

But to do so can be a significant error. This is especially true of mobile phones, which are typically used as a prime example of the problem. In fact, if it were not for the enormous progress in phone technology, paid for by the rapid obsolescence cycle, phones would be very much heavier, more expensive, use more materials, generate far more radiation, and almost certainly still use batteries based on highly toxic heavy metals. A phone today makes very little environmental loading, while adding much more significantly to quality of life, compared to its ancestors. Future generations of phones will progress quickly towards digital jewellery, which will do far more than today's IT with minimal materials.

A person wearing a few grammes of digital jewellery in 2020 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. Without the rapid obsolescence cycle, the enormous environmental benefit of being able to achieve all this with very little material and energy, compared to making a huge loading on material resources and energy will not be achieved.

Obsolescence is therefore one of the environment's best friends, allowing people to do what they want while damaging the environment much less than even today. Holding back obsolescence or regulating gadget lifetime for some short term perceived resource benefit would be disastrous for the environment. Rather, the faster we can progress to tools that minimise resource wastage, the better it will be. This is particularly true because many people who want IT can't afford it yet but soon will be able to. It is essential that progress enables them to come on stream using technology that reduces the impact rather than to use antiques with relatively huge environmental footprints.

VEGETARIANISM, HEALTH FOODS, ORGANIC PRODUCTION, NATURAL FIBRE, BOTTLED WATER

Through their inclusion in the 21st Century piety toolbox, these are all linked to environmental behaviour and thinking. Their impact on the environment can be both good and bad, but the impacts are many and diverse and their complex relationships with other factors make it impossible to guess net impacts without an extensive analysis. For example,

vegetarianism reduces the area of land required to grow enough provide food for people. Growing crops costs less energy, space and water than raising animals. Raising meat animals also contributes significantly to methane production, methane of course being an even worse greenhouse gas than CO_2. The health effects of a vegetable diet will affect the tax recovered over a lifetime, lifetime health care and pension costs. Many other lesser effects could also be considered such as impacts on soil level, biomass availability, transport costs and so on. It is evident that even in this one example, the net environmental impact is hard to estimate.

By contrast, 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, which affects family size in poor countries, which creates a greater population, greater need for aid and so on. It is also chemically different from conventional farming and also affects lifestyle in more subtle ways – organic food is often delivered by a different distribution system.

The desire to wear natural fibres instead of synthetic substitutes 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.

Finally, bottled water has become very fashionable among people who have adopted the 'healthy lifestyle'. But at least in this case, awareness is rapidly increasing that it is very bad to the environment compared to using tap water. Each one litre plastic bottle generates 100g of CO_2 during its production while using 7 litres of water! 27M tones of plastic are needed globally each year for bottles water. Even if the whole system is complex, it is very clear that the consumption of bottles water is environmentally harmful and should be discouraged. One of the strongest objections to use of tap water is that chemicals are added to it, and it tastes bad. The reasons for doing so should be re-evaluated and balanced against the need for people to have access to water that they are prepared to drink, without damaging the environment more than necessary.

With such enormous complexity – and the interactions noted above are just a tiny proportion of the whole - it is little wonder that most mathematical models of the environment ignore most of these deeply interwoven social, political and cultural effects. The inevitable result is of course less accurate predictions.

RECYCLING V CARBON SINKS

Like many areas, East Anglia suffers from a major coastal erosion problem. Environmental policy has recently altered from prevention to acceptance, but in some areas, coastal defence is commercially necessary. One conventional approach is to make huge concrete blocks (making and transporting concrete produces large amounts of CO_2) and dump them in the sea to absorb the wave power. This solution is carbon intensive. Meanwhile landfill sites are filling up fast. And meanwhile, scientists are trying to figure out how to sequestrate carbon into carbon sinks. These problems are connected and can be partially addressed simultaneously. 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 is often done in China. If these blocks were to be dumped in the sea, just off the Norfolk coast, (and suitably contained of course) transport and processing would produce far less CO_2, carbon would be locked up, coastal erosion would be reduced, land would be reclaimed, landfill would fill up more slowly, and CO_2 production greatly reduced. 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. The much levied criticism of conventional plastics, that they will stay around 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.

Another obstacle is that household waste is poorly sorted, so improved sorting processes would be needed if sea pollution is to be avoided. But like many other current problems, upcoming technology will make it much easier to solve.

Other waste could be handled differently. For example, glass is borderline recyclable, yielding an environmental benefit when recycling it rather than producing it from scratch, but since the full-life benefit is actually quite small, perhaps it could also be included with the plastic, giving extra density to the waste.

Organic waste is often composted, returning much of the carbon to the air in the process, especially with home composting, which authorities are currently trying hard to encourage. Home composting can produce significant quantities of methane, a bad greenhouse gas unless. Organic waste can be converted into biomass fuel for power stations instead, displacing the need for fossil fuels and while this sounds sensible at first, it needs to be rigorously compared with the alternative full-system impact of using to increase soil production on farmland, apparently often overlooked in climate analyses. Alternatively, by heating it with a reduced oxygen supply, it could be carbonised, and the carbon dumped into the sea, absorbing pollutants as an active carbon sink. However, doing this would require better quality of rubbish sorting; otherwise pollutants such as dioxins may be produced inadvertently. In any case, there are several alternatives that need to be analysed properly.

Metal waste left over could be recycled conventionally, but there is a need for better education and better regulation. Many people wash out cans before dumping them, and indeed some local authorities ask them to do so, an example of poor thinking applied by authorities who are more concerned to be seen to be doing something than to actually alleviate the problem. Washing cans before throwing them in the trash contributes to the amount of sewage processing needed, accelerates the decomposition and hence production of CO_2, while bypassing the potential to recover the chemical energy in the waste at a biomass power station. This effect needs to be offset against the benefits of can recycling. It seems to make little sense to encourage households to use increasingly limited fresh water supplies to wash out cans, when this could be done centrally with less water, and the resulting slurry used as a fuel source for bacterial power stations. In the home, it might account for 2% of water use. Worse still, many householders use heated water to wash the cans, or even their dishwashers, so there is also a significant energy cost at the household for this recycling, as well as increased detergent release.

In fact, this situation will get far worse if rubbish taxation is implemented as currently being suggested. A lot of the weight and volume of rubbish arises from organic kitchen waste. Under taxation, many households might choose to be waste disposal units, and flush the organic waste down the sink. Again, apart from removing the potential to use this for biomass power generation, it would add substantially both to water use and sewage treatment.

Paper recycling is also of dubious merit. Some studies have suggested recycling paper is on balance damaging to the environment, and at best it is only slightly beneficial. Again, paper could be used as fuel, or charred and dumped as a carbon sink.

When all these factors are taken into account, the current pressure towards recycling everything seems to be over-zealous, even sometimes misguided. Recycling is due for a thorough and updated life cycle costing of the environmental benefits, system wide, with proper consideration of alternatives.

CARBON SEQUESTRATION

Carbon sequestration technologies are being researched intensely now, although there are unfortunately already signs that the first wave is stalling due to financial blockages. There are a variety of possibilities, such as pumping in into underground aquifers, dissolving it in deep seawater, planting forests or seeding ocean algae farms with iron. More recently, synthetic biology has started promising good potential for harnessing biologically inspired techniques, using

synthesized proteins, or even eventually synthetic life forms. Genetic engineering of new types of organisms that can lock up carbon quickly is also being researched. Synthetic organisms that are primarily designed to remove CO_2 from the atmosphere could appear to be very useful indeed.

However, such developments should not be introduced without due consideration of dangers. If the basic processes of life can be mastered by engineers, the threat of self replication and its potential use in weapon systems springs to mind immediately. While it would obviously be useful if we could control the removal by synthetic organisms of just the right amount of CO_2, of course this would need to be done in a fail safe way that could not remove all of it, which would cause mass extinction.

Perhaps a half-way solution would be a good compromise of safety and effectiveness. With the current rapid increase in greenhouse farming around Europe, supplying CO_2-enriched air would be useful to both grow the crops faster and sequester the carbon. Genetic modification of plants to make them grow faster would also help, both in substitution of fossil fuels via bio-fuels and biomass power generation. If trees being planted to absorb carbon are genetically growth-accelerated, this could make a significant contribution to longer term sequestration. The same applies to sea-based algae farms.

Technologies such as synthetic biology could lead mankind further down a very dangerous development path, but of course we are already a little way along it today. And being more optimistic, although synthetic biology is potentially dangerous if care is not taken, the field could also yield potential tools to rescue life on earth if the worst nightmares of climate change take effect, by eventually enabling wholesale redesigning of the ecosystem from the ground up.

NUCLEAR POWER

Nuclear power was until recently anathema to most environmentalists, but many have reconsidered their stance in the light of global warming, and the issue has now split them down the middle, with some environmentalists on either side. There are obvious risks associated with nuclear power, as with other forms of energy production. But since these risks were not properly compared those associated with alternative power sources, nuclear power proliferation was greatly constrained and eventually cut back as a direct result of environmentalist pressure. The clear absence of readily available and economically viable renewable solutions, or political will to develop them, meant that they were replaced by fossil fuel based power production. The antinuclear lobby has therefore contributed in part to the wider climate change problem. It is sad that well-meaning but misguided environmentalists have become one of the big problems facing the environment.

Indeed, some environmentalists remain anti-nuclear in spite of the carbon emission benefits. One of the main sticking points if disposal of nuclear waste. The argument is raised repeatedly, and sounds compelling at first, that our descendants will have to cope with the nuclear waste for ten thousand years or more. But that argument depends entirely on the assumption that technologists will never be able to develop a means of disposal, whereas it is highly likely that the disposal problem will be solved this century, so at worst, we will have to store the waste for decades, not millennia. Nuclear waste includes plutonium, which can of course be used in nuclear reactors itself, but can also be used for nuclear weapons. That the weaponry use of nuclear energy bi-products is a threat is unquestionable, and is one of the better arguments against nuclear power. So, there is of course a need for secure storage for such waste, it cannot be simply dumped. However, Uranium comes from uranium mines, is then processed, used, and as radiation levels decline, it becomes useless for power generation and needs to be disposed of. But, for example, if the depleted uranium and other low grade waste were to be returned to source and essentially mixed up with landfill in the mine that it came from, the mine would be slightly less radioactive than originally, so there should be no problem. The energy would have been harvested, and the uranium mine would be a slightly less radioactive landfill. Of course, the waste is not in its original form so would still need some processing, but the dilution principle is sound. Perhaps the real problem is that current approaches to disposal involve waste concentration rather than dilution. When the waste is

concentrated, it takes up less space of course, and it also becomes more dangerous, and a more attractive target for terrorists.

Another approach for waste disposal is to send it into space, for example, to fire it into the Sun, which is of course a nuclear reactor itself. Although today that would be a dangerous and expensive approach because of the costs and unreliability of rocket technology, at least one space elevator will be most likely built within the next few decades. A space elevator is a huge cable extending into space, allowing delivery of people and materials all the way into earth orbit. It is no longer science fiction. Many engineers are already doing R&D on materials and techniques, with large financial incentives for each milestone along the way. Over time (almost certainly this century), with perhaps several such elevators, and what eventually will become well established technology, this is likely to become a safe way of getting stuff into space. Plutonium and other high level waste could safely be disposed of, for ever. There is therefore no real problem with long term storage. Nuclear waste will have to be kept safe and secure for quite some time, but not the thousands of years often cited by anti-nuclear groups. We will certainly have reliable means of safe disposal within 100 years. It will not be a problem left for many generations. That makes one of the prime arguments against nuclear power generation very much weaker.

AFRICAN SOLAR FARMS

Actually, although we will certainly need nuclear power if we are to provide sufficient energy for the next few decades without creating too much CO_2 renewable energy technology is also progressing quickly and will be able to provide much of our needs within those few decades. Solar power is making good progress towards high efficiency and low cost cells. For example, developments at the Lawrence Berkeley National Laboratory suggested three-band cells with efficiencies up to 45%. Energy companies are looking forward to making grid parity possible in the next decade, at least in sunny regions such as California. Provided costs can be constrained, solar power could provide significantly towards our everyday domestic needs, even in the UK, especially if other energy sources increase in price.

However, on a much larger scale, if solar cells could be manufactured with anything like this efficiency level at reasonably low cost, we might see the emergence of massive solar energy farms in North Africa. These farms could cover large areas of otherwise low value land, producing large quantities of hydrogen. Also, since superconducting cable development is coming along quickly, we may even see direct electricity distribution to Europe from Africa. Scale would be limited mainly only by cost and demand. If it reaches very large scale, there would be significant knock-on economic effects, with hydrogen substituting for oil as it starts to get expensive, and ensuring that much of the oil is left forever in the ground, destroying the last decades of that market. Moving such a major source of income from the Middle East to North Africa would obviously have significant political effects too. In each of the world's regions, it is possible that energy could be produced in the South and transmitted to the richer North.

ENERGY SHORTAGE, OR GLUT?

As we head (possibly) towards a hydrogen economy, nuclear fission and solar power are likely to be the main contributors, displacing fossil fuel burning. Fusion may well come on stream in the 40s or 50s as a major global contributor too. Wind and wave power will contribute on a small scale too, as will geothermal energy and biomass use. With the hydrogen economy, in principle, anyone that can make any form of energy can convert it to hydrogen and then ship or pipe it around the world to anywhere it is needed. In parallel, domestic use of solar power is likely to have a significant impact on energy demand in some countries. And all the while, energy efficiency progress will reduce waste significantly.

As the hydrogen age matures, we are also very likely to have a space elevator. This will greatly reduce the cost and risk of getting things into orbit. It would greatly facilitate the transport of materials and staff to fabricate space based solar power arrays, or even nuclear facilities, as well as providing waste disposal capability for land based nuclear facilities

With all these various forms of power production likely to be used in the future, oil will be long obsolete, and we will have a glut of power, not a shortage. The price is likely to fall significantly below today's levels in real terms.

Considering the many potential energy technologies, a long term energy glut is probable, but it will take a few decades or two from now to really take effect. We will therefore inevitably go through a period of energy shortage and high prices before the price starts a long slide as we enter a long term glut.

In the same time-frame, it is likely that carbon sequestration technology will be highly effective, removing the problem of global warming and restoring the atmosphere and our climate to a healthy state.

DAMAGE FROM PANIC MEASURES

These same time frames are those over which many people are panicking today. Global warming seems already to be having significant adverse effects, but it is the long term future that concerns scientists so much, and it is the perceived long term threat that is forcing many of the measures being designed and implemented today.

It will be a great shame if these reactive panic measures prevent us from capitalizing on this technology windfall by locking us in to inappropriate but long lived solutions, achieving short term success at the expense of long term quality of life.

Among the measures that are already demonstrably ill-conceived is the push towards biofuels. It was always obvious that using prime agricultural land to grow fuel would increase food prices, harm the poor, and make little dent in the need for fossil fuels. However, energy produced by waste matter left over after food is produced, or indeed waste food and domestic organic waste, is more sound. This is to be compared with the use of such biomatter to increase soil thickness, which in itself is a potentially major contributor to solving CO2 sequestration.

The carbon credit scheme is likely to also prove unwise. It has already become more of a source of greenwash than a source of carbon reduction. It is mainly effective as a means of redistributing wealth by adding costs to business and the consumer without ensuring equivalent gains in the environment. The fact is that many companies are happy to pay carbon offset costs without adequately vetting the means of offsetting them. Many forests that would have been planted anyway can now be paid for twice (or even several times if the marketing is sufficiently unprincipled) by receiving carbon offset subsidies as well as their original commercial value.

ARTIFICIAL INTELLIGENCE

Artificial intelligence today is really just clever software, attempting to substitute machine-based algorithms and databases and sensor technology for human intelligence. It can be very effective. For example some expert systems can perform medical diagnoses as well as a human doctor. However, another quite distinct branch of AI aims to develop machines that are intelligent in the same ways as people, conscious, self aware, with their own mental model of the world, their own experiential understanding of the world. There is huge disagreement among practitioners about when we are likely to see the first conscious machines with human levels of intelligence. This could be as early as between 2015 and 2020, with other scientists suggesting 2030, 2040 and some refusing to accept that it will ever be possible.

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, it is a very important consideration for the climate change problem, with its enormous potential to invent solutions, increase understanding of the environment, and accelerate research development, but it is rarely mentioned in climate change 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 bale us out, but we may reasonably expect that it will, even if some of the man-made solutions fail. It gives us hope, but not enough certainty to avoid us using other approaches in parallel.

PUBLIC TRANSPORT

After recycling, the assumption that public transport is always a good thing for the environment is probably the most deeply embedded belief in environmental thinking, and indeed now pervades the mindset of almost all of society, certainly government. Yet it is wrong! Other ways of organising transport could often be more environmentally sustainable, while improving quality of life instead of limiting it. The common assertion that people should have their travel desires curtailed is unnecessary once new thinking is applied to the problem. In fact, the most environmentally friendly solution to transport in most instances is to use a mixture of cars and bicycles, and these can have a variety of ownership. Trains will still have a rightful place, but it is mainly in underground systems rather than on regional railways. Personal transport, properly implemented, can be more environmentally friendly and provide better quality of life, enabling people to travel as they please, without unduly damaging the environment. The current pressure to prevent people from driving cars by means of congestion charging and road tolling should only be a short term response to the problems caused by the low-technology mechanisms of today. It should not be the basis of long term transport policy. People demonstrably want to travel, and they can do so freely without damaging the environment. All that is needed is ongoing development of already-researched transport systems. We should not lock tomorrow's society into yesterday's solutions.

There are some obvious environmental problems with existing public transport that should be addressed. In particular, taxis are usually classed as public transport. A taxi often has to make a two-way journey to take a passenger one way, since it has to get to the passenger, take them to the destination, and often has to return empty once the passenger is dropped off. Of course, sometimes a new passenger is picked up shortly after dropping off the last one, so the ratio of journeys is not as high as two, but the ratio is increased also by taxis driving around empty looking for customers. Taxis are therefore much more damaging to the environment than private cars. Removing their public transport classification would help.

Buses are sometimes packed but also are often nearly empty. They have a very large effect on other transport, slowing it down and causing traffic jams, and the consequential increase in emissions from other vehicles at least partially offsets the savings they make. Their main advantage is that for much of the time at least, the costs of fuel and road space is shared between a higher number of passengers than private transport, and this advantage is worth preserving. The fact that they are public rather than private is immaterial as far as environmental impact is concerned, however much relevance that might have to socio-economic policy. That is not true of their ownership however. Being largely privately owned, bus companies have tended to increase their profits by taking buses on long routes so that they can visit the most potential customers. This means that more CO_2 is produced per passenger journey than if the buses were to go direct, and it deters many potential customers from using them. Buses also have a long lifetime, ensuring that newer, cleaner and more efficient engine technology takes much longer to enter the market.

Trains also seem to be an antiquated transport solution long overdue for a re-think. Today, on a typical piece of regional railway track, a train goes past every 20 minutes. A 200m long train, travels at 40m/s (90mph) takes 5 seconds to go past. So a track may be used 5 seconds out of every 20 minutes, an occupancy of 0.4%. The infrastructure has to be there all the time. Surely we can do better than that! Rail is a greatly underused resource that could improve the environment and reduce congestion on the roads if it were used more effectively. However, trains certainly have a major role in systems such as the London underground, where rail occupancy rates are much higher and trains are often very full indeed, where the only possible capacity improvement seems to be to increase the frequency or speed of trains. The same is true of buses, but only at certain times, on certain routes. So although trains and buses will certainly have an important part to play in future mass transport, they are not necessarily always the most effective solution.

So instead of just accepting the public transport dogma and locking in antiquated public transport architectures, let's first look at whether future technology can offer better alternatives.

PRIVATE TRANSPORT

In the future we will have better identification and tracking technology if surveillance systems continue to develop as they are. We will generally know who people are and where they are. In particular, we should know where known criminals are, or at least where non-criminals are, which is almost as useful for this purpose. That in itself immediately offers the potential for more sharing of private transport. It is dangerous to pick up total strangers today, but if the car can tell us that a person going to the same place is safe, (perhaps because they are a well known member of the same transport club) then there is less of a barrier to transport sharing. In that world, every car is a potential taxi. Future cars are likely to have the equivalent of a black box for a range of reasons, and one of the things it could routinely record is who the passengers were. As well as increasing safety still further, this could be used for a distributed cost sharing system. The boundaries between public and private transport start to erode. But it can go much further.

It is also likely that speed limits will be electronically enforced at some point, linking the engine management system to speed limits. That will essentially mark the beginning of a long path during which the computer takes over from the driver. Cars in the far future will be able to drive themselves. Simple analysis suggests that if the identities of both the cars and the occupants are known, and 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. 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. These will more often have multiple occupancy because of the security advantages above. And because they are driven by computer, with all the cars in a 'road train', electronically linked for acceleration and braking, they could drive much closer together, increasing road occupancy, greatly reducing drag and therefore making road travel more energy efficient. Indeed, they could be just centimetres away from each other, making travel much safer – it is not possible to get much of a speed differential before a collision if cars are very close, so even if electronic braking interlinking fails, the system would fail gracefully without danger. And with electronic control of the travel, the road transport system would become rather like the packet transport systems used today on the telecoms network (which are far more efficient than the old systems that required a call to hog a whole circuit, like trains do today in effect. This would mean firstly that slots can be electronically booked to ensure smooth travel, secondly, that destination time would be known at the outset., and thirdly that speeds could be made much more constant, again making the system much more energy efficient.

A further capacity advantage arises from the computer driver. Lanes are the width they are today mainly for safety reasons. With computers driving the cars, they could be much closer together sideways too, squeezing more lanes onto the same road area. 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. So we will see far more use of this technique.

Such an electronically controlled system would probably have a mixture of public and private ownership, but have all the flexibility of private transport. It would be very energy efficient, so confer an environment advantage over existing public transport. Meanwhile, public road transport would converge with private transport to achieve the same environmental quality.

In fact, without use of these electronic systems, unacceptable congestion is inevitable, with limited road capacity and increasing demand. Also, without use of electronic drivers, people will find it harder and harder to join traffic streams, especially if speed limits are electronically enforced, because traffic will not bunch the way it does today, so there will be very few gaps large enough for a human to safely join the flow. By contrast, electronics can easily slow some cars down a little and speed up others to create a gap while a new car joins the flow.

CARS ON RAIL

The system outlined would be capable of greatly increasing road use efficiency while reducing energy wastage. But the ideas can also be applied to rail. There is really no reason why road train technology could not be implemented on the railways too. As mentioned, rail occupancy is often 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. The current system might have been well suited up to the late 20th century, but it has been possible for many years already to design and build vastly superior systems. With the need to increase capacity and save CO2 emissions, the railways offer enormous potential to help, provided that they are used more intelligently.

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.

This approach could eventually be applied to both rail and road, with electronic control systems automatically managing both systems. As a crude estimate, the resultant capacity of the roads would increase probably three-fold, and the capacity of the railways perhaps as much as 100-fold. Congestion and travel delays could be greatly reduced (though sadly not eliminated, due to other architectural limitations), safety greatly improved, and environmental impact greatly reduced since the whole system could be driven on electricity.

If the electricity required is produced from renewables, the whole transport system could be carbon-neutral. So it is very clear that with adequate redesign of the transport system, there is no climate-change-based need to constrain personal travel at all, and there would be a great deal of spare capacity. Furthermore, there would be strong spin-off social benefits, since public fleets of electronically driven cars could serve the whole population, including those unwilling or not permitted to drive themselves for whatever reason. This technology enabled system would therefore deliver benefits on social equitability, environmental sustainability and quality of life support.

There is a clear cost in implementing such a system. The railways particularly are occupied by conventional trains. New rail-cars could link into virtual trains of course to allow inter-working during the migration phase, but the signalling systems used by the old-fashioned trains are a real barrier. It would cost a great deal to update old trains and their signalling systems to achieve these benefits, but of course the new system wouldn't need them, and the old trains have little advantage over a car based system, so perhaps the cheapest and most effective approach would be to get rid of the trains of the railways. The cost savings made by avoiding centralised signalling systems and train upgrades would go some way to offsetting the cost of the station changes to allow cars to join and leave the traffic.

One clear advantage of this system is that most cars are likely to be paid for either by individuals or fleet management companies. There would really be no need for public subsidy, a welcome change to today's highly subsidised railways in itself. The vastly increased traffic on the railways provides an obviously adequate source of funding for the railways themselves, just as roads are paid for many times over by road fund license fees and fuel duty. Furthermore, the near elimination of traffic jams would also contribute tens of billions in economic growth, making more tax potentially available for other environmental programmes.

In fact, if this system works well, light rail could even be laid eventually on the roads too, with perhaps a heavy duty freight track and some light private transport tracks. Alternatively, it might be feasible to run the whole system without tracks at all, given the ease of implementing electronic tracks for vehicles to navigate along. This would certainly provide a more rapid deployment mechanism and would use far less resources, and would save having to equip cars with dual wheels. And further away still, we will find that trains have little place in a high-tech transport system and could be scrapped, rail disappearing into history.

PUBLIC OR PRIVATE OWNERSHIP

This system could use a mixture of different ownerships, public, corporate, private, clubs, and rental. Any of these could work well together. To make it work technically, standards will obviously be needed for car inter-working, distributed signalling systems, identification and payment technology and so on, but these are the kinds of technical problems that are solved every day in industry. Obviously, multiple occupancy might vary between the different approaches, but if capacity and energy efficiency are less of a problem, then occupancy also becomes less of an issue.

The same is true of the arrangements for acquiring and releasing vehicles. There are numerous ways that location, tracking and management technologies could be implemented. There is no technology barrier here.

A PLACE FOR TRAINS STILL

The system described above would work very well in most areas, but in some big cities, it is likely that there will still be a place for underground systems or other mass transit systems. Of course, electronically driven tube trains could still improve performance comfort and safety a little and save costs. But systems such as the London Underground carry large numbers of passengers fairly efficiently and at low environmental cost, albeit very uncomfortably at times. The potential improvements in capacity would be much less than the 100-fold increase possible on regional railways,

perhaps just a factor of 3 or 4 might be possible, even with a continuous stream of electronically driven cars. So here trains might still have a useful purpose. Overcrowding really just needs many more trains and whatever extra tunnel space is required to accommodate them. Replacement of drivers by electronics would be more to save costs than to improve capacity.

BICYCLES

Bicycles occupy the peak of the moral high ground as far as environmentalism is concerned because once they are built and delivered, their ongoing emissions are low, just the CO_2 from the human riding them. While they are certainly good for the environment overall, the picture isn't quite as clear as is sometimes portrayed and there are some places where the use of bicycles may not be environmentally sensible.

On proper cycle paths, they are certainly a good solution from both a fitness and environmental point of view (hopefully even once the environmental costs of making the cycle paths and the bicycles are factored in). But mixed with cars, they can be very dangerous, with bicycle riders suffering many times more casualties per mile than car drivers. They also force other vehicles to slow down to pass them, and then to accelerate again. On busy narrow roads, this can often cause significant traffic jams. The bicycle (and its all-too-often sanctimonious rider) may not be directly the cause of the extra consequent emissions from the cars, but from a system wide view, the overall CO_2 produced would likely have been less had the cyclist driven a car instead, so this must certainly be taken into account when calculating the impact. The carbon costs of the extra accidents, with the resultant traffic jams and so on, should also be factored in. Accidents have a very high carbon cost.

There is also a high opportunity cost where cycling takes more time to travel (also true of bus and rail travel in some cases), which ultimately amounts to a loss of GDP. This reduces the funding available to government to invest in environmentally friendly solutions across the board.

In the transport system outlined above, cars can drive closer together and this frees up road space both length and width-wise. This means that more space could be made for other car lanes or for cycle lanes. And of course with computers driving the cars, far fewer bicycles would be hit, if any. It is therefore likely that bicycles could be much safer to ride in the future, and because they can be more readily separated from car flow, will be more environmentally friendly, although this advantage is greatly diminished for electric cars. Improving the technology for car transport therefore makes cycling even more environmentally friendly too.

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. 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.

So, bicycles should have a rosy future. More cycle paths are needed and as electronic highway systems come into play, their environmental merits will increase still further.

PLANES AND ALTERNATIVES

Cheap air travel is a strong focal point for environmental hostility, because planes enable people to travel much further than they would with other forms of transport, and lead to far more CO_2 generation. While environmental activists aim their campaigns at trying to force people to travel less, an indirect way of limiting the CO_2 production, it is generally better to solve the actual problem, that of the environmental impact of the travel, rather than attack the travel itself. The universe has no energy shortage, it is the local means of accessing that energy that causes the problem and that is a technology, not a social problem. 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. Reserving bio-fuels for transport where there is no alternative due to energy density might also be sensible – there are plenty of other options for ground travel.

Perhaps more interestingly, taking futurology back 100 years, we find ideas that may just have been ahead of their time. At the turn of the 20^{th} century, futurologists were suggesting long tubes through which people could be propelled in vehicles by compressed air. Now of course there are various other potential propulsion means that could be used, with superconductivity and linear induction motors available to us already. De-pressurising the tubes could of course reduce air resistance. 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. 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.

DISCOUNTED CARBON ACCOUNTING

Many scientific studies have now provided estimates of CO_2 production over coming years, and the likely effects that this will have on the climate. Although they try hard to account for future increases in energy use, many take insufficient account of the ability of future technology to reduce emissions or to remove or sequestrate CO_2. It is important when making estimates of the adverse effects of using fossil fuels to take account of both increased uses and areas where use will decrease or be mitigated by clean-up technology. This depends heavily on when the CO_2 will be produced. Clearly, CO_2 produced in the next few years will have much worse impact than CO_2 produced in 50 years time, by which time we will almost certainly have a wide range of technologies that can deal with it safely. A heavy discount should therefore be applied to estimates of risk when the CO_2 is produced in the far future. Climate change cause by CO_2 is a short and medium term problem because of limited technology, but it will simply not present a big problem in the long term.

CLOSING COMMENTS

Sadly, both dogma and poor thinking are commonplace in environmental debate and this one the biggest barriers to protecting the environment, especially when it is so often coupled with contempt for science and technology. By enforcing misguided policies, society is prevented from adopting solutions that could actually protect the environment. There are far better solutions to climate change than those currently being proposed by mainstream environmentalists, and this paper has listed only a few. With the right incentives and leadership, the science and engineering community could produce far better solutions. Technology can and should bale us out of the climate change problem.

There is a strong need for committees of well informed scientists who can make independent scientific analysis of the wide range of potential solutions on a full system wide full lifecycle basis. 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

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