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Consulting referees:

Mike Childs, Head of Campaigns, Friends of the Earth

Professor Allison Druin, Director, Human-Computer Interaction Laboratory, University of Maryland, USA

Professor I. M. Dharmadasa, Centre for Electronic Materials and Devices, Sheffield Hallam University, UK.

About the author and the consulting referees:

Ray Hammond

Ray Hammond is a futurologist who, for over 25 years, has researched, written, spoken and broadcast about how future trends will affect society and business. He is the author of four futuristic novels, ten non-fiction books and various film, TV and radio dramas. His books have been bestsellers in the USA, UK, France, Spain, Czech Republic and Slovakia, Poland, Japan and China. He is published globally by Macmillan.

Professor Allison Druin

Allison Druin is Director of the Human-Computer Interaction Laboratory at the University of Maryland, USA. She is also a US Commissioner appointed by the White House to The United States National Commission on Libraries and Information Science.

Mike Childs

Mike Childs is Head of Campaigns for Friends of the Earth. Founded in 1971, Friends of the Earth exists to protect and improve the conditions for life on Earth, now and for the future.

Professor I. M. Dharmadasa

I.M. ('Dharme') Dharmadasa is Professor of Electronic Materials & Devices at Sheffield Hallam University, UK. In addition to his research into thin film solar power technologies, Dharme is actively involved in public awareness work on applications of renewable energy in the society. He has also designed a 'Village Power' programme using solar technologies to empower rural communities and to assist in the reduction of poverty.

A Note For Readers

This report is being published in paper form with companion electronic editions in PDF format, on portable electronic media and on the web. Most references are live hyperlinks, although printouts of these links are provided in the printed version. Readers who require index facilities are invited to search the PDF editions electronically.

Author's Acknowledgements

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Contents

Introduction

This report has been commissioned by Plastics*Europe*[1] – the trade association which represents the European plastics manufacturing industry. In their original brief Plastics*Europe* indicated that their aim was to commission a report that would describe future lifestyles and trends in a way that would appeal to the emotions, aspirations and ambitions of the widest possible group of people and which would also demonstrate the sustainable value of plastics as a material for the 21st century.

As a condition of undertaking this task I asked for, and was granted, complete independence and control over the content. I was also delighted to learn that Plastics*Europe* wanted the issues of climate change, sustainability and energy efficiency to be a main focus of this report.

My research has revealed that the plastics industry is strongly carbon beneficial and its products are of great help in tackling climate change. Although mostly produced from oil, the light weight and high strength of plastics (in car components, plane construction, cargo pallets, building insulation, etc.) means that far more energy and carbon is saved through the use of plastics than is consumed in its manufacture. However, if disposed of carelessly, waste plastic can pose a serious environmental problem.

In researching and writing this report, I have been aided by a number of expert consulting referees but it is important to point out that the conclusions that I reach here do not represent their views, nor those of Plastics*Europe*. I alone am responsible for the content and the conclusions drawn.

It is sometimes said that as it is impossible to predict the future accurately, any exercise of futurology is a pointless task; indeed, the discipline itself is often viewed with suspicion. However, the Oxford English Dictionary's definition of the term makes it clear that futurology is more about studying trends in the present, and then extrapolating from them, than it is about speculation or crystal ball-gazing:

> **Futurology:** The forecasting of the future on a systematic basis, esp. by the study of present-day trends in human affairs.[2]

But even if we cannot predict specific events in the future, it is definitely possible to identify trends and forthcoming developments that are likely to act strongly on our future. And long practice in thinking, speaking and writing about the future – the discipline of futurology – produces results demonstrably superior to projections made by those who do not study routinely human progress and things to come.

To deny ourselves the exercise of visionary thought would be to deny the human species its uniquely defining characteristic – to contemplate and plan for the future.

So, even if many of the specifics in this visionary exercise prove to be erroneous, I hope that my work here (and the input from my consulting referees) has identified a number of trends and technologies that will have a strong influence on our lives over the next quarter of a century. Reflecting on these trends and, where appropriate, intervening in each to ensure the best possible outcome, is the responsibility of all of us. The past and the present cannot be altered. Only the future remains plastic and open to our shaping. I hope this report will make a small contribution to improving the world in 2030.

Ray Hammond
October 2007, London

The Backdrop to the World in 2030

There are six key drivers of change that will shape the world of 2030. These are:

1. World Population Explosion and Changing Societal Demographics
2. Climate Change and the Environment
3. The Looming Energy Crisis
4. Expanding Globalisation
5. Accelerating, Exponential Technology Development
6. The 'Prevent-Extend' Model in Medicine (Disease Prevention and Longevity)

Many other factors will shape life and society in the developed and the developing world a quarter of a century from now, but these six are by far the most important drivers of change.

1. World Population Explosion and Changing Societal Demographics

My first inescapable conclusion is that there are already too many people on the planet and, it is credibly forecast, the world's population will increase by at least 50 per cent before the rate of increase in population growth slows down.

Today there are almost seven billion people alive on Earth. By 2030 there will be over eight billion and by the middle of the century there will be at least nine billion.[3] This is the official 'median' estimate of the United Nations Population Division but many other agencies and organisations believe that this estimate is far too conservative. The United Nations itself acknowledges in its alternative 'high variant' projection that it is possible that world population could even double between now and 2050 – a projection that suggests that by as early as 2030 (rather then 2050) there will be nine billion people[4] on the planet.

Other factors that will swell the numbers of humans consuming the resources of the planet include philanthropic medical intervention that will begin to eradicate many large-scale killer diseases on the African continent and much extended life expectancies in the developed world.[I]

This population explosion will present significant problems for every nation in the world. As Dr James Canton,[5] an American futurist who has advised three White House administrations on the future, writes in his 2006 book 'The Extreme Future':

> The global management of nine billion people who demand health, food, work, shelter and security will

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[I] In the poorest communities large families are an economic and social necessity (to provide cheap labour and to insure against high rates of infant mortality).– Despite widespread philanthropic efforts to distribute plastic and latex condoms (to protect against disease) such provision is unlikely to slow climbing birthrates in the foreseeable future.

> be the most daunting challenge any civilization has ever faced…
>
> Feeding nine billion people in 2050 with an environment that cannot sustain six billion today is a challenge of great proportions. We most certainly need to change our perspective about the environment in order to best prepare for the changes in climate that are coming. We probably cannot feed the planet without advanced, accelerated agriculture to head off mass starvation in the future.[6]

According to the World Wildlife Fund,[7] 1986 marked the year that the number of humans alive reached Earth's natural carrying capacity. The organisation goes on to add that by 2050, if world population reaches nine billion, we will require nearly two planet's worth of resources to support ourselves. The inevitable results, they say, will be fished out oceans, overgrazed pasture, destroyed forests, heavily polluted oceans and an overheated atmosphere.

But such conclusions are arrived at by linear projections. Modern futurologists know that such projections are unsafe. In the early 1960s and 1970s it was gloomily forecast[8] that the world would be starving by the year 2000.[II] A simple calculation of projected population growth and the world's annual agricultural output led to this conclusion. But the doomsayers hadn't considered the potential of the 'Green

[II] A fear fuelled in particular by 'The Population Bomb', a book by Paul Ehrlich of Stanford University which was published in 1968.– This book suggested that overpopulation would soon result in the world running out of food, oil and other resources.– It proved spectacularly wrong, but it acted as a clarion call for the modern environmental movement.

Revolution'[9] that was taking place even as they made their prognostications. From the 1950s onwards improved fertilisers, crop breeding programmes and factory methods of farming boosted agricultural output by several hundred per cent. There was no overall shortage of food produced in the year 2000, even if many people in the world went hungry.

By 2030 food production will have been revolutionised yet again. The genetic modification of crops and livestock will produce seeds that can grow in the harshest of conditions[10] (despite worries over the proprietorial commercialisation of agriculture – see the section 'Climate Change and the Environment') and meat that can be grown on its own in factories,[11] without a host animal. Plastic covering films and irrigation systems are already allowing European farmers to produce multiple crops in a single season and these techniques will be widely exported to the developing world to boost food production.

Indeed, for reasons of climate change we cannot go on deforesting our planet to grow more and more crops and rear more and more cattle. We have already exceeded the percentage of land that should be put to agriculture and the planet can yield up no more. As Professor James Lovelock,[12] one of the first scientists to raise the issue of climate change and man who popularised the concept of the 'Gaia Hypothesis'[13] (the Earth as an organism),[III] writes in 'The Revenge of Gaia':

[III] The first scientist to think of the Earth as a 'living organism' was Russian-born Vladimir Vernadsky who laid out the theory in his 1926 book, 'Biosfera'.

> I like to speculate on the possibility that we could synthesize all the food needed by eight billion people, and thereby abandon agriculture…
>
> The chemicals for food synthesis would come directly from the air, or more conveniently from carbon compounds sequestered from power station effluent, and all that we would need in addition would be water and trace elements.[14]

Another factor that will have a major impact on food production methods is climate change, but the impact of this is harder to predict and will vary from region to region. Suffice to say that technological advances in food production methods will continue to have the potential to feed the Earth's enormously expanded population even if, in some of the world's poorest regions, poverty, corruption, bad politics and conflict (and, in some areas, acute climate change) will continue to cause widespread famine. Drinking water, on the other hand, is often forecast to be in very short supply in some parts of the world (fresh water accounts for only 2.5 per cent[15] of all the water in the world and most of that is frozen). Today, over one billion people worldwide do not have access to clean drinking water. Disease resulting from contaminated water leads to 1.8 million deaths every year and can account for 80 per cent of all illnesses in developing countries.[16]

The pressures on water are well illustrated by the following report published by US Nation & World Report in May 2007:

> Over the course of the past 40 years, north Africa's Lake Chad has shriveled to one tenth its earlier size, beset by decades of drought and agricultural irrigation that have sucked water from the rivers that feed it – even as the number of people whose lives depend on its existence has grown. In 1990, the Lake Chad basin supported about 26 million people; by 2004 the total was 37.2 million. In the next 15 years, experts predict, the incredible shrinking lake and its tapped rivers will need to support 55 million.
>
> The population growth has coincided with a 25 percent decrease in rainfall, with global warming very likely a factor. As oceans store more heat, the temperature difference between water and land dissipates, sapping power from rainmaking monsoons. At the same time, desperate people are overusing wells.
>
> Lake Chad, with its confluence of troubles, is emblematic of a burgeoning water crisis around the world. While the western United States faces serious water problems, American money and know-how can at least soften the blow. Not so elsewhere. Worldwide, 1.1 billion people lack clean water, 2.6 billion people go without sanitation, and 1.8 million children die every year because of one or the other, or both. By 2025, the United Nations predicts 3 billion people will be scrambling for clean water.[17]

The United Nations further predicts[18] that by the middle of this century between two billion and seven billion people will be faced with water scarcity and this is likely to cause serious political unrest and conflict.[IV]

In June 2007 Credit Suisse published a report called 'Water'. In the report the insurance firm pointed out:

- Water demand is doubling every 20 years – more than twice the rate of population growth.
- Water utilization rates have doubled in the past 45 years.
- Seventy per cent of global demand for water is agriculture, 22 per cent industry and eight per cent domestic.
- The absolute quantity of water supply is the same now as it was 10,000 years ago.
- Asia is home to 700 million people who drink unsafe water and two billion who do not have adequate sanitation.
- American water consumption is 70 per cent greater than European consumption.
- An estimated third of the world's population currently lives in water-stressed or water-scarce countries.
- In most countries, the price of water fails to reflect adequately the cost of supply.
- An estimated 85 per cent of domestic water usage ends up wasted.
- By 2025, 18 countries will have water demand in excess of supply and 58 countries (or 64 per cent of the population) will be under significant pressure.[19]

[IV] However, some serious long-term efforts are being mounted to address the problem of future water shortage and hopes are high for a new nano-plastic membrane that is capable of converting saltwater into freshwater.

Needless to say, plastic piping and containers will have a huge role to play in the conservation of increasingly precious fresh water.

Societal Demography

The age make-up of the world's population is changing dramatically and the effects of this will be very apparent by 2030.

In 2006, nearly 500 million people worldwide were 65 or older. By 2030, according to a US government report,[20] the total is projected to double to one billion – one in every eight people on the planet. The fastest increases in those 65 and older are occurring in developing countries, which will see a jump in those populations of 140 per cent by 2030.

But although developing countries will see the greatest percentage increase in their elderly populations it is the European nations that are predicted to suffer most economic pressures from low birthrates and ageing populations.[21]

However, it is unsafe to assume that all the ageing European societies of 2030 will have trouble supporting their elderly populations. Three changes to our societies are likely to prevent this. The first is that people will work longer, the second is that there will continue to be massive waves of immigration of young people from the less developed world into the most developed countries and the third is that accelerating technological innovation will increase wealth rapidly in the most highly developed societies (although some of this new wealth is likely to be eaten up in efforts to tackle and adapt to climate change).

On the subject of working longer, most European countries will have raised the official retirement age[22] by at least a year or two by 2030 and improved fitness brought about by preventive medicine and improved health care will render the workforce capable of working (happily, even eagerly) for longer. Indeed life expectancy will be so greatly increased[23] by 2030 that retirement at 60 or 65 will seem pointless. It may be the point at which people merely change career.

On immigration, the latest figures from the UN's population division[24] predict a global upheaval without parallel in human history over the next four decades. At least 2.2 million migrants from poor nations will arrive in the rich world every year from now until 2050, the United Nations said in March 2007.[25] This means that a total of 55 million new immigrants will have settled in developed nations over the next twenty-five years.

In Europe, the UN predicted that Britain, France and Spain would receive the most new immigrants and the Swiss population is expected to reach the eight million[26] mark by 2030, an increase of 9 per cent, mainly as a result of immigration. On the other hand the UN predicts that Germany, Italy, Poland and Russia will see their populations drop because of low birth rates, lower immigration by foreign nationals and increasing emigration by their own citizens. Bulgaria's population will fall by 35 per cent by 2050. Ukraine's will plummet by 33 per cent, Russia's by one quarter and Poland's by one fifth. There will be 10 per cent fewer Germans and 7 per cent fewer Italians by the middle of the century.

But the flow of migrants across borders will dramatically increase the populations of most other developed countries, even though Europe's population will grow more slowly than the USA.

> In 2005, the population of Western Europe was larger than that of the United States by nearly 100 million people; by 2030, it is expected to be greater by just 35 million.[27] Whereas the US population is anticipated to grow by over 65 million during that period (implying a robust rate of increase of about 0.8 per cent per year), western Europe's population is expected to remain virtually stagnant (growing by less than one per cent over the entire 25-year period).

It is clear that by 2030 the majority of developed nations with aging populations (including the United States) will have long since flung open their borders and greeted with enthusiasm young and ambitious immigrants. Those that fail to do so will risk becoming economic also-rans.

The one exception may be Japan, a nation with a rapidly ageing population, but one that has long cherished its cultural isolation. Rather than open its borders to immigration, Japan is investing heavily in developing robots that can take care of its elderly[28] and produce new wealth within society. I have no doubt that by 2030 robots will indeed be producing massive wealth, and that they will be able to take care of the elderly. But it remains to be seen what sort of future awaits a nation made up of mainly old people being cared for by a population of robots.

2. Climate Change

Recently, public concern over climate change has become so fashionable in Europe and some other parts of the world that it may soon run the risk of suffering the contempt that often follows over-familiarity. This would be a grave mistake and must not be allowed to happen. I propose that we should re-name this atmospheric malady 'Climate Disease' or 'Climate Catastrophe' to underline the seriousness of the problem.

The changes to our climate are palpable for all to feel and increasingly easy for scientists to measure. The evidence[29] that such an abrupt change is anthropogenic (caused by humankind) is overwhelming but a few die-hard sceptics[30] still insist it might be a natural phenomenon. However, the argument about whether humankind is responsible for these changes is irrelevant. It is clear that an abrupt alteration to the planet's normal weather patterns is occurring and this poses a great danger for many of our societies.

If storms worsen, sea levels rise, flooding increases, droughts lengthen and heat waves intensify, millions of humans will be killed, millions will be displaced and society will begin to break down. There will be refugees at all of our doors. We may even become refugees ourselves.

We do know that so-called greenhouse gases[31] trap heat in our atmosphere – principally carbon dioxide, methane and nitrous oxide – and, leaving aside the debate as to the root cause of climate change, it is our clear duty now to cut down sharply on the deliberate emission of any gases which increase heat retention. Plastics have a major role to play in combating climate change, both in reducing the weight of components in cars and planes and reducing the weight of cargo itself. Plastics will also make an increasing contribution to insulation and energy efficiency in building construction and in the manufacture of energy generation and distribution systems (see the later section 'The Future of Energy').

Because there are so many variables in the science of climate change, and because human response to the problem is a matter of social and political will, it is impossible for any futurologist to predict how the climate itself will be behaving in 2030. However, it is possible to predict that climate change will still be one of the most pressing problems facing humankind (no matter how efficacious global political response to the issue is over the next twenty-five years) because there is a time delay built into our atmosphere's responses to heating.

In his influential 2006 book 'The Weather Makers', environmentalist and zoologist Tim Flannery (Australian of the Year 2007[32]) writes:

> As our planet heats up it takes the surface layers of the oceans about three decades to absorb heat from the atmosphere, and a thousand years or more for this heat to reach the ocean depths. This means that our oceans are currently reacting to the gases we pumped into the atmosphere in the 1970s.[33]

And that means that the heat-trapping gases we're pumping out now in the first decade of the 21st century will be the heat that is trapped in the oceans in the year 2030, heated water that will become the fuel for future hurricanes and tornadoes. And that quantity of heat will be considerable: since the industrial revolution began in 1751 roughly 305 billion tons of carbon have been released to the atmosphere from the consumption of fossil fuels and cement production. Half of these CO2 emissions have occurred since the mid 1970s.[34]

As a result of the oceans storing the heat trapped by our present greenhouse gas emissions, in twenty-five years' time hurricanes of similar or even greater strength to Hurricane Katrina which devastated New Orleans in 2005 will have become far more frequent events,[35] even if global efforts over the next quarter of a century to reduce future carbon emissions have been heroic. The weather in 2030 will be extreme.

3. The Looming Energy Crisis

It's obvious if you think about it. We're running out of fossil fuels. Even as I write these words new technologies are being announced that can further improve extraction capabilities[36] to mine fossil fuels, pushing back the point at which fossil fuels will be priced out of the energy market. But all such announcements miss the point. It is clear, not least for the very pressing reasons of climate change, that we have to find new and clean methods of providing our societies with the vital energy they need. And this must be done even as world population balloons and energy demands soar.

Yet the clean energy we need is all around us, in the sun, the wind, the waves and the rocks. It's just that we greedy, lazy, avaricious humans haven't had to go to the bother of harnessing it: until now.

Mandatory reductions to our energy usage are not the answer to the looming energy crisis (although conservation and efficiency must be vastly improved). Human evolution spurs us to seek continual growth, both personally and collectively, and any concerted legislative attempt to restrict growth or economic activity would produce great social unrest and alarming macro-economic consequences.

The solution to the energy crisis is complex because the problem is complex. Humans have consumed external energy since the first camp fire was lit and now that there are to be up to twelve billion humans on the planet by mid-century, all of them seeking better standards of living, there's going to be a huge and rapidly growing desire for more and more energy.

I stood in the blazing sunshine of a hot summer's day in Sydney recently contemplating the fact that, per capita, Australians are responsible for releasing more carbon dioxide into the world's atmosphere[37] than any other nation (even the Americans). The reason is simple to understand; Australia has vast, easily mined coal reserves and this dirty fuel is used to produce 85 per cent of the nation's electricity.[38] Along with its partner in shame, the United States, Australia isolated itself from the 1997 Kyoto Protocol[39] on climate change by refusing to ratify the agreement. John Howard, Australia's Prime Minister has recently been forced into a U-turn on climate change[40] (like his reluctant friend George W. Bush).[V]

As I spent an hour in Sydney's beautiful botanical gardens the solar energy beaming down on me was so fierce that my skin was burned, yet I saw not a single solar panel in use in the city. And below my feet I knew that there was enough accessible geothermal energy to provide all of Australia's power generation needs[41] for the rest of the 21st century.

The solution to the energy crisis (and to the ever worsening effects of climate change) is literally all around us, in the wind, in the waves, in hot rocks and in the sun's heat. It will be difficult and expensive to harness natural, clean energy sources (although plastics have a great role to play here) and it will be economically painful to wind down our investments in fossil fuel energy extraction. But it must be done, and quickly.

4. Globalisation

The term 'globalisation' has many meanings and evokes many different emotions. At one extreme the word is used to mean 'global economic exploitation of the poor by the rich' and, at the other, 'a global movement to reduce poverty and

[V] On May 8th 2007 John Howard's finance minister delivered a budget which offered a national A$8000-a-house solar subsidy[6] to assist in installing solar panels in a program costing $150 million over five years.

promote peace'. Both extreme forms of globalisation are being pursued in 2007, along with many more moderate examples and the massive trend towards the internationalisation of trade will be a major driver of the changes we will experience between now and 2030.

Globalisation[42] in essence means unfettered international trade, although the world still has a long way to go before all barriers to trade are removed. In principal, trade – and especially international trade – is a good thing in which all parties to the deal increase their wealth. Increasing global wealth is a noble aim and little is more successful in guaranteeing peace than improving prosperity. The financial benefits of globalisation are explained in an economic theory called 'comparative advantage'.[43]

European nations pioneered a colonial form of globalisation in the 18th and 19th centuries as they expanded their empires and traded goods all around the world, but since then free trade has suffered many setbacks from outbreaks of nationalism, protectionism, world wars (and a complete retreat from globalisation between the world wars) and over fifty years of global ideological polarisation between capitalism and communism.

Following the collapse of the Soviet Union and the end of the Cold War the stage was ready once again for trade on a truly global scale to resume. This time, however, long-distance trade was facilitated by the arrival of the internet, low-cost communications technology and (acknowledging the legitimate concerns over aviation's impact on climate change) low-cost air travel.

The most dramatic, and most obvious, example of the impact of globalisation followed the admission of China into the World Trade Organisation in 2001 when many international trade tariffs were lifted. As a direct result tens of millions of Chinese citizens have been lifted out of poverty[44] and in 2004 China overtook Japan to become the world's third-largest exporter, behind America and Germany.

The effect of WTO membership has been to bind China more tightly into existing and highly sophisticated pan-Asian production networks, a task greatly facilitated by the internet. Everybody in the region has benefited,[45] even rich Japan, which in 2002-03 was pulled out of a decade and a half's slump by Chinese demand for top-notch components and capital goods. South-East Asia has been given a further boost: rich in resources, including rubber, crude oil, palm oil and natural gas, it looks likely to profit from China's appetite for raw materials and energy for a long time to come. Now China's economy is growing by at least seven per cent each year, a trend which is forecast to continue for the next fifteen years.[46] By 2030 China's economy is expected to be the largest[47] or second largest[48] in the world.

But today 'globalisation' seems to be regarded by many people as the rape of poor ethnic cultures by the rich countries of the developed world – witness the mobs of anti-globalisation protestors[49] who turn up at most G8 meetings.

To critics, globalisation is seen as the 'McDonald'sization' and 'Disneyfication' of nations that have been softened up to welcome such a cultural and economic invasion by massive imports of American television shows and films. But the renowned veteran American futurist John Naisbitt[50] (author of the best-selling 1982 book 'Megatrends'[51]) rejects the idea that globalisation is a form of American cultural colonialism. In his 2006 book 'Mind Set! Reset Your Thinking And See The Future' he observes:

> The question is: 'Does globalization mean Americanization?' My short answer is no. In measuring globalization, we can count telephone calls, currency flows, trade sums, and so on, but the spread of culture and ideas cannot be so easily measured. Embedded in the present is the unrecognized paradox that culturally, America itself is changing more dramatically than America is changing the world. Immigration is reshaping America more profoundly than America's influence around the world. In the United States there are more Chinese restaurants than there are McDonald's.[52]

However, another world-famous American futurist, Jeremy Rifkin[53] – author of the bestselling books 'The End of Work',[54] 'The Biotech Century'[55] and 'The Age of Access'[56] – sees both sides of the argument. He writes in his 2002 book 'The Hydrogen Economy':

> Globalization is the defining dynamic of our time. Proponents look to it as the next great economic advance for humanity and as a way to improve the lives of people everywhere. Its critics view it as the ultimate example of corporate dominance over the affairs of society and as a means to deepen the gap

> between the haves and have-nots. Transnational corporations, with the help of the G7 nations, are lobbying to change government regulations and statutes that, they argue, restrict freedom of trade. Anti-globalists are taking to the street in greater numbers to protest what they contend is the systematic gutting of environmental and labour standards designed to protect the Earth's ecological and human communities from corporate rapacity.[57]

Globalisation is also seen as an excuse for multinational corporations to use dirt-cheap labour in the developing world to sell ever cheaper products (yet still profitable products) to greedy consumers in rich western societies.

But on the other hand, offshoring, outsourcing, free capital flows and free international trade (which is a less provocative way of describing the process) have the potential, if pursued fairly and in a sustainable manner, to both reduce poverty in the poorest nations and to bring benefits to consumers in the rich world.

The World Bank claims[58] that globalisation could spur faster growth in average incomes in the next twenty-five years than occurred during the period 1980-2005, with developing countries playing a central role. However, the Bank warns, unless managed carefully, it could be accompanied by growing income inequality and potentially severe environmental pressures.

Driven by globalisation from 1974 onwards, exports have doubled, as a proportion of world economic output, to over

25 per cent, and, based on existing trends, will rise to 34 per cent by 2030.

World income has itself doubled since 1980 because of globalisation, and almost half-a-billion people have been lifted out of poverty since 1990! According to current trends, adds the World Bank, the number of people living on less than the equivalent of $1 a day, will halve from today's one billion to 500 million by 2030. This will take place as a result of growth in Southeast Asia, whose share of the poor will halve from 60 per cent to 30 per cent, while Africa's share of the world's poor will rise from 30 per cent to 55 per cent. This represents a continental inequality which carries significant dangers to world stability.

By 2030 the world's richest nations will either be pursuing ethical, sustainable globalisation – by which I mean fair trade with proper concern for those with whom we trade and the environment in which we trade – or we will be manning the barricades against those who we have dispossessed.

As James Canton puts it in 'The Extreme Future':

> In its crudest sense, globalization is either going to be the most successful revolution to accelerate global democracy, free trade, and open markets, or it will victimize the poor nations of the world… This is perhaps the greatest challenge facing our civilization today. People without a future are the most dangerous people in the world. They will do anything to get a future – or to destroy those who they believe are robbing them of that future.[59]

But even as globalisation is starting to lift about five billion people out of abject poverty there are approximately one billion people trapped in about fifty-eight nations which are experiencing only minute growth, no growth at all, or actual economic shrinkage.

The people in these 'bottom states' don't have access to global markets (and even if they did get such access, they would have little to sell except natural resources).

Most, but not all, of these countries are in sub-Saharan Africa and, typically, their societies have reached a stage of development that is the equivalent to where the societies of Europe were between the 8th and 14th century A.D. These societies are so poor that the people are constantly fighting amongst themselves for what little wealth they possess (as European societies used to do). These societies suffer from plagues and famine, are largely illiterate, have only the most rudimentary healthcare and, because of chronic instability, they attract no foreign investment capital. Indeed, what little domestic capital exists or is generated is almost immediately exported to overseas bank accounts in the rich countries for fear of the same political instability.[60]

Massive amounts of western aid, both financial and in kind, have been given to the countries which are home to the bottom billion – no less than $2.3 trillion, according to William Easterly,[61] Professor of Economics at New York University – but it has made very little difference to the lives of ordinary people in the bottom billion.

The reason our aid has helped so little is that the problem is so great: many of the societies to which we gave our cash were so poor that it was immediately grabbed and embezzled by all who had any power at all – presidents, dictators, ministers, bank managers, customs officials, diplomats, contractors, even shippers.[62] Many such embezzlers may well have had extended families living in poverty and to put the general good of society above such personal considerations would require the conscience of a saint.

Economist Professor Paul Collier,[63] Director for the Study of African Economics at Oxford University writes in his 2007 book 'The Bottom Billion':

> All societies used to be poor. Most are now lifting out of it; why are others stuck? The answer is traps. Poverty is not intrinsically a trap, otherwise we would all still be poor. Think, for a moment, of development as chutes and ladders. In the modern world of globalization there are some fabulous ladders; most societies are using them. But there are also some chutes, and some societies have hit them. The countries at the bottom are an unlucky minority, but they are stuck.[64]

In this survey of what the world may be like in the year 2030 why should it matter so much to us in the developed world that a billion people (and, potentially, many more by 2030) will be stuck in abject poverty? There are two reasons; the first is the enormous financial cost to the developed world that failing and fighting nations inflict, the second is the almost certainty that such countries will increasingly exact their revenge on us for their abject poverty through international terrorism.

Globalisation must now be extended to specifically include the bottom billion, otherwise their vengeance on the rich world will become a seventh major factor that will shape our future – and for the worse.

5. Accelerating Technological Change

There will be more technological change in the next twenty-five years than occurred throughout the whole of the last century. And that was the century that produced aeroplanes, cars, plastics, nuclear power, television, the computer, the internet and mobile phones.

The reason I forecast such extreme change ahead is that the speed of technology development is itself accelerating. The key to understanding why this is occurring lies in realising that, a) technology development is itself an extension of human evolution and, b) the speed of technological development is the direct product of the rapidly increasing speed and richness of information flows around the world.

The noted American futurist and inventor Ray Kurzweil[65] has pointed out that since humans first began to extend their biological powers by inventing technology, technological innovation has itself been accelerating at an exponential rate. He writes:

> An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense 'intuitive linear' view. So we won't

> experience 100 years of progress in the 21st century – it will be more like 20,000 years of progress (at today's rate). The 'returns,' such as chip speed and cost-effectiveness, also increase exponentially. There's even exponential growth in the rate of exponential growth. Within a few decades, machine intelligence will surpass human intelligence, leading to The Singularity – technological change so rapid and profound it represents a rupture in the fabric of human history.[66]

Ray Kurzweil's reference to 'The Singularity'[67] in the above paragraph prompts me to explain the reason that I decided to fix the focus point of this report a quarter-century ahead and not fifty years hence or some other point further into the distant future.

Like Ray Kurzweil, I too am convinced (and have been so for decades) that we are rapidly approaching the point at which machine intelligence will reach a point of equality with human intelligence. Most futurists estimate that this seemingly disturbing phenomenon will occur sometime during the period between 2025 and 2035 and soon after this milestone is reached human life and society will begin to change in ways that are impossible to imagine using human insight alone.

Within a year or two of machines achieving human-level intelligence exponential technological development means that machines will have the potential to become twice as smart as humans. A year or so later they will be four times as capable. Soon afterwards their capabilities will be beyond any human form of measurement and beyond human understanding.

As I shall discuss in my later section on 'Accelerating, Exponential Technology Development', this is not necessarily the alarming prospect that it might seem, but it is the principal reason that current futurology is unable to peer much further ahead than the fourth decade of the 21st century. After that the future will become alien, unrecognisable and indescribable to present-day human audiences.

I regard the phenomenon of accelerating technological development as the 'joker in the pack' when it comes to considering future trends. During the next quarter of a century it is possible that presently unforeseeable 'wild card' technologies will be developed that will solve the world's demand for clean energy and, perhaps, even provide some degree of control over the world's climate. It might even solve the drinking water shortage. I shall return to these speculations in the relevant sections.

6. The 'Prevent-Extend' Revolution in Medicine (Prevention and Longevity)

While machines may be on what appears to be the verge of usurping our species on this planet, we humans will not be standing still. In fact we will be altering what it means to be human, and in some very dramatic ways.

Because humans often lack a language for the technological future I have created a portmanteau phrase – 'prevent-extend' – to describe a new form of medicine that will emerge over the next twenty-five years. Instead of attempting to provide cures for existing disease and ailments, the next medical revolution will produce a new discipline in the rich world that will focus on personalised medicine that will prevent illness and increase human longevity very dramatically.

The human genome was first sequenced[68] in 2001 and this provided pharmaceutical companies, medical researchers and academics with a map of what computer scientists would call 'human source code'. In other words, the sequencing laid bare all the component genes that go to make up a human being. The problem is that we are only now beginning to identify which genes do what in human biology and, as researchers are discovering, how combinations of seemingly separate genes work together to cause a particular effect.

Although a daunting task, considerable progress in gene identification is being made. Biologists at Harvard recently identified the gene responsible for triggering tanning[69] when skin is exposed to ultraviolet light. It turns out to be a well-known tumour suppressor called *p53*, often dubbed the 'guardian of the genome'.

Such knowledge may be put to use in both trivial and critical applications. A tanning lotion may one day be produced which turns on the *p53* gene to produce a natural tan within the skin without the user having to be exposed to the harmful effects of ultra-violet radiation from the sun. A more serious use might be to stimulate the body's *p53* genes to attack skin cancer.

As New Scientist reported in July 2007:

> It's not quite the elixir of life, but researchers may have found a way of keeping us younger for longer. In mice at least, increasing the production of two proteins called p53 and Arf enabled more of the animals to survive to old age while showing fewer signs of ageing.
>
> Since its discovery in 1979, p53 has been a key therapeutic target for cancer research. When activated, it encourages damaged cancer cells to commit suicide – a process called apoptosis.[70]

News of new gene identification now seems to increase daily. Key genes for fighting HIV-Aids[71] have been identified as has a gene that causes a particularly severe form of catatonic schizophrenia.[72] Researchers led by University of Cincinnati scientists have located a narrow region of genes that can sharply increase a person's risk of developing lung cancer[73] – one of the world's worst killers – and researchers in Montreal recently discovered a gene that seems to inhibit memory retention[74] (which, one day, may lead to a treatment for Alzheimer's disease).

Other disease-related genes identified include those for motor neuron disease, Type 2 diabetes, a gene that appears to inhibit breast cancer, one that causes stomach cancer, a gene that causes deafness and many more. We are starting to understand the buildings blocks of human biology.

Over the next few years the 'master map' of the human gene pool will be completed to a large extent and, as computer power rapidly increases, it will become possible to sequence the genomic map of each individual patient (at least, of those patients lucky enough to be living in the developed world).

In 'Extreme Future,' James Canton describes the coming medical revolution in the following way:

> Speculation about disease and treatment will give way to a more precise, predictive and health-enhancing type of medicine: Longevity Medicine. Medicine that has, at its core, an ability to peer into the genomic map of a specific individual, from birth to death. Doctors will have an unparalleled diagnostic tool: a person's own DNA. The next stage will include engineered disease prevention, health promotion and life extension.[75]

In addition to such a powerful approach to diagnostics, gene therapy[76] will harness the power of gene identification to produce new drugs and treatments many times more effective than present therapies.

Stem cell research[77] is another exciting new development that promises to revolutionise medicine. A stem cell is a basic embryonic human cell which has the ability to grow into almost any kind of cell. A number of stem cell therapies already exist, particularly bone marrow transplants[78] that are used to treat leukaemia.[79] In the future, medical researchers anticipate being able to use technologies derived from stem cell research to treat a wider variety of diseases including forms of cancer,[80] Parkinson's disease,[81] spinal cord injuries,[82] and muscle[83] damage, amongst a number of other impairments and conditions.

In the near future, stem cell medicine even promises to grow new bone and tissue for human use that is based on the patient's own DNA. There is good reason to believe that stem cells may allow us to repair and re-grow damaged organs[84] and, eventually, to grow 'replacement organs' which would be at no risk of rejection from our immune systems. Replacement human bladders[85] have already been grown and transplanted into humans using stem cell techniques. Recently heart tissue was grown from stem cells[86] suggesting that within five years whole replacement hearts could be grown and scientists have recently succeeded in producing pancreatic cells[87] from stem cells that produce insulin, holding out the hope that diabetes might one day be curable by the growth of a new pancreas. By 2030 such organ regeneration will be routine and almost all other organs will also be grown from stem cells. We will have our 'back-up' parts.

From this discussion of personal DNA mapping, gene therapy drugs and stem cell research you will begin to see why I have contracted and combined the words preventive and longevity to produce my new phrase, 'prevent-extend.'

Writing in 2006, James Canton also observed:

> In the decades to come, medicine will be revolutionized. The convergence of pharma, biotech, and nanotech industries will form the biggest global marketplace with one underlying theme: life extension for sale.
>
> Botox today will lead to gene-replacement therapy tomorrow. Face-lifts today, nano-engineering stem

> cells for babylike, wrinkle-free skin tomorrow. Even memories will be for sale, with superagility and enhanced intelligence thrown in for good measure.[88]

Well, leaving aside Dr. Canton's focus on the commercial bonanza that may derive from the new medical revolution (a perspective all too understandable given the USA's ultra-capitalist approach to social healthcare), I agree with his conclusions and I would add that plastics will play an increasingly large part in healthcare provision over the next twenty-five years. It seems to me that within the period covered by this report, those of us in the rich world will be immeasurably healthier and will live far longer than we currently anticipate.

It is even possible that a child born in the year 2030 may have the option of extending his or her healthy and youthful life almost indefinitely.

Section One

Accelerating, Exponential Technology Development

Consulting Referee:

Professor Allison Druin,[89]
Director, Human-Computer Interaction Laboratory,
University of Maryland, USA

The wealth of the developed world has been generated largely by the invention and application of increasingly sophisticated technology. It is for this reason that I cover this subject first; technology development will have a significant impact on all of the other subjects discussed in this report.

In a paper called 'Technological Revolutions: Ethics and Policy In The Dark', Dr Nick Bostrom[90], Director of the Future of Humanity Institute, the Faculty of Philosophy at Oxford University, makes clear technology's role in our modern society:

> Technological change is in large part responsible for the evolution of such basic parameters of the human condition as the size of the world population, life expectancy, education levels, material standards of living, the nature of work, communication, health care, war, and the effects of human activities on the natural environment. Other aspects of society and our individual lives are also influenced by technology in many direct and indirect ways, including governance, entertainment, human relationships, and our views on morality, cosmology, and human nature. One does not have to embrace any strong form of technological determinism or be a historical

> materialist to acknowledge that technological capability – through its complex interactions with individuals, institutions, cultures, and the environment – is a key determinant of the ground rules within which the game of human civilization is played out at any given point in time.[91]

In the previous section 'The Backdrop to 2030' I quoted the American futurist Ray Kurzweil's observation that 'the rate of technological development is exponential' and that even this rate is itself speeding up exponentially. Other futurists agree and some go so far as to suggest that accelerating technological change produces accelerating change in society itself.

Rolf Jensen[92] of the Copenhagen Institute for Future Studies[93] describes this in his 1999 book 'The Dream Society':

> The pace of development from one societal type to another is accelerating. The agricultural society originated 10,000 years ago, the industrial society between 200 and 100 years ago, the information-based society 20 years ago. Who knows how many more years the logic and economics of the Information Society will last?[94]

And Alvin Toffler,[95] the world-famous American futurist whose work initially inspired me to go into the field, put it even more bluntly in his best-selling 1970 book, 'Future Shock':

> Western society for the past 300 years has been caught up in a fire storm of change. This storm, far from abating, now appears to be gathering in force.[96]

I agree with these views about constant increase in the velocity of development, both technological and social, and it is for this reason that I have coupled such seemingly tautologous terms as 'accelerating' and 'exponential' in my heading for this section.

But 'exponential' is an easy concept to understand in theory (a doubling every so often – usually over a set, regularly recurring period) but it is hard to appreciate fully how powerful exponential effects are. When a small number doubles the change is almost unnoticeable; when a large number doubles the effect is overwhelming. We are now moving into a period when the effects of exponential technological development will be very noticeable indeed.

Ray Kurzweil also makes the apparently astonishing claim that such exponential development is a natural part of human evolution. In his 2005 book 'The Singularity Is Near' he writes:

> The future is widely misunderstood. Our forebears expected it to be pretty much like their present, which had been pretty much like their past. Exponential trends did exist one thousand years ago, but they were at that very early stage in which they were so flat and so slow that they looked like no trend at all. As a result, observers' expectation of an unchanged future was fulfilled. Today, we anticipate continuous technological progress and the social repercussions that follow. But the future will be far more surprising than most people realise, because few observers have truly internalised the implications of the fact that the rate of change itself is accelerating.

> Most long-range forecasts of what is technically feasible in future time periods dramatically underestimate the power of future developments because they are based on what I call the 'intuitive linear' view of history rather than the 'historical exponential' view.[97]

Kurzweil is a man whose views should be taken seriously. As well as being a noted futurist[98] and best-selling author he is an inventor and engineer, recipient of 12 honorary doctorates, the Lemelson-MIT Prize and the US National Medal of Technology. He was the principal developer of the first omni-font optical character recognition, the first print-to-speech reading machine for the blind, the first CCD flat-bed scanner and the first text-to-speech synthesiser.

His suggestion that exponential technology development is a natural evolutionary trait that has, until recently, been masked from view by slow progress during its early phase, appears to be borne out by an examination of the history of technological progress.

The agricultural revolution began about 12,000 years ago but it took another 6,000 years before humans developed the three virtual technologies that have shaped our modern world; alphabetic writing, mathematics and the invention of money. (When I describe these technologies as 'virtual' I use the word in its original meaning, not in the computing sense of 'virtual reality.' The English word 'virtual' derives its etymology from the Latin word 'virtualis', which implies something which has an essence or an effect without necessarily having a physical existence.)

The development of physical technologies was even slower in early history. Humankind didn't discover how to produce iron for another 4,000 years (approximately 3,000 BCE, at about the same time as our species learned how to harness wind power for sailing).

The (relatively) stable period of Greek and Roman civilisation ushered in many new military and domestic technologies but, following the collapse of Rome, there followed the Dark Ages – almost 800 years of conflict, pestilence and plague that created a stasis which prevented the invention of any significant new technologies (at least, in Europe).

The ramping up of exponential technological development which has led to today's (seemingly) frenetic pace of innovation began in the 15th century with the European invention of printing with moveable type. This allowed the knowledge learned by each generation to be stored, replicated inexpensively, distributed and forwarded for the benefit of future generations – and it triggered the Renaissance.

Now, as the young first began to stand on the shoulders of giants, the speed of technological development started to gather pace and it is possible in hindsight to discern its exponential nature (an acceleration fuelled by faster and richer information flows – the key driver of all accelerating technological development).

In the 16th and 17th centuries the science of navigation developed alongside the measurement of time and the shipbuilding technology necessary to build galleons and warships. Telescopes were invented to gaze into the heavens, anatomists peered inside the human body and natural philosophers pondered the physical laws of the universe.

By the time civilisation reached the 18th century, scientific discovery and technological development were proceeding at such a pace that it triggered the industrial revolution that was to change western society for ever. Workers left rural areas for cities and began to create our modern way of life. Today cities dominate our economies, our nations and our way of life. (Eckard Foltin, resident futurist at Bayer Materials Science in Germany, has postulated in a report called 'A Picture Of Tomorrow'[99] that by 2020 there may either be a strong trend towards ever larger and more dominant 'megacities' or a technological elite will emerge which will polarise society between the extremely wealthy and the rural poor.)

In the 19th century, 'technological invention' in the sense we understand the phrase today began to shape history and drive progress. The harnessing of electricity and the subsequent development of the telegraph, the telephone, railroads, the automobile and radio laid the foundations for the most recent century of technological innovation (and technology-mediated war). Information and knowledge flows within society became ever faster.

And here, considering the momentous developments of the Victorian Age, we first notice a difficulty that inhibits our ability to think meaningfully about the future: when developments come thick and fast we lack a language with which to describe our technological future. And, I suggest, where there is no language, there can be no meaningful thought.

By definition the invention of new technologies produces actions and capabilities for which we have not yet invented words and for which we do not have concepts. We struggle to describe the capabilities of new technology by shoe-horning existing words and concepts together.

For example, when the projector was first invented it was called a 'magic lantern' and the railway locomotive was an 'iron horse'. The automobile was a 'horseless carriage' and the radio was a 'wireless.' A refrigerator was an 'ice box' and an aeroplane was a 'flying machine' – you get my point.

But even though society lacked the language with which to think about and describe new capabilities, technological development continued on its ever quickening exponential curve through the 20th century – delivering automobiles, television, computers, jet travel, space exploration, plastics, high performance polymers and composites, computer networks, the internet and mobile phones to mention just a few 20th century innovations.

The American futurist John Naisbitt explores the problems that such accelerating development brings to society in his 2006 publication, 'Mind Set! Reset Your Thinking And See The Future':

> The advances of technology have always resulted in social change. The discovery of fire led to warmth, better food, and the beginning of real community.

> The wheel, electricity, and the automobile all dramatically changed our social arrangements. The difference today is that the accelerated rate of technological change has been so great that the social accommodation to new technology has lagged further and further behind. The evolution of technology is now running ahead of cultural evolution, and the gap is increasing.[100]

And in the 'gap' between technological evolution and cultural evolution that John Naisbitt describes is a no-man's land in which we lack even the language to describe the new technologies and the new concepts they bring to our lives.

A good example of our paucity of language for describing new technology is the term 'mobile phone.' Nobody has a mobile phone which is just a phone any more. All popular models (made mostly of plastics) store information in a database, many models have cameras built in, some are able to play music, others offer GPS tracking systems and one model is also a magic lantern.[101]

The phrase 'mobile phone' will probably come to seem as quaint as 'horseless carriage' once a new, more accurate and all-embracing term for this universal network device gains widespread acceptance.

But whether or not we have got the words with which to describe new technologies and their potential (what they can do and the social, economic and political repercussions they will bring), new inventions, concepts and techniques are flooding out of the world's laboratories and development centres at an ever increasing pace.

And it is for this reason that I open the main part of this report with a discussion about the type of technologies that may emerge between now and 2030 (and because the implications of this exponential technology development are so extreme). As I mentioned in my 'Backdrop' section, new technology is the 'joker' in the pack of cards that will shape our future. It has the greatest potential to affect dramatically all of the other 'key drivers' of change that I have identified – except, alas, the continuing explosion in the world's birthrate.

New technologies likely to be developed between now and the year 2030 may even have the potential to offer partial solutions to problems such as climate change and the looming energy deficit. For example in May 2007 the San Francisco Chronicle reported:

> Scientists are eyeing the jet stream, an energy source that rages night and day, 365 days a year, just a few miles above our heads. If they can tap into its fierce winds, the world's entire electrical needs could be met, they say.
>
> Dozens of researchers in California and around the world believe huge kite-like wind-power generators could be the solution. As bizarre as that might seem, respected experts say the idea is sound enough to justify further investigation.[102]

And in July 2007 New Scientist reported on plans to counteract the effect of global warming by blocking some of the sun's rays from reaching the planet:

> Basically the idea is to apply 'sunscreen' to the whole planet. It's controversial, but recent studies suggest there are ways to deflect just enough of the sunlight reaching the Earth's surface to counteract the warming produced by the greenhouse effect. Global climate models show that blocking just 1.8 per cent of the incident energy in the sun's rays would cancel out the warming effects produced by a doubling of greenhouse gases in the atmosphere. That could be crucial, because even the most stringent emissions-control measures being proposed would leave us with a doubling of carbon dioxide by the end of this century, and that would last for at least a century more.[103]

Whether or not new technologies will play a role in mitigating climate change, new technologies and techniques seem almost certain to radically enhance human health and longevity and, setting aside potential, unpredictable catastrophes such as global epidemics, natural disasters or massive nuclear war, new technological developments (coupled with globalisation) seem certain to drive robust economic growth all around the world. To put it simply, machines are now generating value and wealth for our societies and they will generate more and more wealth as they become rapidly smarter.

Any dissertation on the potential benefits of technological progress always risks the author being accused of hubris, techno-prolepticism and an overly optimistic attitude to the future. This is not my standpoint and while many analysts study technologies in isolation, I believe that it is important to see them in their social and human contexts. Technology is no panacea, as we shall see in the later sections of this report that deal with 'Climate Change and the Environment' and 'The Future of Energy'.

However, I have been certain for some decades that in creating intelligent machines the human race is in the early stages of creating a successor to or companion species for human beings. Many other commentators have reached the same conclusion. Writing in the New Scientist magazine Dr James Hughes,[104] Executive Director of The Institute for Ethics and Emerging Technologies[105] in Connecticut, observed:

> It seems plausible that with technology we can, in the fairly near future, create (or become) creatures who surpass humans in every intellectual and creative dimension. Events beyond this event–call it the Technological Singularity–are as unimaginable to us as opera is to a flatworm.
>
> The preceding sentence, almost by definition, makes long-term thinking an impractical thing in a Singularity future.[106]

We are, however, able to project a likely pathway towards the point of disjuncture in human evolution that is being called 'The Singularity', even though along the way the ever increasing rate of technological development will produce wrenching and continuous change in all of our lives.

We don't have any option but to embrace change, and very rapid change, in the 21st century and the only successful antidote to the painful symptoms of change that I have discovered is continuous, life-long learning. Keeping up to date is vital to weather the storms produced by high-speed, violent change. As Louis Pasteur remarked: 'Change favours the prepared mind.'

Rolf Jensen of the Copenhagen Institute for Future Studies describes it very simply in 'The Dream Society':

> The past is receding from us at a dizzying speed. The future is heading toward us with increasing velocity. You might say that the future is drawing closer – it is almost becoming part of the present.[107]

At the root of almost all of this change is the computer – these days specifically the microprocessor and its associated architectures – which until a few years ago was doubling in power and speed every two years but which now appears to be developing even faster.

Moore's Law

The most important of all of mankind's inventions will turn out to be the computer – and, by extension, computer networks, wired and, increasingly, wireless. As the computer is a universal tool it is of crucial importance to the future of science, medicine, security, business, education and industrial activity. The most dramatic technological change in society is driven by advances in computer power and miniaturisation – for example in drug development, mobile phones and cellular networks, the internet, nanotechnology and brain scanners. In fact, almost all technological development is now wholly dependent on the computer (which itself is wholly dependent on plastic components).

In April 1965 Gordon Moore,[108] one of the two founders of the chip maker Intel, saw an article of his published in the American publication Electronics Magazine. He wrote:

> The complexity for minimum component costs has increased at a rate of roughly a factor of two per year... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65,000. I believe that such a large circuit can be built on a single wafer.[109]

This prediction was proved correct and the phenomenon of computer power continuing to double every two years became so startling that the visionary observation came to be honoured as 'Moore's Law.'[110]

Today, even though 'Moore's Law' is often evoked (usually inaccurately) to describe the high speed of microprocessor and computer development, the concept has become something of a self-fulfilling prediction (more 'lore' than 'law') and has become a 'bench-mark' to which the computer industry works.

Tellingly though, Moore's law has contracted sharply and microprocessor speeds and densities have for many years been increasing much faster than Gordon Moore predicted in 1965.

Dr. Nick Bostrom observed in a 1997 paper on super-intelligent machines:

> Moore's law states that processor speed doubles every eighteen months. The doubling time used to be two years, but that changed about fifteen years ago. The most recent data points indicate a doubling time as short as twelve months. This would mean that there will be a thousand-fold increase in computational power in ten years. Moore's law is what chip manufacturers rely on when they decide what sort of chip to develop in order to remain competitive.[111]

Also in 1997 noted American futurists Marvin Cetron[112] and Owen Davis[113] wrote in their best-selling book 'Probable Tomorrows':

> If the most optimistic computer scientists are correct, tomorrow's shirt pocket computer could hold a billion bytes (a gigabyte) in its working memory (RAM) – and run at 50 million times the speed of today's fastest personal computers.[114]

Well, that ten year old prediction was heading in the right direction; my shirt pocket iPod offers 80 gigabytes rather than a single gigabyte of storage but shirt-pocket processing power has not yet multiplied by a factor of 50 million.

So where precisely are we ten years later, and where will we be in terms of processor speed and power in the year 2030?

The answer is that this simplistic question about microprocessor power is no longer adequate or appropriate to judge computer performance.

Computer power no longer relies on the speed of a single processor. Today, computing is a networked activity, both within microprocessor architecture and between independent computers. Microprocessors now have multiple ‘cores’ (i.e. processing engines) and many multi-core processors are harnessed together in a ‘cluster’ or ‘grid’ of computer power which can be ‘local’ or truly ‘global’.

An idea of how powerful multi-core processors are becoming may be gleaned from the following story which appeared in the magazine MIT Technology Review in February 2007:

> Last week, Intel announced a research project that made geeks jump with glee: the first programmable ‘terascale’ supercomputer on a chip.
>
> The company demonstrated a single chip with 80 cores, or processors, and showed that these cores could be programmed to crunch numbers at the rate of a trillion operations per second, a measure known

> as a teraflop. The chip is about the size of a large postage stamp, but it has the same calculation speed as a supercomputer that, in 1996, took up about 2,000 square feet and drew about 1,000 times more power.[115]

This news from Intel, still an industry leader after many decades, suggests that Dr. Nick Bostrom's 1997 prediction about the increase in computer power that would occur between the years 1997-2007 is at least accurate and has probably been exceeded. But the important point to note in the extract from the MIT Technology Review story is that dramatic miniaturisation occurred in the chip design along with a significant reduction in energy used during operations.

In fact, the amount of energy now demanded by multi-core microprocessors has become a significant issue. The Economist observed in March 2007:

> The first (energy conservation method) is new 'multi-core' processor chips, in which performance is improved not by increasing clock speed, but by building several processing engines, or 'cores', into each chip–a far more energy-efficient approach. AMD, Intel and Sun now boast of their chips' 'performance per watt' (i.e. work done for each unit of energy), rather than simply emphasising raw performance. Dual-core chips are commonplace, and quad-core chips are spreading too. The switch from dual-core to quad-core over the past 18 months increased performance per watt by a factor of 4.5, says Stephen Smith of Intel.[116]

It is possible that chip developers may hit some sort of physical barrier in the next quarter of a century as they struggle to make their processors ever faster and ever smaller. They are already working at close to nano-scale[117] and making great use of plastics for insulation, even for microprocessor manufacture.[118] However, it is still possible that difficulties of heat dissipation, input and output connects, the barrier of the speed of light itself or problems with the materials in use, may bring an end to the super-charged Moore's law speed of development.

For example, the following comes from a ComputerWorld article published in March 2007:

> Makers of memory chips are looking ahead to a day, not too far off, when technology based on silicon bumps up against the laws of physics and memory can't be made any smaller. That development will have implications for gadgets like MP3 players and digital cameras.
>
> These concerns have major memory makers pouring hundreds of millions of dollars into perfecting the next big technology.
>
> The possible alternatives sound like science fiction: M-RAM, P-RAM, molecular memory and carbon nanotubes.[119]

Yet in 1982 I was writing similar qualifications about future chip development as I surveyed what then seemed the breathless pace of microprocessor development. Back then scientists were suggesting that a move to super-cooled computing would be required for development to continue at its present pace (using Josephson Junctions[120]) and many were suggesting that the chip substrate silicon would have to be replaced with more exotic materials such as gallium arsenate.[121]

Today chip designers are contemplating the move to nano-scale design, new substrates (including plastics) and even quantum-level computing. According to the academic journal Nature, one new substrate with promise for future processor designs is graphene:

> The latest contender to succeed silicon's throne is graphene. It has been used to make a truly tiny transistor that works at room temperature, offering hope for making faster, smaller electronics devices once silicon reaches its limits (around 2020).
>
> Graphene is a two-dimensional form of carbon, discovered just three years ago. It is very thin – just one atom thick – and highly conductive with minimal resistance, which has sent physicists and materials scientists into a frenzy to find applications that exploit these properties.[122]

Polymers (plastics) also play a role in allowing chip developers to design and fabricate at nano-scale. In May 2007 Hewlett-Packard made an important announcement:

> Hewlett-Packard and Nanolithosolutions say they have a machine that will let semiconductor manufacturers produce chips sporting wires measuring a few atoms wide.

> And the device takes only a few minutes to install.
>
> The machine is a system for imprint lithography. Imprint lithography sounds like what it is: a mold with an intricate pattern is pressed into a substrate, which creates a pattern. The grooves and channels created in the substrate are then filled with metal to make wires.
>
> What makes imprint lithography different from a waffle iron or a rubber stamp are the dimensions. The HP-Nanolitho system is capable of creating grooves that will measure as small as 15 nanometers, smaller than the width of wires in today's chip. The mold, or module, does not make grooves in silicon, but in a thin layer of polymer on top of the silicon.[123]

I am of the opinion that no insurmountable physical barrier to ever accelerating microprocessor development lies ahead in the foreseeable future. It is clear that a move to nano-scale fabrication will be needed and new materials may very well be required (and here plastics will play a significant role) but I have no doubt that in a quarter of a century's time commentators will still be wondering whether there is any end in sight for the exponentially accelerating development of microprocessors (or will they then be called nanoprocessors?).[VI]

[VI] In August 2007 IBM's Zurich Research Lab demonstrated a molecular switch that could replace current silicon-based chip technology with processors so small that a supercomputer could fit on a chip the size of a speck of dust.– IBM also claims its atomic-scale demonstration promises to pack up to 1,000 times as much information on a hard disk than current technologies.– Such hard disks could store 30,000 full-length movies on a device the size of an iPod.

In the end, because the exponential rate of technology development is, itself, increasing exponentially it is almost impossible to estimate precisely how much more powerful and more capable the computers of 2030 will be.

There are, however, some well-qualified experts prepared to stick their necks out and make firm predictions about the likely speed and power of computers and their networks in the year 2030. Dr. Paul D. Tinari,[124] Director of the Pacific Institute for Advanced Study (and formerly a Professor of Future Studies at San Francisco University) writes:

> According to Moore's Law, computer power doubles every 18 months, meaning that computers will be about 500,000 times more powerful by 2030. Furthermore, according to Nielsen's Law of Internet bandwidth,[125] connectivity to the home grows by 50 per cent per year; therefore by 2030, people will have about 100,000 times more bandwidth than today. By that year, chances are you will own a computer that runs at 2.5 PHz CPU speed, has half of a petabyte (a thousand terabytes) of memory, one quarter of an exabyte (a billion gigabytes) of hard disk-equivalent storage, and will connect to the Internet with a bandwidth of an eighth of a terabit (a trillion binary digits) per second.[126]

So, Dr. Tinari suggests that the computers of 2030 will be half-a-million times more powerful than today's machines. My view, however, is that he has underestimated. His projections seem to ignore the evidence that the rate of exponential change is itself speeding up exponentially and he also has done his calculations from a starting assumption that Moore's law is still holding at eighteen months when there is considerable evidence that it is currently running at twelve months or even less.

And, in an interview given to InstaPundit.com Ray Kurzweil laid out his own prediction for computing speeds in 2030:

> By 2030, a thousand dollars of computation will be about a thousand times more powerful than a human brain. Keep in mind also that computers will not be organized as discrete objects as they are today. There will be a web of computing deeply integrated into the environment, our bodies and brains.[127]

Given these two very different methods of predicting the future speeds of computers let me conclude this section by adding that my view is that the networked computers of 2030 will be at least several million times more powerful than today's machines - a prediction, which if correct, will carry vast implications for the future of humankind.

The 'Always On, Always Connected' Society

I suggested earlier that we often lack a language with which to describe a new technology or a concept. We are just entering a startling period in which the internet, the Web, cellular telephony, television, radio and wireless communication will all merge to become a new global 'communications medium.'

This new ‘medium’ (and what a poor, underpowered term that word is) is one in which people and things will be ‘always on, always connected, everyone to everyone, everything to everything, always and everywhere’.

That last long-winded and very wordy sentence was necessary because we don’t yet have a word or a phrase to describe such a pervasively connected electronic firmament. But even though we are just starting to build this new habitat for humankind, and we lack the language necessary to describe it, the technology will be in place, fully mature and available at very low cost in all countries of the world (and in space and on at least one other planet) by the year 2030.

Everybody is familiar with the internet and its graphical interface, the World Wide Web. Everybody is familiar with cellular phones, television and radio. The new components in this merged ‘wireless super-web’ are minute intelligent machines that will communicate with each other wirelessly. At its simplest, these machines may be no more than plastic Radio Frequency Identification Tags (RFID tags[128]) that send out self-identifying signals and data when interrogated by a nearby wireless scanner. On a more complex level, machine sensors will be embedded in bridges and other vital structures to transmit data about stress loading and construction integrity. Machines transmitting wireless signals will travel our bodies sending out information about our physical condition and, to pick just one further example, firemen in burning buildings will all wear wireless sensors that send back their position and details of the conditions they are encountering.

Soon, almost everything in the world will become attached to this 'enlarged internet' for which we do not yet have a name. All sorts of technologies will be employed from traditional internet protocol communications to cellular radio signals, stand-alone wireless communications and satellite transmissions. In the end all of these discrete technologies will become one and the same thing: a global communications 'mesh' in which everything from local street lights to a jet plane travelling at 30,000 feet will be connected.

The signs of the emergence of this new 'medium' are already clear to be seen now. In April 2007 a contributor to The Economist wrote:

> Gizmos and gadgets will talk to other devices – and be serviced and upgraded from afar. Sensors on buildings and bridges will run them efficiently and ensure they are safe. Wireless systems on farmland will measure temperature and humidity and control irrigation systems. Tags will certify the origins and distribution of food and the authenticity of medicines. Tiny chips on or in people's bodies will send vital signs to clinics to help keep them healthy.
>
> Imagine how wireless communications could change motoring. Carmakers are starting to monitor vehicles so that they know when to replace parts before they fail, based on changes in vibration or temperature. If there is a crash, wireless chips could tell the emergency services where to come, what has happened and if anyone is hurt. Traffic information can be

> instantaneous and perfectly accurate. They administer tolls based on precise routes. One American firm leases cars to people with bad credit who cannot get a loan, knowing that if payments are missed it can block the ignition and find the car to repossess it. British insurers offer policies with premiums based on precisely when and where a person drives.[129]

Dr David Clark,[130] a computer scientist at the Massachusetts Institute of Technology who helped develop the internet, believes that in fifteen or twenty years' time the network will need to accommodate a trillion devices, most of them wireless.

> Even though we are only at the beginning of the development of what some people have called 'the internet of things', novel and supremely useful applications are emerging. Companies like the giant retailer Wal-Mart[131] are already tracking their inventories with RFID tags and soon shoppers will no longer need to unload their shopping carts at checkout tills. The RFID tags on every item will simply transmit their identities to a scanner and a bill will be presented to customers (who will pay it by waving their mobile devices over the scanner) – and all of these enabling devices will be made largely of plastic, a material that is rapidly becoming 'smart'.
>
> Wireless sensors will make a huge contribution to energy conservation. If every light fixture in a building contained a small wireless node, people would not only be able to control the lighting more effectively

but put them to many other uses too. If the nodes were programmed to serve as online smoke detectors, they could signal a fire as well as show its location. They could also act as a security system or provide internet connectivity to other things in the building. In 'The Hydrogen Economy' Jeremy Rifkin tells us:

> In the very near future, sensors attached to every appliance or machine powered by electricity – refrigerators, air conditioners, washing machines, security alarms – will provide up-to-the-minute information on energy prices, as well as on temperature, light and other environmental conditions, so that factories, offices, homes, neighborhoods and whole communities can continuously and automatically adjust their energy requirements to one another's needs and to the energy load flowing through the system.[132]

The Dutch electronics manufacturer Philips plans to introduce wirelessly controlled lighting systems for commercial buildings by 2012. And the company's researchers are working on making networked light fittings capable of monitoring the objects throughout a building, tracking equipment in hospitals or preventing theft in offices.

In the UK the building services firm Rentokil[133] has added a small plastic sensor and a wireless module to its mousetraps so that they notify the building staff when a rodent is caught. This is a big improvement on traps that need to be inspected regularly. A large building might contain hundreds of them, and a few are bound to be forgotten.

Since June 2006 thousands of digital mousetraps have been put in big buildings and venues such as London's new Wembley Stadium. The traps communicate with central hubs that connect to the internet via the mobile network to alert staff if a creature is caught. The system provides a wealth of information. The data it collects and analyses on when and where rodents are caught enable building managers to place traps more effectively and alert them to a new outbreak.

New examples of 'machine-to-machine' (M2M) communications applications are being announced almost every day. In the USA some prisons have already placed location and identification sensors[134] in plastic bracelets worn by all of their inmates (and their guards) and they report significant reductions in violence as a result of their use.

By 2030 we will all be 'tagged' but it will be for our protection, rather than to restrict out movements (and if you don't like the idea of humans being 'tagged' consider the fact that your mobile phone negotiates with your cellular wireless network 800 times every second and your network always knows where your phone is whenever it is switched on).

We will all transmit our locations constantly, data about our bodies' vital signs and physiology will be collected and transmitted to ensure our well being and, if we are taken ill, help will be summoned automatically. All soldiers on battlefields will transmit their location, all passengers on underground railways will transmit their location (Londoners, remember the plastic Oyster card you carry is an RFID chip), shop doorways will recognise returning customers and football fans will carry tickets which identify which team they are supporting and whereabouts they are in the stadium. Leaky taps in our buildings will call the plumber themselves and energy-consuming devices will shut themselves down when they sense they are not required.

There will be massive privacy issues when we are all permanently connected, along with our possessions and the environment around us. New laws will be required to protect our rights and new ways of enforcing such legislation will be necessary; but despite these concerns, we are rushing headlong into a fully connected, 'always on, always connected, always and everywhere' future.

This 'permanently connected' environment is stimulating new ways of human interaction as the web itself becomes more powerful. Recently a slew of new technologies known under the umbrella term 'Web 2.0'[135] brought significantly enhanced levels of functionality to web communication and processing (and allowed software applications such as word processing and spreadsheets to be used as an inherent part of the web rather than as stand-alone software on individual computers). And, as the web becomes ever more capable, humans are finding new ways to exploit its potential and collaborate in new ways.

One of the most interesting of these new developments – and one that will scale up easily as web capability increases – is the emergence of so-called 'Wiki communities'.[136] Named after the free, user-built online encyclopedia, Wikipedia,[137] Wiki communities use Wikipedia-style collaborative spaces to brain-storm particular problems, to manage projects and to develop a pool of social community knowledge (and maybe even wisdom). One good example of a Wiki community in action is discussed on a website called Wikinomics:

> A wiki is used in the Netherlands to plan wind turbines, to realise a CO_2 cut of 20 to 30 per cent. On the wiki, extended with a googlemaps plug-in, maps with proposed wind turbine locations are designed. The goal of the wikiprocess is to present locations for 6,000 3MWatt turbines, enough to provide for all electricity in the Netherlands.[138]

This new, emerging 'wireless firmament' (for want of a better phrase) will be the place where we chat, play, conduct business, earn money, administer government, learn, fall in love, have sex, store our memories, remember and honour the dead, and connect all of our loved ones and friends, our inanimate objects and ourselves. It is humanity's future.

This is not a new idea to me. Twenty-five years ago I wrote 'The On-Line Handbook'[139] in which I said:

> The linking of computers around the world is going to have far-reaching effects, and the spread of knowledge, the interchange of ideas and the dissemination of information are going to produce a revolution in our society.
>
> The moment you go on-line you feel as though the revolution has sprung down the telephone line and invaded your own room.

> You will know what the wired world is like and you will begin to understand the implications! You become a pioneer of the information age, experiencing with awe the power of linked computers which the next generation will take for granted.[140]

And by 2030 the experience of using this ‘super combined web’ will also be far more rich and multi-sensory than it is today, but it will be totally invisible and wholly pervasive. ‘Internet access’, in the absence of future language, will be provided by lamp posts, windows, in trains, on planes, by buildings and by church steeples. It will be ‘the internet of the air’ in which we, our children, our pets and trillions of inanimate objects (and some very intelligent machines) commune every second of the day.

The high speed super-web of 2030 will deliver 3D holographic images of sports events, dramas, games and sex simulations. The super-web will be able to provide tactile simulations, odours and tastes. The multi-sensory super-web will create virtual experiences that will seem so real they are almost indistinguishable from the real thing (and as we sense the ‘real thing’ solely though our own human sensory apparatus, who is to argue which is the more real?).

In time, perhaps before 2030, our minds will be directly attached to the super-web by a neural interface and, with a thought, we will be able to access the world’s entire stock of information, communication, learning, entertainment and leisure activities in full sensory glory. It sounds like science fiction, but by 2030 some people will be enjoying such astonishing access.

Machine Super-Intelligence (Strong Artificial Intelligence)

If some of the above has left you breathless, I am afraid that there are more breathtaking ideas to come in this survey of likely (or almost certain) technological development in the next twenty-five years. The first of these is super-intelligent machines or, to use plain language, machines that are as clever as you or me.

The science of trying to develop super-intelligent machines used to be called 'Artificial Intelligence' (AI) and, in the early 1980s, there was intense debate about how soon AI could be developed and how soon really clever computers would be helping surgeons, controlling traffic flows, running air traffic control and generally making human life better and safer.

But to the outside world the efforts of the AI community appeared to fail and the quest to develop Artificial Intelligence seemed to dissipate and fade away. In reality, it did no such thing; it just developed in a way that was unexpected. Our anthropomorphic impulses led us to assume that a human-like robot would spring from the artificial laboratories of the 1980s ready to become our companion. But twenty years ago we hadn't even begun to understand what a human was either in terms of brain function or physiology. Our chances of building a copy of ourselves at that time were zero.

However, sophisticated machine intelligence (albeit not very human seeming) has been developed and deployed out of the continuing research into what was once called 'artificial intelligence'. Software systems now run and control (with human oversight) jets in flight, air traffic control systems, human surgery and military weapons systems. These AI systems are robust and extremely useful and our modern world couldn't run without them.

Professor Marvin Minsky[141] of the Massachusetts Institute of Technology in Boston, USA, is widely regarded as the 'father of artificial intelligence'. Speaking to Discover magazine in 2007 he explained:

> The history of AI is sort of funny because the first real accomplishments were beautiful things, like a machine that could do proofs in logic or do well in a calculus course. But then we started to try to make machines that could answer questions about the simple kinds of stories that are in a first-grade reader book. There's no machine today that can do that. So AI researchers looked primarily at problems that people called hard, like playing chess, but they didn't get very far on problems people found easy. It's a sort of backwards evolution. I expect with our commonsense reasoning systems we'll start to make progress pretty soon if we can get funding for it. One problem is people are very skeptical about this kind of work.[142]

Asked about his latest 2007 book 'The Emotion Machine' Minsky went on to describe the sort of artificial intelligence machine he would like to build today:

> The book is actually a plan for how to build a machine. I'd like to be able to hire a team of programmers to create the Emotion Machine architecture that's described in the book–a machine that can switch between all the different kinds of thinking I discuss. Nobody's ever built a system that either has or acquires knowledge about thinking itself, so that it can get better at problem solving over time. If I could get five good programmers, I think I could build it in three to five years.
>
> We humans are not the end of evolution, so if we can make a machine that's as smart as a person, we can probably also make one that's much smarter. There's no point in making just another person. You want to make one that can do things we can't. [143]

But because 1980s AI research was mistakenly considered to be a failure, current research into developing computers with human-like intelligence and characteristics and intelligence is no longer called artificial intelligence. The field of study is now called 'super-intelligence' or 'strong AI'.

Dr. Nick Bostrom again:

> Given that superintelligence will one day be technologically feasible, will people choose to develop it? This question can pretty confidently be answered in the affirmative. Associated with every step along the road to superintelligence are enormous economic payoffs.
>
> The computer industry invests huge sums in the next generation of hardware and software, and it will

> continue doing so as long as there is a competitive pressure and profits to be made. People want better computers and smarter software, and they want the benefits these machines can help produce. Better medical drugs; relief for humans from the need to perform boring or dangerous jobs; entertainment – there is no end to the list of consumer-benefits. There is also a strong military motive to develop artificial intelligence. And nowhere on our path is there any natural stopping point where technophobics could plausibly argue 'hither but not further'.[144]

But how will we know when computers of the future become as intelligent as humans? At this stage it is necessary to explain the 'Turing Test'. Alan Turing[145] was a British mathematician who, while studying at Cambridge, published a paper called 'On Computable Numbers'[146] in 1936. This paper laid the foundations for modern computer science and explicitly described a theoretical machine that we would today call a computer.

During World War II, Alan Turing built the world's first computer to enable the British government to decode Nazi and Japanese encrypted communications and, in 1950, he published a paper called Computing Machinery and Intelligence[147] in which he described a test that could be used to determine when a computer's intelligence came to equal human intelligence.

Now known as the Turing Test[148] the evaluation method involves a human talking to a machine (via a keyboard in Turing's original vision) and holding a complex conversation.

When the human in the test is unable to tell whether he or she is talking to a machine or to another human being, the machine is said to have passed the Turing Test.

Today we would add many other features to the test such as emotional responsiveness and humour yet, in essence, Turing's idea remains an ideal evaluation.

So when are we likely to meet computers which approach human levels of intelligence? This is Ray Kurzweil's prediction:

> Once we've succeeded in creating a machine that can pass the Turing test (around 2029), the succeeding period will be an era of consolidation in which non-biological intelligence will make rapid gains.
>
> Once strong AI is achieved, it can readily be advanced and its powers multiplied, as that is the fundamental nature of machine abilities. As one strong AI immediately begets many strong AIs, the latter access their own design, understand and improve it, and thereby very rapidly evolve into a yet more capable, more intelligent AI, with the cycle repeating itself indefinitely. Each cycle not only creates a more intelligent AI but takes less time than the cycle before it, as is the nature of technological evolution (or any evolutionary process). The premise is that once strong AI is achieved, it will immediately become a runaway phenomenon[149] of rapidly escalating super-intelligence.[150]

Those of you who struggle daily with incalcitrant and mind-numbingly stupid PCs may think Kurzweil's prediction of a machine that could pass the Turing Test by 2029 as ludicrous, but I ask you to examine the rapidly changing nature of Google and other internet search engines. Have you noticed that Google, in particular, seems to become 'smarter' every day? This is not an accident.

Larry Page,[151] one of the two founders of Google, told an audience in New York in February 2007:

> 'We have some people at Google who are really trying to build artificial intelligence and to do it on a large scale. It's not as far off as people think.'[152] (There's a video of Larry Page talking further on this subject here.[153])

And in May of the same year Google CEO Eric Schmidt told the Financial Times that the search engine hopes to provide practical advice to its users about their major life decisions:

> Google's ambition to maximise the personal information it holds on users is so great that the search engine envisages a day when it can tell people what jobs to take and how they might spend their days off.
>
> Eric Schmidt, Google's chief executive, said gathering more personal data was a key way for Google to expand and the company believes that is the logical extension of its stated mission to organise the world's information.

> 'The goal is to enable Google users to be able to ask the question such as "What shall I do tomorrow?" and "What job shall I take?" '[154]

I think Google is no less than an awakening global brain, such as I imagined in my 2001 novel, 'Emergence'[155] (the title refers to the phenomenon of consciousness 'emerging' from within a dense global network). And I don't think I am being fanciful. Google holds much of the world's information in its vast databases and it holds search histories and the preferences of all the people who have ever used the service. The knowledge of what the world's internet-using population wants, and in what territories of the world, is like having the ultimate guide to the global Zeitgeist. Couple that with rapidly developing computer intelligence and it is not hard to see where the first signs of human-like intelligence in a computer system are likely to be encountered.

How will we cope with machines that are as intelligent or more intelligent than ourselves? Bill Hibbard,[156] Emeritus Senior Scientist at the Space Science and Engineering Center in Wisconsin, and the author of 'Super-intelligent Machines' suggests:

> A critical event in the progress of science is imminent. This is the physical explanation of consciousness and demonstration by building a conscious machine.
>
> We will know it is conscious based on our emotional connection with it. Shortly after that, we will build machines much more intelligent than humans,

> because intelligent machines will help with their own science and engineering.
>
> And the knowledge gap that has been shrinking over the centuries will start to grow. Not in the sense that scientific knowledge will shrink, but in the sense that people will have less understanding of their world because of their intimate relationship with a mind beyond their comprehension. We will understand the machine's mind about as much as our pets understand ours. We will fill this knowledge gap with religion, giving the intelligent machine the role of god.[157]

In his 2007 book 'Beyond AI: Creating the Conscience of the Machine', Dr J. Storrs Hall,[158] Research Fellow of the Institute for Molecular Manufacturing in Palo Alto, California, describes the abilities of an artificial intelligence of what he calls an 'epihuman' (just above human level) of intelligence:

> My model for what an epihuman AI would be like is to take the ten smartest people you know, remove their egos, and duplicate them a hundred times, so that you have a thousand really bright people willing to apply themselves all to the same project. Alternatively, simply imagine a very bright person given a thousand times as long to do any given task. We can straightforwardly predict, from Moore's law, that ten years after the advent of a learning but not radically self-improving human-level AI, the same software running on machinery of the same cost would do

> the same human-level tasks a thousand times as fast as we. It could, for example:
>
> – read an average book in one second with full comprehension;
> – take a college course and do all the homework and research in ten minutes;
> – write a book, again with ample research, in two or three hours;
> – produce the equivalent of a human's lifetime intellectual output, complete with all the learning, growth, and experience involved, in a couple of weeks.[159]

Perhaps the last word on super-intelligent machines should go to Irving John Good[160] (one of the British World War II cryptographers who worked alongside Alan Turing), author of the 1965 paper, 'Speculations Concerning the First Ultraintelligent Machine':

> Thus the first ultraintelligent machine is the last invention that man need ever make.[161]

Nanotechnology

The term 'nanotechnology'[162] is simple to define (the control of matter on a scale smaller than 1 micrometer, normally between 1-100 nanometers) but the types of science and technology being developed at this sub-microscopic level vary greatly.

This area of research was first identified by the legendary physicist Professor Richard P. Feynman[163] in his seminal 1959 lecture entitled 'There's Plenty Of Room At the Bottom'[164] in which he proposed that much could be achieved by scientists who chose to work at the atomic level. But the field of nanotechnology only began to develop properly in the mid-1980s when a graduate PhD student called Eric Drexler[165] wrote a thesis which went on to become a highly influential book called 'Nanosystems Molecular Machinery Manufacturing and Computation'.[166] Serious scientific research began at that point.

Simple nanotechnology is already being used today with nano-scale additives being used to make plastics. As Technology Research News reported in 2003:

> Researchers from the University of Groningen in the Netherlands and the University of Massachusetts at Amherst have found ways to use electricity to coax microscopic amounts of plastic to form patterns containing columns and tubes.
>
> The microscopic plastic features are as small as 100 nanometers, which is 50 times smaller than a red blood cell, and could be used to make electronic and mechanical devices at that scale. 'The structures can be fairly complicated and we have a wide range of different patterns,' said Ullrich Steiner, a professor of polymer physics at the University of Groningen.
>
> The method could be used for plastic electronics, light-emitting diodes, solar energy devices, and optical filters, according to Steiner.[167]

Nanotechnology can also be used to provide plastics and other materials with special properties (e.g. antiseptic, anti-UV, fire-resistant, heat-absorbing, stain resistant and electrical conducting functions) but the term also encompasses research into engineering at a molecular level, experimentation that is expected to lead to truly astonishing developments.

Molecular nanotechnology[168] (MNT) when fully developed will, theoretically, allow us to construct almost anything from the atomic level up, including food, water, computers and even nano-scale robots which will carry drugs to the precise site at which they are needed in the human body.

Nano-optimists,[169] including many governments (and futurists), see nanotechnology delivering environmentally benign material abundance for the world's population by providing universal clean water supplies; atomically engineered food and crops resulting in greater agricultural productivity with less labour and land requirements; nutritionally enhanced interactive 'smart' foods; cheap and powerful energy generation; clean and highly efficient manufacturing; radically improved formulation of drugs, diagnostics and human organ replacement; much greater information storage and communication capacities; interactive 'smart' appliances; and increased human performance through convergent technologies.

Critics of MNT development[170] suggest that nanotechnology will simply exacerbate problems stemming from existing socio-economic inequity and the unequal distribution of power by creating greater inequities between rich and poor through an inevitable nano-divide (the gap between those who control the new nanotechnologies and those whose products, services or labour are displaced by them); destabilising international relations through a growing nano arms race and increased potential for bio-weaponry; providing the tools for ubiquitous surveillance, with significant implications for civil liberty; breaking down the barriers between life and non-life through nanobiotechnology, and redefining even what it means to be human. Some suggest[171] that nano-scale molecules could even escape into the environment and self-replicate, taking over the world as a 'grey goo'[172] which will consume everything.

Whatever the potential benefits and dangers of the technology almost all futurists and futurologists agree that nano-scale engineering will become possible in the next few decades, but few of us can be sure when the products of this science will begin to emerge.

Ray Kurzweil writes on his website:

> Although most nanotech projects today focus on structural nanotechnology, development of molecular nanotechnology will surely become a priority within a few years. Full MNT capability may not be developed for a decade or longer, but preparation for it should probably start now.
>
> The economic value – and military significance – of a nanofactory will be immense. Even a primitive model will be able to convert CAD files to products

> in a few hours. Duplicate nanofactories will cost the same as any other nano-built product. The capital cost of manufacturing will be negligible by today's standards, and manufacturing capacity can be doubled in a matter of hours.[173]

In 'The Extreme Future' Dr. James Canton sees nanotechnology potentially offering a similar bonanza:

> Nanoscience represents a radical change in material science, drugs, devices, and manufacturing. Nano-based products could change everything, reducing functions down to 100,000 times smaller than a human hair. Total nanotech investments worldwide were more than $10 billion in 2005. By 2008, the nanomarket may grow to more than $32 billion worldwide. Nanomaterials will drive the near-term market growth, while nano-devices will dominate future growth.[174]

The implications of the coming nanotech revolutions are extreme and by 2030 we will be in the thick of it with astonishing new applications enriching (and, perhaps, potentially endangering) our physical world. Nanotech is one of the more extreme 'wild cards' in the technology pack and it is possible that some of the problems examined elsewhere in this report could be completely or partially solved by the science (e.g. nanotech might provide new sources of clean energy). In 2003 the late Professor Richard Smalley[175] of Rice University in Texas – a Nobel Laureate prize winner for his chemistry research – delivered a lecture called 'Nanotechnology, the S & T Workforce, Energy &

Prosperity'. In the lecture he described fourteen ways in which he thought nanotech will affect society (n.b. most of these technological developments will rely on plastic for their construction):

14 Enabling Nanotech Revolutions

1. Photovoltaics – a revolution to drop cost by 10 to 100 fold.
2. H_2 (hydrogen) storage – a revolution in light-weight materials for pressure tanks, and/or a new light weight, easily reversible hydrogen chemisorption system.
3. Fuel cells – a revolution to drop the cost by nearly 10 to 100 fold.
4. Batteries and super capacitors – revolution to improve by 10-100x for automotive and distributed generation applications.
5. Photo catalytic reduction of CO_2 to produce a liquid fuel such as methanol.
6. Direct photo conversion of light + water to produce H_2 (hydrogen).
7. Super-strong, lightweight materials to drop cost to LEO, GEO (space orbit paths), and later the moon by > 100 x, to enable huge but low cost light harvesting structures in space; and to improve efficiency of cars, planes, etc.
8. Nanoelectronics to revolutionize computers, sensors and devices.
9. High current cables (superconductors, or quantum conductors) with which to rewire the electrical transmission grid, and enable continental, and even worldwide electrical energy transport;

and also to replace aluminum and copper wires essentially everywhere – particularly in the windings of electric motors (especially good if we can eliminate eddy current losses).

10. Thermo chemical catalysts to generate H_2 from water that works efficiently at temperatures lower than 900° C.
11. CO_2 mineralization schemes that can work on a vast scale, hopefully starting from basalt and having no waste streams.
12. Nanoelectronics-based Robotics with AI to enable construction maintenance of solar structures in space and on the moon; and to enable nuclear reactor maintenance and fuel reprocessing.
13. Nanomaterials/coatings that will vastly lower the cost of deep drilling, to enable HDR (hot dry rock) geothermal heat mining.
14. Nanotech lighting to replace incandescent and fluorescent lights.[176]

Clearly molecular-level nano-engineering will have the most profound impact on our future. But however weird and futuristic molecular nanotech manufacturing may sound today as we approach 2030 almost everything will be overshadowed by a rapidly approaching rupture in human evolution.

The Singularity

In the summer term of 1965, I persuaded my sixth form school colleagues (16-18 year olds) that we should hold a debate on the topic, 'Man Will Transfer His Mind To Machines.' I was the main proposer and supporter of the motion which I duly lost comprehensively.

Now, over forty years later, we can contemplate a time when it will be necessary for us not only to consider the moral and ethical issues of transferring a human mind to a machine but to consider how we should respond when machine intelligence becomes more capable than human intelligence.

This section of my report on the likely shape of the world in 2030 is likely to be the most controversial and, for many readers, will seem the most far-fetched, as it describes a period in which machines become as clever as humans and in which humans will enhance their own biology to rival the machines they are building. The period immediately after the point at which machine intelligence exceeds human capabilities is becoming known as 'The Singularity'.

'The Singularity'[177] is a phrase adopted by futurists, futurologists and computer scientists to describe the time when human intelligence is no longer the dominant form of intelligence on Earth. Usually we lack appropriate language for the technological future but, in this instance, I think the term 'singularity' is appropriate, even if it is somewhat opaque. In astronomy a 'singularity' is an event horizon beyond which nothing can be seen. The coming singularity in human evolution is similar; once machines are cleverer than humans they will create a world which is impossible for unenhanced humans to imagine. The development will be, indeed, a singularity in human affairs.

The term 'singularity' was first applied in the context of human-machine evolution by Vernor Vinge,[178] a Professor of Mathematics at San Diego State University. In a paper written in 1993 he began as follows:

> Within thirty years, we will have the technological means to create superhuman intelligence. Shortly after, the human era will be ended.
>
> Is such progress avoidable? If not to be avoided, can events be guided so that we may survive? These questions are investigated. Some possible answers (and some further dangers) are presented.
>
> The acceleration of technological progress has been the central feature of this century. I argue in this paper that we are on the edge of change comparable to the rise of human life on Earth. The precise cause of this change is the imminent creation by technology of entities with greater than human intelligence. There are several means by which science may achieve this breakthrough (and this is another reason for having confidence that the event will occur).[179]

Much work on the subject has been done since 1993 and writing in 1994 researcher Dani Eder of the Boeing AI Center[180] speculated:

> When will the Singularity Occur?
>
> The short answer is that the near edge of the Singularity is due about the year 2035 AD. Several lines of reasoning point to this date. One is simple projection from human population trends. Human population over the past 10,000 years has been following a hyperbolic growth trend.
>
> Since about 1600 AD the trend has been very steadily accelerating with the asymptote located in the year 2035 AD. Now, either the human population really will become infinite at that time, or a trend that has persisted over all of human history will be broken. Either way it is a pretty special time.
>
> Since computer capacity doubles every two years or so, we expect that in about 40 years, the computers will be as powerful as human brains. And two years after that, they will be twice as powerful, etc. And computer production is not limited by the rate of human reproduction. So the total amount of brainpower available, counting humans plus computers, takes a rapid jump upward in 40 years or so. 40 years from now is 2035 AD.[181]

In 1995 biologist and writer Dr Steve Alan Edwards[182] wrote an article for the Australian 21C website (21st Century magazine) in which he described the growing army of 'singularitists' and 'tranhumanists' and discussed their goals:

Wouldn't it be really great if we, by packaging ourselves into a machine (or a machine into ourselves) could somehow achieve that greater-than-human intelligence, and become our own evolutionary successors?

Wouldn't it be great if we could survive the Singularity?

Meet the Transhumanists – an Internet-connected virtual community of futurists whose stated goal is self-transcendence through technology. International in scope, though few in number, transhumanists tend to be young, intelligent, and technologically literate – often graduate students in neuro- or information science.

Along with (Vernor) Vinge, their intellectual heroes include roboticist Hans Moravec, artificial intelligence pioneer Marvin Minsky, nanotechnology guru K. Eric Drexler, and physicist/cosmologist Frank Tipler.

Moravec and Minsky have argued for the theoretical feasibility of 'mind-uploading' wherein a person's mind and personality could be emulated by a computer. Drexler has argued that the Singularity is even closer than we think, driven by – you guessed it – nanotechnology, the science of creating objects by controlling matter on a molecular scale. Tippler's cosmological scheme holds that the universe is evolving into a giant supercomputer which he chooses to call

> the Omega Point – but is, perhaps, indistinguishable from God.[183]

There are many different routes to The Singularity. I wrote earlier that the world's networks and the billions of computers which will be attached to it may prove to have emergent qualities of consciousness and super-intelligence on their own. As Professor Marvin Minsky wrote in one of his most famous books, 'Society of Mind' (1988):

> This book tries to explain how minds work. How can intelligence emerge from nonintelligence? To answer that, we'll show that you can build a mind from many little parts, each mindless by itself.
>
> I'll call 'Society of Mind' this scheme in which each mind is made of many smaller processes. These we'll call agents. Each mental agent by itself can only do some simple thing that needs no mind or thought at all. Yet when we join these agents in societies – in certain very special ways – this leads to intelligence.[184]

But perhaps the most remarkable 21st century work on the subject is Ray Kurzweil's previously quoted book 'The Singularity is Near'. In it, Kurzweil suggests:

> Once we've succeeded in creating a machine that can pass the Turing test (around 2029), the succeeding period will be an era of consolidation in which nonbiological intelligence will make rapid gains. However, the extraordinary expansion contemplated for the Singularity, in which human intelligence is

> multiplied by billions, won't take place until the mid 2040s.[185]

Clearly, it is impossible to be precise about when The Singularity will occur, but it will be the most momentous development in human evolution since our species discovered language and began using tools (the earliest form of technology).

There are many who will be sceptical about the notion of machines ever becoming more capable than humans but, after forty years of observing technological progress, I personally have little doubt that this will be achieved, and probably by this report's time line of 2030. And, despite my robust defeat in the debate I sponsored in 1965, I have little doubt that later this century humans will begin to upload their minds and their memories to machines.

Of course, the idea of super-intelligent machines becoming our successors (with or without our brains uploaded into them) is not new, or even a product of 20th century thinking. In 1864, Samuel Butler,[186] a writer, philosopher and New Zealand sheep farmer, wrote to Charles Darwin, the man who first developed the theory of evolution, suggesting a new chapter to end Darwin's famous 'Origin Of The Species':

> Who will be man's successor? To which the answer is: We are ourselves creating our own successors. Man will become to the machine what the horse and dog are to man; the conclusion being that machines are, or are becoming, animate.[187]

But even as machines (made partly of plastic) are developed to become a new form of life by human efforts, we humans will be changing ourselves into a more capable, more durable and longer-lived species (as I discuss in my later section on 'Human Health and Longevity').

What will happen after 'The Singularity'? As I mentioned above, post-singularity events cannot be predicted or even imagined with any degree of certainty by the unaided human minds of the early 21st century. But I have long been of the opinion that human evolutionary destiny is to merge human biology with machine intelligence to create a successor species, a semi-plastic species which, freed of biological time constraints, will be free to leave this planet and begin to colonise the universe with a form of intelligence that, because of our lack of language for the future, can only be described as post-human.

Section Two

Climate Change and the Environment

Consulting Referee:

Mike Childs,
Head of Campaigns,
Friends of the Earth

CNN Online News:
Europe, 18 October, 2030

Winter Ice Grips Europe Again

Harbours around Ireland and the United Kingdom are already being closed by autumnal ice floes and the whole of Western Europe is bracing itself to face yet another frozen winter.

Since climate change reached a tipping point ten years ago and the Atlantic conveyor stopped working (the conveyor was a system of underwater currents which brought the warm waters of the Gulf Stream up to Europe) millions have fled their homes in Ireland, the UK, Holland, Scandinavia, the Benelux, Germany and Northern France to find better living conditions in Southern Europe and even in North Africa.

The economic impact of failing agriculture and forced migration over the last decade has been devastating, with national GDPs falling by up to 50 per cent across the affected regions. Food aid and

> economic assistance has been provided in large measure by Russia, Asia and Canada to help the plight of millions of European refuges fleeing Siberian conditions.
>
> Evidence of past climate patterns found buried in rocks and sediments (paleoclimatic evidence) suggests that these abruptly altered climatic patterns in Europe could last for as much as a century, as they did when the ocean conveyor last collapsed 8,200 years ago, or, at the extreme, could last as long as 1,000 years as they did during the Younger Dryas period, which began about 12,700 years ago.

The above paragraphs are not a prediction of the results of climate change produced for this report. They are an extrapolation from a 'worst case' prediction made by US defence advisors in a 2003 report entitled 'An Abrupt Climate Change Scenario and Its Implications for United States National Security'.[188]

The report's authors, Peter Schwartz,[189] a CIA consultant and former Head of Planning at Royal Dutch/Shell Group, and Doug Randall[190] of the California-based Global Business Network,[191] are two highly respected future scenario planners.

Schwartz and Randall went on to add that in the worst case scenario, annual average temperatures would drop by up to five degrees Fahrenheit over Asia and North America and six degrees Fahrenheit in northern Europe. They suggested that annual average temperatures would increase by up to four degrees Fahrenheit in key areas throughout Australia, South America, and southern Africa and, they predicted, drought would persist for most of the decade (the 2020s) in critical agricultural regions and in the scarce water resource regions for major population centres in Europe and eastern North America.

In addition they postulated that winter storms and winds would intensify, amplifying the impacts of the changes. Western Europe and the North Pacific, in particular, would experience enhanced winds. The document concludes by predicting that abrupt climate change could bring the planet to the edge of anarchy as unstable countries develop a nuclear threat to defend and secure dwindling food, water and energy supplies. The authors added that climate change as a threat to global stability vastly eclipses that of terrorism.

The George W. Bush White House administration suppressed the report,[192] but concerned individuals leaked it to the press and it is now in the public domain.

OK, so that report painted a worst case scenario. What's the best predicted outcome of climate change, and what's the middle ground? And, more importantly how real and urgent is the threat?

In August 2001 I travelled to the South Pacific Ocean to discover for myself the effects of climate change on sea levels. As a former science journalist I knew the importance of evaluating evidence at first hand (even if I hadn't then fully appreciated the seriously damaging effect of air travel).

Like many others, I had been exposed for some years to arguments for and against the phenomenon that is commonly called 'global warming' and although I'd read a lot of the original scientific evidence for myself, nothing beats a personal inspection.

I visited Samoa, Tuvalu and several other islands in the South Pacific. On each island I went into the coastal villages, sought out the older men and asked if they would be kind enough to show me their beaches.

Without exception, these village elders pointed out to sea, sometimes dozens of metres out to sea, and indicated where the sea level had been when they had been young, fifty or sixty years before. One of the men on Samoa asked me to wade out into the surf with him to find a rock, now submerged, on which he had stood to fish when he was a child. The transparent, turquoise water was almost up to my chest before he found the rock and, after he had helped me clamber up beside him, we turned to look back at the new shore line. It was at least twenty metres further inland.

Today, most of the beaches on the smaller South Pacific islands are no more than a metre or two wide and in many places the sea has encroached onto what were once village greens. Villagers have had to cut down rain forest to move their communities further into the interior.

Ocean levels rise for many reasons. Over long cyclic periods the Earth's sea levels rise and fall naturally, but there is no previous record of oceans levels rising at such a rapid rate[193] as they have in the past half century, and particularly over the last fifteen years. Not all the extra water comes from the melting of the ice caps,[194] although this has surely been occurring. There is also run off from thousands of land-locked glaciers[195] and, of course, water itself expands[196] when it is heated.

Responsible scientists suggest that all three causes have contributed to the sudden rise in global ocean levels but, whatever the reason, the effect was clear to see. I incorporated my research into a novel that was published in 2005 in which the main action takes place in the year 2055. In my fictional story climate change has run out of control and humankind is attempting to use advanced technology to bring the climate back under control. The book is called 'Extinction'[197] (the clue to the outcome is in the title).

Some highly qualified and distinguished scientists who approach the issue of climate change from a far more rigorous scientific standpoint than me, draw a similar conclusion as to the possible outcome. Only what *they* are describing is non-fiction and may become all too real. This is what Professor James Lovelock wrote in The Independent in May 2004:

> Unless we stop now, we will really doom the lives of our descendants. If we just go on for another 40 or 50 years faffing around, they'll have no chance at all, it'll be back to the Stone Age. There'll be people around still. But civilisation will go.[198]

James Lovelock is, of course, the scientist who invented the means of measuring chlorofluorocarbons[199] (CFCs) in the atmosphere. These molecules were widely used in aerosols and fridges and they were destroying the protective ozone layer around the planet. As a result of his demonstrations the international Montreal Protocol[200] to outlaw CFCs was signed in 1987. Since 1995 the developed nations have ceased producing these propellants and coolants for aerosols and fridges. Now the ozone holes have started to shrink again.[201] Had the ozone layer continued to deplete, millions of us would have died prematurely of skin cancers resulting from excess ultraviolet radiation reaching the planet's surface.

James Lovelock is also the man who produced the 'Gaia' theory'[202] of the Earth, suggesting that this planet is like a super-organism in which every part is dependent on every other part. Whether you choose to believe in the more mystical and spiritual interpretations of Gaia is up to you, but it is clear that many parts of this planet's environment are indeed closely interlinked.

Lovelock is not alone in forecasting an apocalypse caused by climate change. James Canton, a futurist who has advised former White House administrations, writes:

> I am not an alarmist, but there is abundant evidence that climate change and environmental threats present a real and present danger to life as we know it on the planet. If we do not fix this problem, the safety, health and survival of the world's population is at stake.[203]

And Australian writer and zoologist Professor Tim Flannery agrees. As he puts it in his acclaimed book 'The Weather Makers':

> When we consider the fate of the planet as a whole, we must be under no illusions as to what is at stake. Earth's average temperature is around 15°C and whether we allow it to rise by a single degree, or 3°C, will decide the fate of hundreds of thousands of species and most probably billions of people. Never in the history of humanity has there been a cost-benefit analysis that demands greater scrutiny…
>
> If humans pursue a business-as-usual course for the first half of this century, I believe the collapse of civilisation due to climate change becomes inevitable.[204]

Even politicians have been bold enough to cast the future in similar terms. Tony Blair, one of the world's politicians who was engaged most with the problems of climate change while in office, said in 2004:

> The emission of greenhouse gases…is causing global warming at a rate that began as significant, has become alarming and is simply unsustainable in the long term. And by long term I do not mean centuries ahead. I mean within the lifetime of my children certainly; and possibly within my own. And by unsustainable, I do not mean a phenomenon causing problems of adjustment. I mean a challenge so far-reaching in its impact and irreversible in its destructive power, that it alters radically human existence… There is no doubt that the time to act is now.[205]

A year later Britain's then Chancellor of the Exchequer, Gordon Brown, commissioned Sir Nicholas Stern to research and to write a report on climate Change. When the Stern Review[206] was published in October 2006 it caused a sensation. Addressing the United Nations Sir Nicholas's views were reported as follows:

> Mr. Stern warned that 'even if we are sensible about climate change and get the emissions down, the climate is going to change still more than it has'. While the world was currently experiencing the effects of an increase in global temperatures of 0.7 degrees Celsius, he said that 'even if we act strongly to decrease emissions, we've got another 1.5 to 2.0 degrees centigrade to come. So we've seen maybe a quarter or a third of temperature increase we're going to have to cope with. St. Petersburg, New York, London, Cairo, Cape Town, Shanghai, Bombay, Calcutta, Dhaka - they're all under threat from sea-level rise, and many parts of the world will be under threat from hurricanes, typhoons, droughts and floods.'
>
> Mr. Stern also warned that the heatwaves that killed thousands of people in Europe in 2003 'will probably be standard by the time we get to 2050', and the Nile river, which ten countries depend on, could drop to one half of current water levels in the second half of this century. However, the 'business as usual' scenario - where no action is taken to reduce emissions - would lead to changes in the earth's climate, he said, 'that we don't really understand, absolutely unprecedented and earth-transforming – the difference between where we are now and the last ice age.'[207]

And in 2007, Angela Merkel, Chancellor of Germany and then President of the European Union told the Financial Times why she had pushed for EU agreement[208] on significant carbon reductions by 2020:

> We made a choice: We could have muddled through and looked away because it was not clear what the cost (of climate change) was going to be. Instead, we decided to act under the assumption that, whatever happens, the cost of inaction will be higher. This, as made clear by the Stern report, is the main paradigm change.[209]

The Fuzz on the Skin of a Peach

If you want to picture Earth's atmosphere, think of the white fuzz on the skin of a peach. In relative terms, that fuzz is the same thickness as our planet's atmosphere. To use another simile, it is as thick as an onion's outmost layer.

Yet, despite being so thin, this clinging strata of gases is what makes Earth unique among all of the other planets known to humankind. This thin coating of atmosphere[210] has brought life to Earth and all of our teaming, swarming diversity of biology relies totally on this invisible, fragile and threatened halo.

It is impossible to know for sure how much more heated the planet's atmosphere will have become in twenty-five years, partly because so much depends on our actions over the next quarter of a century. What is clear is that mankind's activities are almost certainly causing the climate to warm up in an unnatural and dangerous way. The United Nation's Intergovernmental Panel On Climate Change[211] (the IPCC) produced a report[212] as this document was being written which stated that it is '90 per cent likely' that human activity is responsible for global warming. They said the evidence was 'unequivocal.'

Here are just three of the IPCC's conclusions (with links to the data sources):

1). World sea levels are rising 50 per cent faster[213] today than predicted in the last IPCC report in 2001.
2). The Gulf Stream has slowed by about 30 per cent[214] between 1957 and 2004.
3). The IPCC itself says there's a dangerous lag with atmospheric warming. Eighty per cent of the extra heat currently being trapped by greenhouse gases is being drawn into the oceans. As the oceans warm, more of that heat will remain in the air. Even if emissions were sharply reduced, the world would continue to warm by 0.1° C per decade for some time.

Over 2,000 scientists specialising in studying climate change and related disciplines contributed to the IPCC report and all had to agree unanimously with the report's findings. For all reasonable people the debate about whether or not climate change is a real and worrying phenomenon is over. Perhaps the Australian environmentalist Tim Flannery should be allowed the last word on the IPCC's global consensus position on climate change: 'If the IPCC says something, you had better believe it – and then allow for the likelihood that things are far worse than it says they are.'

James Lovelock managed to prod the international community into action over the dangers of CFCs causing ozone depletion. Now there is urgent need for another accord, one far more powerful than the Kyoto Protocol. If we are to stabilise our climate, Kyoto's target needs to be strengthened twelve times over[215] says Tim Flannery: cuts of 70 per cent by 2050 are required to keep CO_2 at double the pre-industrial level.

If we do nothing there will be a doubling of CO_2 in our atmosphere – from three parts per 10,000 that existed in the early 20th century to six. That has the potential to heat our planet by around 3°C and perhaps by as much as 6°C.

If, magically, we were able to stop all greenhouse gas emissions today Earth would continue to heat up from the effect of emissions already generated until the year 2050. CO_2 persists a long time in the atmosphere. Much of the CO_2 released as the world started to recover from the First World War is still warming our planet today.

As Tim Flannery puts it:

> Since the beginning of the Industrial Revolution a global warming of 0.63°C has occurred on our planet, and its principal cause is an increase in atmospheric CO_2 from a round three parts per 10,000 to just

> under four. Most of the increase in the burning of fossil fuels has occurred over the last few decades and nine out of the ten warmest years ever recorded have occurred since 1990.[216]

In other words, it's the Baby Boomer (or 'war baby') generation that's really to blame because half of the energy generated since the Industrial Revolution has been consumed in the last twenty years.

Only it's not any single generation's fault – it's all of our faults in the developed world and, in the future, the culprit responsible for any further man-made climate change will be the looming and inescapable global population explosion.

The 20th century opened to a world population of a little more than one billion people and closed on a world of six billion. Every one of those six billion is using on average four times as much energy[217] as people did 100 years ago.

As I said in my introduction to this section, we are now confronted with the physical proof of climate change and Europe is a good place to go looking for extreme weather. Such extremes are caused by the atmosphere heating up. For every single degree the atmosphere is warmed, world rainfall increases by 1 per cent.[218] This does not sound like much, but the increase is very unevenly distributed.

The 1990s were the warmest decade in Britain since records began in the 1660s, with 2006 the hottest year ever, 2005 the second warmest year ever, 1998 the third warmest ever and 2001 the fourth warmest

In January 2007 The British Meteorological Office warned that 2007 will be the warmest year on record.[219] (although it looks as if it will turn out to be the wettest). The trend towards extreme weather is starkly obvious – and it is being repeated across much of mainland Europe.

And in October 2007 The New York Times reported alarming news under a headline 'Arctic Melt Unnerves The Experts':

> The Arctic ice cap shrank so much this summer that waves briefly lapped along two long-imagined Arctic shipping routes, the Northwest Passage over Canada and the Northern Sea Route over Russia.
>
> Overall, the floating ice dwindled to an extent unparalleled in a century or more, by several estimates.
>
> Now the six-month dark season has returned to the North Pole. In the deepening chill, new ice is already spreading over vast stretches of the Arctic Ocean. Astonished by the summer's changes, scientists are studying the forces that exposed one million square miles of open water – six Californias – beyond the average since satellites started measurements in 1979.[220]

The IPCC specifically identified human activity over the last 250 years as the culprit for the atmospheric warming but new evidence now suggests that the problem started way before that. Emeritus Professor William F. Ruddiman[221] of the University of Virginia is a paleo-climatologist with over sixty years' experience. In his recent book 'Plows, Plagues and

Petroleum'[222] he presents evidence from fossil records and ice/soil core samples that unnatural global warming began 12,000 years ago when Man first started growing crops and husbanding animals – the agricultural revolution.

Trees felled to make way for agriculture could no longer absorb CO_2 from the atmosphere and as landscapes were burned to create crop growing areas, more carbon dioxide was released. Then, as soil was turned over for planting and rice paddies were flooded, methane gas – a powerful climatic warming gas – was also released into the atmosphere. Growing herds of husbanded animals bred for food and clothing also contributed by releasing methane gas produced by their own diets.

Of course, 12,000 years ago the number of humans on the planet was still very small – a few million at most – and the unnatural warming effect of their activities on the atmosphere was very slight indeed. But Professor Ruddiman and his colleagues were able to measure those subtle changes, changes that contradicted the expected cyclical change to which our planet's atmosphere is subject. So sensitive is our climate – and so accurate are the fossil records – that Ruddiman's team was also able to specifically plot the reduction in the output of man-made CO_2 and methane during the periods when plagues swept through Europe and Asia reducing human activity by as much as 50 per cent for a period of years.[VII]

[VII] William Ruddiman pointedly states in the introduction to his book that he has received no funding from any individual, body or organisation which has an interest in proving the case about climate change either way.

In the year 2030 historians may look back on the first decade of the 21st century and identify it as the period in which humans first became serious about tackling climate change. A clear and almost palpable change in the Western Zeitgeist is occurring – even as this report is being written – and it now seems as if hardly a day can pass without a major public figure, a supermarket chain or a government leader pledging new-found allegiance to the battle against global warming.[VIII]

One former political leader who can claim to have been involved in tackling climate change longer than most is former US Vice President Al Gore. As well as starring in a feature film about climate change called 'An Inconvenient Truth'[223] (which won an Oscar for 'Best Documentary'), Mr Gore also remains active politically. Called to testify to the US Congressional Committee on Energy and Air Quality in March 2007 he said:

> 'I want to testify today about what I believe is a planetary emergency, a crisis that threatens the survival of our civilization and the habitability of the Earth.
>
> 'The planet has a fever. If your baby has a fever, you go to the doctor. If the doctor says you need to intervene here, you don't say 'I read a science fiction novel that says it's not a problem.' You take action.'[224]

[VIII] Indeed, in commissioning this report (and encouraging a focus on climate change and energy conservation) PlasticsEurope has acted on behalf of the European plastics manufacturing industry to raise public awareness about this serious problem.

Touching on some Less Well-Known Causes of Climate Change

Much has been written on the causes of climate change and I do not intend to describe in this section details about the number of new power stations being built in China every year, nor the USA's growing appetite for coal as a power-generation resource. Suffice to say that the majority of human-produced carbon dioxide that enters the atmosphere is produced by electricity power generation and transport (road, rail, shipping and aviation).

Before examining some lesser known sectors that emit carbon – in particular aviation and shipping, two forms of transport that because of their international nature makes it convenient for domestic politicians to overlook – it is worth noting that China, in particular, is a rapidly emerging economy which clearly understands how critical it is to reduce carbon output even as it ramps up its power generation capacity. The following article was published by the Ethical Corp think tank in February 2007:

> One recently completed 'supercritical' coal-fired plant in Shanghai shows the way forward. Phase two of the Waigaoqiao plant, which has two 900 MW generating units and uses turbines made by Siemens, is one of the most advanced coal-fired plants operating in China. With a net efficiency of more than 42 per cent – significantly higher than the worldwide average of 31 per cent for hard coal-fired units – it will save an annual one million tonnes of coal and cut carbon dioxide

> emissions by 2.1 million tonnes in comparison with a typical Chinese power station of the same size.[225]

And in September 2007 China's National Development and Reform Commission announced a $133.3 billion project to develop renewable energy sources:

> China has released an ambitious plan to develop renewable energy to cut its surging carbon dioxide emissions.
>
> The 'Middle and Long-term Development Plan of Renewable Energies' promises to derive ten per cent of China's energy supply from renewables by 2010 and 15 per cent by 2020.[226]

Cleaning up power stations, finding renewable and sustainable sources of energy (see the following section on energy), conserving energy and sharply reducing our emissions from transport are all necessary and urgent actions. But there are also other factors to be considered.

As the paleo-climatologist Professor William Ruddiman points out, climate change began the moment humans started deforesting the planet and growing our food plants and husbanding our meat, instead of hunting and gathering. And deforestation is, itself, a major but under-appreciated source of global warming. The Independent reported in May 2007:

> In the next 24 hours, deforestation will release as much CO_2 into the atmosphere as 8 million people flying from London to New York.

> Stopping the loggers is the fastest and cheapest solution to climate change. So why are global leaders turning a blind eye to this crisis?
>
> The rampant slashing and burning of tropical forests is second only to the energy sector as a source of greenhouse gases according to a report published today by the Oxford-based Global Canopy Programme,[227] an alliance of leading rainforest scientists.
>
> Figures from the GCP, summarising the latest findings from the United Nations, and building on estimates contained in the Stern Report, show deforestation accounts for up to 25 per cent of global emissions of heat-trapping gases, while transport and industry account for 14 per cent each; and aviation makes up only 3 per cent of the total.[228]

And, what is done with the land once it has been deforested? Most is used for cattle husbandry. You may be surprised to learn that cattle themselves are responsible for producing 18 per cent of greenhouse gases, their noted flatulence leading pugnacious Ryanair boss Michael O'Leary to remark famously that governments 'should do something about cows farting'[229] rather than pick on his airline (although he has no reason to be smug; see the section on aviation below). According to the Christian Science Monitor:

> It's not just the well-known and frequently joked-about flatulence and manure of grass-chewing cattle that's the problem, according to a recent report by the Food and Agriculture Organization of the

> United Nations (FAO). Land-use changes, especially deforestation to expand pastures and to create arable land for feed crops, is a big part. So is the use of energy to produce fertilizers, to run the slaughterhouses and meat-processing plants, and to pump water.
>
> Livestock are responsible for 18 per cent of greenhouse-gas emissions as measured in carbon dioxide equivalent, reports the FAO. This includes 9 per cent of all CO_2 emissions, 37 per cent of methane, and 65 per cent of nitrous oxide. Altogether, that's more than the emissions caused by transportation.[230]

And we are not about to cut back on our cattle rearing, it seems. Despite my earlier reference to meat of the future being grown in factories (without a flatulent host animal) it seems that cattle-producing countries are confident about their future markets for beef. Under the headline 'Greater demand for cattle beef to come from developing nations' the Arab-Brazillian Chamber of Commerce reported:

> According to a sector study, by 2030 emerging countries will consume 350 million tonnes of cattle beef, against 100 million in developed countries. Brazil, which is already the greatest exporter in the sector, should occupy a special position in this market. 'The world needs Brazil to eat,' stated Abiec president, Marcus Vinícius Pratini de Moraes.[231]

Even the United Nations blames the cow. Under a headline that read, 'Cow "emissions" more damaging to planet than CO_2 from cars', The Independent reported:

> Meet the world's top destroyer of the environment. It is not the car, or the plane, or even George Bush: it is the cow.
>
> A United Nations report has identified the world's rapidly growing herds of cattle as the greatest threat to the climate, forests and wildlife. And they are blamed for a host of other environmental crimes, from acid rain to the introduction of alien species, from producing deserts to creating dead zones in the oceans, from poisoning rivers and drinking water to destroying coral reefs.[232]

What can be done? Well, some California dairy farmers are turning manure into electricity.[233] Also, Australian scientists are working on isolating bacteria in Kangaroos[234] which allow them to eat grass and release no methane and British scientists claim to have already made a breakthrough in developing a low-methane diet for cattle.[235] The magic bacteria could hopefully be introduced into sheep, pigs, and cattle feed to reduce or eliminate methane release. And since more methane comes from garbage than from any other source, maybe we could find a way to harness that gas as a form of energy.

One good piece of news is that although methane is a potent greenhouse gas, it lingers in our atmosphere for only ten years (compared with 100 years or more for carbon dioxide) and thus any attempt to reduce methane emissions would produce effects that would be noticeable rapidly.

But even though cattle emissions has a comical quality, the notion of clearing more and more land on which to raise promiscuously flatulent cattle is not sustainable. There is no easy answer as the world must eat, but synthetic food (produced from chemicals), factory-grown meat and even thoroughly tested and closely controlled genetically modified food plants (genetically modified organisms or GMOs) will have a role to play in some parts of the world.

This last observation is a matter of fact rather than prediction as the trend is very clear. Between 1996 and 2005, the total surface area of land cultivated with GMOs had increased by a factor of 50,[236] from 17,000 km² (4.2 million acres) to 900,000 km² (222 million acres), of which 55 per cent were in the United States.

Friends of the Earth points out that even if the environmental and human safety issues of GM crops could be satisfactorily answered (and that, they say, is a very big 'if') the switch from natural seeds and crops to GM seeds and crops would make the production of food the intellectual property of the large corporations which own the relevant patents. Food, which since the beginning of human existence has been a natural resource would, if the GM model were to prevail, become yet another product of big business. Such proprietorial development does not chime with the ambition for sustainable development and the effort to help the world's poorest people to help themselves to improve their lives. Friends of the Earth states:

> GM crops are not cheaper, are not better in quality and do not present any benefits for consumers. This is now even recognised by some parts of the biotech industry. After 30 years of research and public money,

> only two modifications are grown commercially to any extent: herbicide tolerance and insect resistance.[237]

On the other hand, the temptations of future GM bounty, especially the so-called 'third generation' genetically-modified 'pharma-crops', will seem very hard to resist. As SciDev.net explained in June 2007:

> Growing pharmaceuticals and industrial products in plants through genetic engineering presents an important opportunity that Africa should grasp now.
>
> Such crops include plants engineered to produce biodegradable plastics, fibrous proteins, adhesives and synthetic proteins. For example, tobacco and potato plants have been engineered to produce spider silks.
>
> 'Pharmacrops' are plants genetically modified to produce pharmaceuticals, for example vaccines, antibodies and proteins to treat human or animal diseases. Maize engineered to express human gastric lipase, used to treat cystic fibrosis, is already in advanced clinical trials.[238]

What is unarguable, however, is that given the problem of continuing deforestation, the world's populations must be educated to reduce the amount of meat in their diets. Meat is about the least land-efficient and energy-efficient way of transferring protein/energy from our environment into our bodies (although the fastest method of energy ingestion at the point of consumption). And a reduced meat diet would improve the health of most citizens.

As Jeremy Rifkin explains in 'The Hydrogen Economy':

> One third of the world's agricultural land has been converted from growing food grains for human consumption to growing feed grain for cattle and other livestock. Cattle production is now the most energy-consuming agricultural activity in the world. It takes the equivalent of a gallon of gasoline to produce a pound of grain-fed beef in the US. To sustain the yearly beef requirements of an average family of four people requires the consumption of more than 260 gallons of fossil fuel. When that fuel is burned, it releases 2.5 tons of additional CO_2 into the atmosphere – as much CO_2 as the average car emits in six months of normal operation.

Shipping

Shipping is a transport sector producing significant carbon emissions but one which is rarely discussed (and one which is often omitted from domestic climate change recommendations and legislation). But, although relatively small, shipping is the fastest growing of all transport sectors, according to The Economist:

> World merchandise trade (shipping) is growing at 15 per cent a year. Trade between China, India, America and Europe accounts for 65 per cent of the 250m-plus containers moved around the world each year. Freight rates rose by nearly one-third in the four

> years to the peak of the cycle in the third quarter of 2005. That led to a splurge in orders for new, larger ships.[239]

Perhaps one of the best places in the world to witness for yourself the impact of ships' greenhouse gas emissions is Istanbul. The beautiful old city sits either side of the narrowest shipping lane in the world, the Bosphorus, a strait which links the almost completely enclosed Black sea to the Aegean Sea and the Mediterranean beyond.

For all of the rapidly developing countries around the Black Sea – Bulgaria, Romania, the Ukraine, Georgia, and Northern Turkey itself – the Bosphorus (which at places is only 700 metres wide) offers the only access channel for tankers and container ships. Every ten minutes huge cargo vessels pass in each direction, piloted by local watermen and controlled by a marine equivalent of an air traffic control system. All of them belch out large quantities of CO_2, SOx[240] and NOx[241].

Istanbul already has a serious pollution crisis as its twelve million inhabitants attempt to get around their vast city. The transport infrastructure is poor because of a difficult topography, earthquake risk and chronic long-term under-investment. There is almost no metro system and the ancient ferry boats which criss-cross the Bosphorus add their noxious outpourings to those of millions of cars and the giant cargo vessels and cruise liners which sail through the strait.

As a result of all this shipping and heavily-jammed road transportation beautiful Istanbul is choking to death inside a foul brown miasma which contributes heavily to the region's high carbon output and to appalling public health and Turkish mortality figures.[242]

However, some technological breakthroughs are occurring which are allowing new ships to run far more cleanly. Interestingly, these developments are being made in the region responsible for most of the growth in global shipping. A news story published in China makes the following claims:

> China has made substantial breakthroughs in shipbuilding as the first liquefied natural gas (LNG) ship made in China, one of the most advanced in the world, will be delivered in September.
>
> The boat with a capacity of 47,200 cubic meters is under construction by the Hudong-Zhonghua Shipbuilding, a subsidiary of the China State Shipbuilding Corporation (CSSC), China's top and the world's third largest shipping group.
>
> Another four such LNG vessels also under construction would be delivered in the end of this year while the research and development for LNG ships with a capacity of 200,000 cubic meters is underway.[243]

And sail power may even make a come-back both to save shipping fuel and to reduce carbon emissions. The German company Sky Sails[244] is now marketing giant 'kite-style' plastics-based sails for large ships to use during their long ocean crossings. The company claims:

> By using the SkySails-System, a ship's fuel costs can be reduced by 10- 35 per cent on annual average, depending on wind conditions. Under optimal wind conditions, fuel consumption can temporarily be reduced by up to 50 per cent. Even on a small, 87 metre cargo ship, savings of up to 280,000 euros can be made annually.
>
> In 2007 the first SkySails-Systems with towing-kite areas of up to 320 m² for cargo vessels, superyachts and fish trawlers will be available. Series production will start in 2008.[245]

And finally, to end this very incomplete survey of shipping emissions, don't even consider thinking about using passenger liners for travel, or even of taking a luxury cruise. In his influential 2006 book 'Heat, How To Stop The Planet Burning,' British environmental campaigner George Monbiot publishes his calculation about how much carbon is produced by the cruise liner Queen Elizabeth 2 on behalf of each of its passengers.

> Cunard says the ship burns 433 tonnes of fuel a day, and takes six days to travel from Southampton to New York. If the ship is full, every passenger with a return ticket consumes 2.9 tonnes. A tonne of shipping fuel contains 0.85 tonnes of carbon, which produces 3.1 tonnes of carbon dioxide when it is burnt. Every passenger is responsible for 9.1 tonnes of emissions. Travelling to New York and back on the QE2, in other words, uses almost 7.6 times as much carbon as making the same journey by plane.[246]

But there is one way in which you can cross the Atlantic by sea without being responsible for emitting a single atom of carbon – ask for a ride on a solar-powered motorised fibre-glass catamaran called Sun21. As Gizmag.com reported in May 2007:

> In a giant leap towards unfuelled travel, a full-sized motorised catamaran, the 'Sun21,' has just completed a leisurely crossing of the Atlantic ocean without consuming a drop of fuel. Stored solar energy powered the 5-man crew from Spain to the USA at a constant rate of 5-6 knots around the clock via electric engines. This is a major achievement – a reliable, long-distance, powered vehicle with zero fuel costs – and its successful journey hints at a cleaner, greener, cheaper future of transport.[247]

Aviation

And now we come to a very difficult topic; aviation. Jet travel is a mode of transport that has such serious potential as a contributor to climate change that it deserves its own section – especially because international aviation, like shipping, is often conveniently excluded from domestic thinking and policy-making on climate change.

Although carbon emissions from jet aircraft currently amount to only 2-3 per cent of global CO_2 emissions, aviation is a transport sector that is growing very rapidly (in China, at 40 per cent a year) and emissions from aircraft seem to have a greater detrimental impact on the atmosphere than other forms of carbon emission.

In 'Heat', George Monbiot has a great deal to say about jet travel:

> Aviation has been growing faster than any other source of greenhouse gases. Between 1990 and 2004, the number of people using airports in the United Kingdom rose by 120 per cent, and the energy the planes consumed increased by 79 per cent.[248] Their carbon dioxide emissions almost doubled in that period – from 20.1 to 39.5 million tones, or 5.5 per cent of all the emission this country produces.
>
> Unless something is done to stop this growth, aviation will overwhelm all the cuts we manage to make elsewhere. The government predicts that, 'if sufficient capacity were provided', the number of passengers passing through airports in the United Kingdom will rise from roughly 200 million today to 'between 400 million and 600 million' in 2030. It intends to ensure that this prophecy comes to pass. The new runways it is planning 'would permit around 470 million passengers by 2030'.[249]

In 2006 Friends of the Earth[250] and the Co-operative Bank commissioned the Tyndall Centre For Climate Change Research[251] in Manchester, UK to produce a report called 'Living Within A Carbon Budget', which made an excellent attempt to lay out a road map for how Britain could achieve sufficient cuts in carbon emissions to meet the targets necessary to escape the worst effects of climate change. On the topic of aviation the report was particularly fierce:

> The scale of carbon emissions from aviation allied with very high annual growth in the industry and the limited opportunity for efficiency improvements should place aviation at the forefront of the climate change agenda.
>
> Despite this, Government is reluctant to actively curtail the rise in aviation emissions, when self evidently the associated emissions profile cannot be reconciled with the Government's existing 60 per cent emission reduction target, and completely undermines any chance of achieving the more stringent targets that increasingly scientists connect with the 2°C threshold. The long-term repercussions of such an approach are difficult to overstate.
>
> In relation to propulsion, jet engines are a mature technology, and consequently the efficiency of the current fleet is not set to change substantially within the foreseeable future. Exacerbating this absence of a step-change in fuel efficiency is the long design life of aircraft, effectively locking society into current technology for at least the next 30-50 years.[252]

And carbon emissions from aircraft do seem to be particularly harmful to our atmosphere. In 'Heat' George Monbiot explains:

> The climate impact of aeroplanes is not confined to the carbon they produce. They release several differ-

> ent kinds of gases and particles. Some of them cool the planet, others warm it.
>
> The overall impact, according to the Intergovernmental Panel on Climate Change, is a warming effect 2.7 times that of the carbon dioxide alone. This is mostly the result of the mixing of hot wet air from the jet engine exhaust with the cold air in the upper troposphere, where most large planes fly. As the moisture condenses it can form condensation trails which in turn appear to give rise to cirrus clouds – those high wispy formations of ice crystals known as 'horsetails.'
>
> While they reflect some of the sun's heat back into space, they also trap heat in the atmosphere, especially at night. The heat trapping seems to be the stronger effect.[253 254]

The fact that jet contrails reflect 'some of the sun up' does cause confusion within the community of concerned environmental writers. In 'The Weather Makers' Tim Flannery writes:

> Air travel is currently growing at between 3 and 5 per cent per year and cargo transportation by air is increasing by 7 per cent per year. The researchers at Imperial College London[255] are combining predictions from climate change models with air traffic simulations to predict contrail formation and identify ways of reducing it.

> But the above researchers' assumption about clouds formed by contrails heating up the atmosphere may be wrong. Some climate scientists have theorised that aircraft contrails[256] (also called *vapour trails*) are implicated in global dimming,[257] but the constant flow of air traffic previously meant that this could not be tested.
>
> The near-total shutdown of civil air traffic during the three days following the September 11, 2001 attacks afforded a rare opportunity in which to observe the climate of the United States absent from the effect of contrails. During this period, an increase in diurnal temperature variation of over 1°C was observed in some parts of the US, i.e. aircraft contrails may have been raising nighttime temperatures and/or lowering daytime temperatures by much more than previously thought.
>
> In other words, global dimming may be masking the effect of global warming but, in doing so, is slowing down its worst effects. Scientists are not agreed on this subject.[258]

In the end, most environmentalists come to the conclusion that the growing world population must *reduce* its use of air transport, rather than allowing it to grow vigorously as is predicted. However, I fear that unless high carbon taxes or even legislation limiting air travel is introduced (something that would be very difficult to achieve on international routes) the business community and the general public will continue to increase its demand for aviation.

However, relatively little media attention is being paid to possible alternative fuels for jet engines. It has been received wisdom that jet engines require from their fuels such a high density of energy to their weight (and the ability to remain liquid at the very low temperatures of stratospheric travel) that there is no practical alternative to carbon-dense kerosene.

Even the Intergovernmental Panel on Climate Change is certain that there is no alternative to kerosene for jet fuel. In its report Aviation and the Global Atmosphere, the panel says**:**

> There would not appear to be any practical alternatives to kerosene-based fuels for commercial jet aircraft for the next several decades. Reducing sulfur content of kerosene will reduce SO_x emissions and sulfate particle formation.
>
> Jet aircraft require fuel with a high energy density, especially for long-haul flights. Other fuel options, such as hydrogen, may be viable in the long term, but would require new aircraft designs and new infrastructure for supply.[259]

Despite such apparent authoritative certainty about the bleak future for aviation emissions, Time Magazine reported in 1988 that the Soviet Union had successfully converted a Tupolev Tu-154 passenger jet modified to burn a mixture of liquid hydrogen and natural gas.[260]

To be fair to the Tyndall Centre, the authors of 'Living Within A Carbon Budget' did recognise that bio-fuels must play an important role in aviation:

> In addition to the demand management and fuel efficiency improvements therefore, a third of aviation fuel must come from low-carbon, technologically compatible sources such as bio-diesel and bio-kerosene to ensure that the industry meets its carbon obligations.[261]

British transport mogul (and self-interested airline boss) Sir Richard Branson also thinks there is a future for cleaner biofuels in jet aviation. Writing about Virgin Atlantic, the airline Sir Richard heads, The Independent newspaper reported in April 2007:

> Virgin Atlantic will also announce today that it is to become the first carrier in the world to use green aviation fuel. Virgin Atlantic is planning to launch trials next year with Boeing and the US engine manufacturer General Electric, flying a 747 aircraft using a mixture of bio-fuel and conventional aviation fuel.[262]

Virgin Atlantic is also upgrading its fleet of aircraft to include 15 Boeing 787 Dreamliners,[263] which are claimed to burn 27 per cent less fuel than other comparably sized twin-engine jets. Boeing claims that the 787 uses less fuel, largely because it is made with composite plastics and metals and weighs less than standard aluminium-frame airplanes, another role in which plastics is making a positive contribution towards reducing carbon emissions. (And as well as playing an important role in the construction of new, more fuel efficient aircraft, plastics also has a role to play in making existing fleets more efficient. Retrofitting plastic ‘winglets’ –

the upturned ends of wings – increases fuel economy by up to 6 per cent.[264])

Of the semi-plastic Boeing 787, The Economist reported in June 2007 under the headline 'Travelling green tonight':

> With half its primary structure, including the fuselage and wings, made from composites, the 787 is much lighter than any metal aircraft of similar size. That not only saves fuel but allows other improvements. For example, the air is nicer to breathe. Airliners have to be pressurised when flying above 10,000 feet because oxygen levels drop dangerously low. At cruising height, usually around 35,000 feet, cabin pressure in most aircraft is kept at the equivalent of around 8,200 feet (about the same as Mexico City) because maintaining a higher pressure in a conventional aircraft might accelerate metal fatigue. To add to passengers' discomfort, the air is kept as dry as possible because moisture causes metal to corrode. But the 787 is pressurised at the equivalent of 6,000 feet and the air can be kept less dry because the composites are stronger than metal and unaffected by moisture.[265]

Producing biofuel for jet engines would not have the vast and potentially disastrous environmental impact that switching to biofuels such as ethanol for road transport would have (see my later section 'The Future of Energy'). Even the enlarged jet fleets of the future would use only a tiny fraction of the fuel consumed by the world's millions of road vehicles and aviation's potential for harmful carbon emissions is so great that a good case for switching to biofuels can be made easily.

But even though the development of green biofuels points to a future in which jet travel is no longer a significant polluter (certainly by 2030) it will be years before biofuels can be thoroughly tested and production ramped up to the necessary levels. In the meantime, what can we do?

Airlines themselves have understood that unless they somehow reduce their greenhouse gas emissions they will either lose business as customers become more environmentally conscious or as governments become more interested in regulation – or a combination of both. The rapidly-growing European low-cost airline Easyjet itself launched a design for a low-emissions airliner in June 2007 called the 'EcoJet'[266] – an aircraft that would have a high-performance plastics composite fuselage and wings and open-rotor jet engines.

As a large customer of both Boeing and Airbus (Easyjet is currently adding a new plane to its fleet every twelve days[267]) the company insisted that the technology exists for such a super-clean aircraft to be operational by the year 2015. By 'super clean' the airline said that the new aircraft should be 25 per cent quieter and emit 50 per cent less carbon dioxide than current aircraft. The new planes should also emit 75 per cent less oxides of nitrogen than the present A320 and 737 families of aircraft.[268] But how do we offset aircraft emissions between now and 2015?

Carbon offsetting schemes[269] vary in quality and efficiency and even the best of such schemes cannot be safely regarded as true mitigators of the damage caused by aviation. In essence, carbon offset schemes enable us to make a payment to an organisation which then undertakes to plant trees or to invest in energy saving projects in order to reduce CO_2 emissions elsewhere in the world, at some time in the future, to a degree that roughly equals the carbon that you as an airline passenger have been responsible for emitting.

In The Guardian environmentalist George Monbiot made his position regarding carbon offsets clear:

> Any scheme that persuades us we can carry on polluting delays the point at which we grasp the nettle of climate change and accept that our lives have to change. But we cannot afford to delay. The big cuts have to be made now, and the longer we leave it, the harder it will be to prevent runaway climate change from taking place. By selling us a clean conscience, the offset companies are undermining the necessary political battle to tackle climate change at home. They are telling us we don't need to be citizens; we need only to be better consumers.
>
> Yet aviation emissions, to give one example, are rising so fast in the UK that before 2020 they will account for the country's entire sustainable carbon allocation. A couple of decades after that, global aircraft emissions will match the sustainable carbon level for all economic sectors, across the entire planet.[270]

Tony Juniper, director of Friends of the Earth, said in January 2007:

> Carbon offsetting schemes are being used as a smokescreen to avoid real measures to tackle climate change. We urgently need to cut our emissions, but offsetting schemes encourage individuals, businesses and governments to avoid action and carry on polluting. There is still time to act, but we cannot afford to be distracted by measures that at best only have a small role to play in providing the solutions to global warming.[271]

So, if biofuels are years away and carbon offsetting schemes offer no solution what else must we do about aviation? Completely redesigning aircraft is one possible answer. In August 2007 Gizmag.com reported:

> The standard aircraft design with which we have all become so familiar throughout the 20th century is headed for the scrap heap. Despite its ubiquitous nature, the traditional shape is set to be superseded in the push towards cleaner, greener aircraft that can transport people around the globe using less and less fuel.
>
> Now a new research group at a Netherlands university has been formed with the explicit goal of consigning the current shape of passenger airliners to the history books. The CleanEra project will investigate BWB (blended-wing-body), high-tech propeller engines and even UFO-style body shapes in their efforts to produce a light, efficient airliner model that produces less noise and cuts carbon dioxide emissions by at least 50% over current designs.[272]

But completely new aircraft will take many years to design, test and build and, in the meantime, something must be done urgently to reduce emissions produced by aviation.

The simple fact is that if we are to meet the IPCC's emissions reductions targets, carbon has to be taxed at the point where it is emitted (i.e. taxing the airlines as they fly). The money raised must be used to undertake very large-scale tree planting (an excellent low-tech way of combating climate change – especially as young, rapidly growing forests absorb far more CO_2 than mature forests) and to hasten the development of biofuels (where appropriate) and the development of renewable and sustainable clean energy sources.

Strong carbon taxation will slow aviation's growth (as a recent tax hike on UK aviation[273] is proving) and those of us who bought second homes abroad (not me) because of cheap airline fares will, unfortunately, feel some pain. Business travel may be reduced (or at least, not grow so quickly) and some cargo may transfer to the shipping lanes. There is no alternative.

What we must do about Climate Change

There are as many prescriptions for saving the planet as there are concerned 'environmentalists' and the challenge is so vast, so important, that political agendas invariably shape many of the proposals.

Given that we face a serious and very dangerous global crisis in the early part of the 21st century, it is clear that something has to be done. 'Business as usual' simply isn't an option.

As mentioned earlier, climate change is already so advanced that it is impossible to head off its early symptoms. A February 2007 report by Lehman Brothers called 'The Business of Climate Change' provides more details:

> Even if global emissions completely ceased today, Earth's mean temperature would continue to rise, by around 1°C, as a result of past emissions and oceanic thermal inertia – the so-called 'climate change commitment'.
>
> Given that emissions will not cease today, Earth's mean temperature stands to rise by more than 1°C over the coming century. Projections of temperature increase depend on postulated future carbon emissions. If the growth of emissions remains at around the 'business as usual' rate, the concentration of CO_2 in the atmosphere will reach around 500ppm by 2050. According to the Intergovernmental Panel on Climate Change's Third Assessment Report (IPCC TAR), and recent research by the Hadley Centre, such a continued increase in greenhouse gas emissions through the rest of the 21st century would lead to global warming of between 2°C and 5.8°C.[274]

The 'California Progress Report', also published in early 2007, came to a similar conclusion:

> In effect, the battle is already lost. The globe will continue the warming trend that began in the middle of the last century. More frequent heat waves, stronger storms, more devastating droughts, rapidly melting glaciers, and rising sea levels are coming our way no matter what we do. The question the report asks is whether we have the will to change our behavior quickly enough to prevent this bad news from becoming horrific. Even if we somehow stopped all greenhouse gas emissions immediately, global temperatures would still rise 1.1°F by century's end. That would mean shutting down every plant, automobile, or device that runs on oil, coal, or natural gas today, while also stopping all rainforest destruction – an impossibility surely. The IPCC report says we can only afford another 2.5°F rise before the weather changes would become catastrophic. To decarbonize our economies quickly enough to slip below that threshold, scientists say we would need to cut emissions by 80 per cent by 2050.[275]

How difficult will it be to cut emissions by 80 per cent by the year 2050? Well, given the right mindset, I think we can achieve this target without causing major damage to the global economy and the expectations of the millions in the world's rapidly emerging territories such as China, India and parts of Latin America.

The Right Mindset

Even though some symptoms of climate change cannot, now, be avoided our principal task in the 21st century must be to work to mitigate the worst effects that climate change could bring and to avoid the human deaths, the misery and the huge costs that would follow in their wake.

To do this, we need to change minds and lifestyles around the planet. If this sounds like a tall order, I would disagree. I have been speaking and writing about the effects of climate change since the early 1990s (very recently by some standards) and I have seen a shift in public attitudes in Europe which can only be described as extremely heartening. According to a 2006 Financial Times opinion poll:

> Europeans are overwhelmingly convinced that human activity is contributing to global warming, and a majority would be prepared to accept restrictions on their lifestyle to combat it, according to a poll for the Financial Times.
>
> Research carried out this month by Harris Interactive in Germany, France, the UK, Italy and Spain found that 86 per cent of people believed humans were contributing to climate change, and 45 per cent thought it would be a threat to them and their families within their lifetimes.[276]

Then, in late June 2007, The Independent reported:

> There has been a double-digit increase in the proportion of Americans who say environmental problems are a major global threat – from 23 per cent to 37 per cent, according to a comprehensive survey published this week by the Pew Centre in Washington.
>
> The environment is increasingly in the news in the US, thanks to violent and unusual weather patterns – mainly floods and severe drought – combined with the rising cost of petrol. The past few days have seen dramatic rainfall across the southern states. More than a foot of rain fell across central Texas and Oklahoma yesterday, with more storms predicted.
>
> The survey found that the Chinese are far more likely than Americans to cite environmental problems as a major global danger (70 per cent against 37 per cent).
>
> Worldwide, most people in the surveyed countries agree that the environment is in trouble and most blame the US and, to a much more limited degree, China.[277]

Given such clear public alarm, we now need effective and closely policed legislation from our politicians, legislation that doesn't only set targets for the reduction of our carbon emissions, but which offers incentives and inducements for businesses and individuals to help meet them.

But the change that matters must occur within our businesses and within our daily lives. And the one thing that causes change in a personal lifestyle is EDUCATION.

By 'education' I don't mean a series of television ads exhorting the populace to save energy (although that might help), I mean continuing education by the media, by governments, by businesses and NGOs and by industry to make the public more and more aware of its responsibility to our planet.

One ideal place to start this process is in schools and the FuturEnergia campaign[278] being run by Plastics*Europe* is an excellent example of an initiative to encourage young people to learn about energy conservation.

In essence, we all have to develop a conscience (and a consciousness) about the cost of our lifestyles.

Energy (by which I mean transport fuel, electricity and gas) has been so relatively cheap in the developed world that most of us have used it with an uncaring, rapacious profligacy that will seem shocking to future generations.

A visitor to the United States who witnesses that nation's absolute reliance on automobiles might conclude that nothing can be changed in US domestic policy without completely dismantling a society that has become wholly addicted to cheap energy (which is why, perhaps, so many American citizens are pig-headed about refusing to accept that climate change is a serious problem). And I understand that in societies and communities that were designed *after* the automobile was invented a legislative prescription to restrict citizens using such transport would be doomed to fail.

The answer has to be to redesign vehicles to be far more frugal with energy, to change the nature of the fuels they use and to develop rapidly renewable and sustainable sources of energy (I cover this aspect in more detail in the following section, 'The Future of Energy').

'The right mindset' means that we each have to become conscious of the cost of our actions in our daily lives. If, magically, all of us in the developed world lived our lives in a way that acknowledged the environmental cost of our lifestyle, the targets for emissions cuts would be far more easily met.

Do you ensure that the electrical devices in your home do not waste energy idling in 'standby' mode (7 per cent of electricity consumed in the UK goes to feed devices on 'standby'[279])? Do you walk, cycle or take public transport as often as possible and eschew the use of a car unless absolutely necessary? When you are forced to use a car do you ensure that it has the lowest carbon emissions possible (or do you drive a 4X4 in a city)? This is what the May 2007 IPCC report on what we must do about climate change had to say on transport:

> Unless there is a major shift away from current patterns of energy use, projections foresee a continued growth in world transportation energy use by 2 per cent per year, with energy use and carbon emissions about 80 per cent above 2002 levels by 2030.[280]

Do you take the time to separate your waste and recycle items which have energy stored within them (like plastic) or which can be recycled to save the use of virgin resources? Have you replaced your wasteful incandescent electric light bulbs with energy-saving bulbs? You should – here's what the magazine New Scientist wrote on the subject in March 2007:

> Western governments are gunning for the humble light bulb because it wastes huge amounts of energy. First to propose calling time was the state of California: on 31 January it unveiled the 'How Many Legislators Does it Take to Change a Light Bulb Act', which, if passed, will ban the bulbs by 2012. Three weeks later, Australia announced a plan to do likewise. This month the UK government promised to phase them out by 2011.[281]

Of course many people have aesthetic objections to today's energy-efficient light bulbs. But new LED-based lights (mostly made from plastics) are arriving to widen the range of alternatives to the standard 100-year-old incandescent bulb.

Have you honestly worked to make your home as energy-efficient as possible? In 'Heat', George Monbiot makes the following observation about British energy efficiency compared with other countries in Europe:

> Houses which meet the building codes in Norway and Sweden use around one quarter of the energy of houses meeting the standards in England and Wales. In fact, the building regulations in Sweden were tougher in 1978 than they are in Britain today. In

> Germany the air tightness standard – which determines how leaky a house is allowed to be – is three times as stringent as the standard in Britain. The 'Passivhaus' (passive house with zero carbon emissions) was first developed in Germany in the late 1980s.
>
> There is nothing magical about these constructions, and they rely on little in the way of innovative technology. The builders need only ensure that the 'envelope' of the house – the bit that keeps weather out – is as airtight as possible and contains no 'thermal bridges'. A thermal bridge is a material that conducts heat easily from the inside of the house to the outside. At every point – even where the wall meets the ground or the roof – contact with outside temperatures must be interrupted with insulating materials.[282]

Governments are, of course, moving rapidly to introduce legislation which lays down energy efficiency standards for new home construction and in Germany legislators are preparing to introduce an 'Energy Passport'[283] which will guarantee the energy efficiency of private homes. In the UK the government has introduced Home Information Packs[284] which force property sellers to include an energy efficiency audit of their homes for the benefit of prospective buyers.

But legislation and good intentions on their own are not enough. In 'Heat', George Monbiot cites the Energy Savings Trust and Energy Efficiency Partnership for Homes who say that a large percentage of new buildings constructed in the UK do not meet the energy efficiency ratings required by law:

> A study by the Buildings Research Establishment found that 43 per cent of the new buildings it tested, which had received certificates saying that they complied with the regulations, should have been failed.
>
> Professor David Strong, the head of the Establishment, observes that plenty of new homes have the requisite amount of insulation in their lofts, but quite often it is still tied up in bales, as the builders, knowing that no one would be checking, couldn't be bothered to roll it out.[285]
>
> One of the reasons for this is that the government has allowed builders to turn to the private sector to get their certificates.[286]

Independently, The New Scientist reported on findings that seem to bear out these allegations:

> Last year, when the UK's Building Research Establishment inspected 99 new homes to see how well they complied with building regulations, one-third failed the standards for airtightness. A common shortcoming was holes round pipes where they went through walls. Property owners that want to ensure that insulation has been properly fitted can use thermal-imaging cameras to spot areas where heat is being lost.[287]

Plastics have a huge role to play in improving energy efficiency in new building (and in retro-fitting old buildings). Plastic insulation materials (and thermal bridges and barriers), construction materials and even glass replacement materials offer massive opportunities for energy saving.

And what else should we do if we want to avoid the worst case climate change scenario in 2030 with which I opened this section? Lord Robert May, Fellow of Merton College, Oxford, and formerly Chief Scientific Adviser to the Government (and, perhaps, Britain's most distinguished scientist), spelled it out very well in The Times Literary Supplement, April 4, 2007. After noting that there has been a collapse in the market for 4X4 sports utility vehicles in the UK he provided the following advice, most of which I agree with:

> But what actions should we be taking? One thing is clear: the magnitude of the problem is such that there is no single answer. Our possible actions can be usefully divided into four categories.
>
> First, we can adapt to change: stop building on flood plains; start thinking more deliberately about coastal defences and flood protection, recognizing that some areas should, in effect, be given up.
>
> Second, we can reduce wasteful consumption, in the home, marketplace and workplace: we can now design houses which consume roughly half current energy levels without significantly reducing living standards.
>
> Third, and necessary in the medium term while we continue to burn fossil fuels, we could capture as

> much as possible of the carbon dioxide emitted at source, and sequester it (burying it on land or under the seabed).
>
> Fourth, we could move more rapidly towards renewable sources of energy, which do not put greenhouse gases into the atmosphere: these include geothermal, wind, wave and water energy; solar energy (from physics-based or biology-based devices); fission (currently generating 7 per cent of all the world's energy, and – despite its problems – surely playing a necessary role in the medium term); fusion (a realistic long-term possibility); biomass (assuming that the carbon dioxide you put into the atmosphere was carbon dioxide you took out when you grew the fuel). Some of these renewables are already being used, others are more futuristic.
>
> Ultimately, we need a shift in cultural norms, in the mores that shape everyday behaviour. In this sense, the current collapse of sales of SUVs in the UK is perhaps encouraging.[288]

Even though the United Kingdom emits only 2 per cent of the world's carbon dioxide, British politicians are leading the way in legislating to prevent climate change from becoming too severe. Following a two-year campaign called 'The Big Ask'[289] by Friends of the Earth the British government announced a new Climate Change Bill in November 2006 and in March 2007 published a first draft of what the legislation will cover. The announcement reads:

> The Government's blueprint for tackling climate change is published today (13 March 2007).
>
> The draft Climate Change Bill, the first of its kind in any country, and accompanying strategy, set out a framework for moving the UK to a low-carbon economy. It demonstrates the UK's leadership as progress continues towards establishing a post-Kyoto global emissions agreement.[290]

The Tyndall Centre produced a thoughtful response not long after the draft bill was published. The analysts working at the Centre criticised the bill for not covering aviation or shipping and warned that instead of reducing the likelihood of us suffering the worst effects of climate change, the mistaken logic behind the proposals in the bill would actually cause global warming to increase considerably more than the target set by the IPCC.

Two months after the bill's publication, Mike Childs, Head of Campaigns for Friends of the Earth (and a consulting referee on this section of this report) referred to the criticism made of the bill by three parliamentary committees when he said:

> 'The Climate Change Bill must be strengthened. This is the clear conclusion from this joint report by members of the House of Commons and House of Lords. Gordon Brown now has a golden opportunity to demonstrate his green credentials. The Government must listen; it must include international aviation in the emissions reductions targets and it must set

> a higher target to cut emissions based on the latest scientific evidence.'[291]

On May 4, 2007 the IPCC published its fourth report (and for the present, final report – the next IPCC assessment is due in six years) on climate change, 'The Mitigation Of Climate Change'.[292] This document spelled out how the global community can tackle climate change.

The Economist commented:

> Some greenhouse-gas emissions, as the IPCC points out, can be cut at no cost at all–through straightforward measures such as improving insulation and binning wasteful incandescent light bulbs. Such measures could both save people and companies money, and save the planet from a chunk of carbon emissions. At present, they don't bother to do much, because electricity bills are not threatening enough; but governments might take a hand. The European Commission, for instance, is planning to ban incandescent light bulbs in two years' time. Such measures could make a difference, given that lighting accounts for 17 per cent of global power consumption.
>
> In other areas, low-carbon technologies would be more expensive than conventional ones–but not necessarily exorbitant. In power generation, for instance, the biggest single source of carbon, the cost of wind and solar power has fallen sharply over the past couple of decades to the point where, in favourable locations, wind power can compete, in price terms, with more

> conventional forms of energy. Better still, the cost is likely to fall further. Wind turbines are going to go on getting bigger and thin-film technology is likely to bring down the price of producing solar panels.[293]

Plastics and the Environment

Plastics bring many benefits to the world – e.g., increased carbon efficiency for cars and planes, energy conservation through the use of plastic insulation materials and food preservation through the use of anti-contaminant plastic packaging which can double or even triple the amount of time food stays fresh. However, the consumer image of plastic products is harmed by thoughtless and careless disposal.

The biggest problem of waste plastics is that the material is extremely durable and although this is a benefit during a product's life cycle, consumer carelessness sometimes thwarts the plastics industry's attempts to educate the public about re-use and recycling. The low unit cost of most common forms of plastic also tricks consumers into considering the material to have little intrinsic value and thus thoughtless disposal is a widespread problem.

The world is littered with carelessly dumped plastic bags, bottles and packaging. This is a behavourial problem and the responsibility might seem to lie with the careless consumer, but the plastics industry takes its responsibilities seriously and is anxious to find ways to reduce such environmental pollution.

Plastics material going into landfill is a major concern for some environmentalists. Most plastics take a very long time to degrade in such conditions (typically hundreds of years) and even plastics which some producers class as 'biodegradeable' (or 'oxo-degradable') may not break down when denied the effects of sunlight and/or water. The plastics industry believes that wherever possible plastics should be re-used or recycled and, when this is not possible, should be burned to release the energy trapped within plastic to produce heat.

Another major problem caused by the careless disposal of plastics is seen in the pollution of the world's oceans and beaches. Past carelessness (and, in some cases, criminal neglect) has led to microscopic shards of plastics becoming widespread in the marine environment. In 2004, researchers from the British Universities of Plymouth and Southampton reported:

> A team of experts has carried out research which proves – for the first time – that oceans and shores are now contaminated with microscopic plastics and fibres.
>
> Eight scientists from the Universities of Plymouth and Southampton and the Plymouth-based Sir Alister Hardy Foundation for Ocean Science has today published a paper detailing their research in the prestigious international journal *Science*.
>
> The results of the project, which was funded by the Leverhulme Trust, show that oceans and shorelines

> are now contaminated with microscopic plastic fragments. In addition, large items of plastic debris are known to be accumulating in the oceans and on beaches, harming marine life including turtles, fish, seabirds and mammals.[294]

Around the world efforts are being made by both the plastics industry and by legislators to reduce the scale of this problem. The Pacific Ocean is particularly polluted and in California action is being taken. The Record, a newspaper published in Orange County, Southern California ran the following story in February 2007:

> Wildlife experts, state officials and plastics manufacturers this month are putting more emphasis on keeping nurdles out of the environment. The California Ocean Protection Council passed a resolution calling for manufacturers to keep closer tabs on the pellets; and a bill proposed in the Legislature would require increased monitoring of businesses that use nurdles improperly.
>
> Nurdles, of course, are only one piece of the plastic problem. Worldwide, plastic makes up 60 per cent to 80 per cent of ocean trash. In parts of the Pacific Ocean, researchers have documented up to six times more floating plastic than plankton, the microorganisms that feed nearly all aquatic creatures.[295]

These problems must be greatly reduced or, even better, completely eliminated by 2030. The global plastics industry is, itself, working to counter these problems. Operation

Clean Sweep[296] is an American-led initiative to clean up the oceans. Endorsed by environmentalists such as Jean-Michel Cousteau, Operation Clean Sweep provides information and tools to help plastics companies eliminate any transfer of plastic feedstock pellets to the outside environment.

The larger-scale solutions to the problems of waste plastic include wider plastics re-use, recycling and energy recovery, the use of new forms of fully biodegradable plastics, re-education about the benefits and the disposal of packaging (both within the retail industry and to the consumer) and the encouragement of new patterns of consumer behaviour. By 2030 we must be able to live a lifestyle that is close to 'zero waste'; it will help if we start to see waste as simply a design flaw.

Recycling of plastics is an excellent place to start on our way towards a cleaned up environment. Recycling plastics produces new products which, in some cases, require 70 per cent less energy than making them from scratch (the figure for aluminium is 95 per cent, for glass 30 per cent and paper re-making requires 40 per cent less energy).[297] Recycling also reduces emissions of pollutants than can cause smog, acid rain and the contamination of waterways.

One of the unique things about plastic is that the energy in the fuel source from which polymers are derived (usually a fossil fuel) still remains present to a large extent in the finished product. Thus a plastic chair, electronic casing or carrier bag will still retain much of the component energy that belonged to the original source material. The considerable 'value added' by the plastics industry to the price of crude oil is revealed by a comparison of the US market sectors for transport fuel and petrochemicals (which include plastics). Although petrochemical processes consume only 3.4 per cent of the oil consumed in the USA, the value of that sector is $375 billion, whilst the value of the 70.6 per cent of the oil that is burned for transport fuel is only slightly larger, at $385 billion.[298]

Professionals in the plastics industry say that the energy contained in plastic is merely ‘borrowed’ for the life-time of the product and most of it can be recovered. Plastics products can be burned to produce heat (and thus electrical power) and if plastics products were to be burned in an incinerator in which carbon emissions were sequestered (trapped) waste plastics products could potentially produce heat which could be used to generate almost carbon-free power. Only pilot projects for carbon-trapping during plastics incineration are currently in use and it is still unclear whether or not such a procedure would be a net producer of energy. Friends of the Earth supports landfill for waste plastics to ensure CO_2 sequestration (although landfill itself is highly controversial and frowned on by the European Commission) and in preference the organisation argues that re-use and recycle is the best model of all. Certainly, if recycled, some waste plastics products can produce new plastics products without using much more additional fuel as a component.

In theory, most plastics can be recycled but today’s market forces mean that it is often cheaper to throw away some forms of waste plastic than it is to recycle them. Unfortunately, there is widespread recycling for only two types of plastics[299] – polyethylene terephthalate and high-density polyethylene.[IX] This is one reason for the selectiveness of recycling programmes used in most countries.

As the Economist reported in June 2007:

> Plastics, which are made from fossil fuels, are somewhat different. Although they have many useful properties – they are flexible, lightweight and can be shaped into any form – there are many different types, most of which need to be processed separately. In 2005 less than 6% of the plastic from America's municipal waste stream was recovered. And of that small fraction, the only two types recycled in significant quantities were PET and HDPE. For PET, food-grade bottle-to-bottle recycling exists. But plastic is often 'down-cycled' into other products such as plastic lumber (used in place of wood), drain pipes and carpet fibres, which tend to end up in landfills or incinerators at the end of their useful lives.
>
> Even so, plastics are being used more and more, not just for packaging, but also in consumer goods such as cars, televisions and personal computers. Because such products are made of a variety of materials and can contain multiple types of plastic, metals (some of them toxic), and glass, they are especially difficult and expensive to dismantle and recycle.[300]

[IX] It is also possible to recycle other forms of plastics, e.g. PVC and EPS, but the 'cherry picking' approach of the recycling industry currently offers fewer options for these materials.

This situation will change as energy prices rise (assuming no 'wild card' new technology emerges which can produce very cheap energy), as legislators get tougher about protecting the environment and as consumers become much better educated about the costs that their existence places on the world's environment.

Germany, the Scandinavian countries, Austria and Belgium have long been leading the way on recycling as a whole and on plastics recycling and energy recovery in particular. A combination of strict legislation and public education has pushed recovery rates in these countries over 80 per cent. On the other hand, citizens of countries such as Greece and the United Kingdom have been behaving as irresponsible profligate consumers, historically recycling less than 10 per cent of their potentially recyclable waste. This is changing rapidly, however.

In March 2007 the International Herald Tribune published a report on recycling activity around Europe and, although not an exhaustive survey, the trends are encouraging. In Paris, plastic not suitable for economic recycling is burned to produce heat for apartment buildings and plastic suitable for recycling is processed locally.[301]

In London, there is a heartening trend towards increasing the amount of recycling (which was at a very low level)[302] while in Sweden, recycling is mandatory and is paid for by industry and the consumer.[303]

Italy has also legislated to enforce recycling and in Milan many plastics are recycled to make parts for the local automobile industry.[304] And in Germany, where deposits are paid on plastic bottles, and return is a legal requirement, recycling is undertaken very conscientiously by citizens:

> Germans separate their trash with an earnestness and conviction that often confounds newcomers. There are bins for paper, compost and general trash. There are three bins for glass – clear, green and amber – and a yellow bin for plastics, metals and packaging. As many as seven bins can crowd the back courtyards and side alleyways of German homes.
>
> Berlin residents, who pay a deposit on plastic bottles, may also take them back to the store where they were purchased and claim a refund - the most popular solution.[305]

In Ireland citizens have been so responsible about recycling that the nation has hit a recycling target well ahead of schedule. In 2005 Ireland recycled 60 per cent of its packaging waste,[306] meeting its EU proscribed target for 2011 six years early.

One of the problems with the economics of plastics recycling has been that plastics recovered from foodstuff packaging and bottling hasn't been considered 'clean' enough to be re-used to make food containers or bottles. The plastic recovered has been used for products such as plastic garments (see the Marks and Spencer recycled-plastics fleece[307]) and plastic insulation materials. The problem is that these types of plastic yield far less income for recyclers than plastic which can be re-used to contain foodstuffs.

But, as New Scientist magazine explained in May 2007:

> A new generation of plastics recycling plants promises to change all that. The plants will use technologies that reduce or even eliminate the need for water and produce plastics clean enough for food packaging, at a lower cost than existing techniques. If successful, such plants could significantly increase the number of plastic bottles that are recycled in the US and Europe each year.[308]

And the magazine article goes on to point out that the economic prospects for recycled plastic have never been better:

> The high price of oil is boosting demand for recycled plastics, which is outstripping supply, so the new plants cannot be built quickly enough, says Patty Moore of Moore Recycling Associates in Sonoma, California. 'Right now we have economics that are pretty favourable for expanding recycling. The environment has changed from barely scraping by to people saying, 'hey, we can make some money at this'.[309]

In Britain the process of recycling plastic food containers to make new plastic food containers has already begun. In March 2007 Recycling Today reported.

> The first successful commercial trial of plastic milk bottles containing recycled HDPE, using world first technology has been completed this month.

> The trial, which involved the production of 60,000 recycled content milk bottles for commercial sale, is the culmination of a three-year project. The project was initiated and funded by WRAP, and is aimed at developing a recycling process capable of producing food grade polythene from milk bottles. The project was delivered by Nampak Plastics, Dairy Crest, the Fraunhofer Institute, Sorema, Erema and Nextek.[310]

Packaging of all sorts (much of it plastic) is a highly emotive issue for environmentalists. But it is hard to live in the developed world without buying packaged products and it is clear that much packaging is highly worthwhile (that which protects foodstuffs, medicines, etc. from contamination and increases shelf life).[x] In the less developed world up to 50 per cent of food is spoiled on its way from production to the shelf because of a lack of packaging.[311]

Meanwhile other forms of packaging (perfume, cosmetics, etc.) have in a few cases become a perverted end in themselves and require regulation. Certainly some forms of packaging are simply plain daft (shrink-wrapped coconuts) but such examples form only a small minority of the market. As packaging production accounts for 40 per cent of the overall plastics industry in Europe, attention must be paid to its responsible use.

Writing in New Scientist in April 2007, Jessica Marshall opened up the packaging industry to scrutiny.

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[x] The UK Cucumber Growers' Association has produced research indicating that a shrink-wrapped cucumber loses only 1.5 per cent of its water content after two weeks' storage compared with 15 per cent in an unwrapped cucumber.

> One factor behind the packaging explosion is the way goods are mass-produced in one part of the world and shipped to another to be sold. Products need to be boxed, wrapped or bagged in a way that gets them from the farm or factory and into the consumer's home in one piece. If the environmental impact of producing the items that might get damaged on the way is greater than that of the packaging needed to keep them safe, then the wrapping makes environmental sense.[312]

And, as Ms. Marshall uncovers, there is no simple answer to what type of packaging is most suitable for a specific purpose (although plastics comes out overall best):

> Plastic is light and uses relatively little energy, but it is non-renewable, non-biodegradable, and only some types can easily be recycled. Glass is energy-hungry to make, and even to recycle. Glass containers are also heavier than plastic ones, so shipping them consumes more fuel, but on the plus side they are easier to reuse and refill. Paper is renewable and degradable, but it is bulky to ship, can be energy intensive to produce, and uses environmentally damaging chemicals in its manufacture. Aluminium's environmental performance depends heavily on recycling: it takes a lot of energy to produce in the first place, but recycled aluminium has significantly lower environmental impact. Steel takes less energy to produce, but it's heavier.[313]

The plastic shopping bag is another topic which ignites environmentalists, and it is easy to see why. Although they are cheap, light and durable, these same qualities become distinct drawbacks when they are disposed of thoughtlessly. Some countries have banned plastic shopping bags, others have taxed them and some retail companies have taken matters into their own hands and produced durable, re-usable bags.

But it is by no means clear that plastic bags per se are bad (although careless disposal certainly is). In 1990 the American Institute for Lifecycle Environmental Protection produced a report which examined the environmental impact of both plastic and paper shopping bags. The report stated:

> Plastic bags, having less mass than paper, produce less solid waste. At current recycling rates two plastic bags produces 14 g of solid waste while one paper creates 50 g. Two plastic bags produce 72 per cent less solid waste than their paper bag equivalent. As the recycling rate increases, postconsumer waste decreases accordingly, so if 25 per cent more bags are recycled, the solid waste decreases by 25 per cent. Every recycled bag avoids contributing to postconsumer solid waste. However when recycling rates increase, pre-consumer solid waste increases for plastic though it decreases for paper. Still because paper creates substantially greater quantities of solid waste, two plastic bags never surpass a third of the solid waste from one paper bag.[314]

Using biodegradable plastics to make shopping bags may provide a useful alternative and the American plastics services and sales website Plastemart.com makes the following observation:

> From a Life Cycle perspective, biodegradable polymers offer the potential for gains by enabling the diversion of waste from landfills, where some 80 per cent of plastic waste now end up, to a fully recoverable resource in the form of either energy or compost products that can be further recycled through soil and plants, thereby closing out the carbon cycle.
>
> European research indicates starch based polymers offer energy and emission savings of 12-40 GJ/ton of plastic, and 0.8-3.2 tons of CO_2 emissions/ton of plastic compared to one ton of fossil derived polyethylene. For oil seed based plastic alternatives, green house gases emissions savings in CO_2 equivalents has been estimated to be 1.5 ton per ton of polyol made from rapeseed oil.[315]

Despite this optimism, biological fuels cannot be produced on sufficient scale to supply anything but a minority share of the market (because of environmental considerations) and we must, therefore, focus on re-use, recycling and recovery of energy to conserve our resources.

It seems clear that given improvements in recycling options which will occur over the next twenty-five years we must all work towards creating a 'zero waste' society. As is often the case with really good ideas, the concept of zero waste is not new. It was first developed in 1971 by the American biologist and former US Presidential candidate Barry Commoner[316] in his far-seeing book 'The Closing Circle.' He writes:

> Suddenly we have discovered what we should have known long before: that the ecosphere sustains people and everything that they do; that anything that fails to fit into the ecosphere is a threat to its finely balanced cycles; that wastes are not only unpleasant, not only toxic, but, more meaningfully, evidence that the ecosphere is being driven towards collapse.[317]

Thirty-six years later cities and corporations are trying to make the aptly named Commoner's vision come true. As CNN reported in January 2007:

> Wal-Mart and the city of San Francisco do not have much in common, but there is this – both are working to achieve zero waste.
>
> They aren't alone. The Australian territory of Canberra, a third of local governments in New Zealand, the cities of Oakland and Berkeley, a bunch of small towns in California, and Carrboro, N.C., ('Paris of the Piedmont') all have embraced a goal of zero waste.
>
> But what is zero waste? It's just what it sounds like – the idea that we can design, produce, consume and recycle products without throwing anything away. It's the idea that industry should mimic nature, so that, as the writer Joel Makower put it, 'one species' detritus is another's pantry.'[318]

By the year 2030 we will all have learnt to conserve, recycle and re-use. We don't have a choice. With over eight billion of us on the planet our resources, natural or human-made, will be stretched almost to the limit. Of course we will learn to make more of everything – that is the wondrous ability of humanity and its technologies – but the irresponsible profligacy that is today's defining characteristic of the developed world will have disappeared for ever. In its place will be a new form of consumerism; we will still have our goods and services but we will all know how they arrived and where they go once we have finished with them. Not to be responsible for the resources we consume will, by 2030, have become a moral crime. It may even have become a legal crime.

Section Three

The Future of Energy

Consulting Referee:

Professor I. M. Dharmadasa,
Centre for Electronic Materials and Devices,
Materials and Engineering Research Institute
Sheffield Hallam University, UK

Little in our world is as politically charged as energy generation and energy supply. Perhaps only national defence is regarded by governments as having more strategic importance. Just as individual humans must consume energy each day to survive, so must our modern high-tech societies. Politicians know that if there is a sustained failure in energy supply, or a long-term shortage of gasoline, citizens will take to the streets.

In 'The Hydrogen Economy' Jeremy Rifkin describes the social and political role of energy in stark terms:

> Societies collapse when the energy flow is suddenly impeded. Energy is no longer available in sufficient volume to sustain the increased populations, defend the state against intruders, and maintain the internal infrastructure. Collapse is characterised by a reduction in food surpluses; a winnowing of government inventories; a reduction of energy consumed per capita; disrepair of critical infrastructures like irrigation systems, road, and aqueducts; increasing popular defiance towards the state; growing lawlessness; a breakdown in central authority; a depopulation of urban areas; and increasing invasions and pillaging by marauding groups or armies.[319]

Nations go to war to secure their long-term supplies of energy and in 2007 alarm bells have started to sound in many countries because projections suggest that the world is going to demand much more energy between now and 2030. And in that timeframe global oil reserves will start to run out.

Estimates for future energy consumption vary widely, but at a minimum it is suggested that world energy consumption will increase by 50 per cent[320] by 2030 and the maximum projected increase is put at 100 per cent.[321] These nice round figures indicate just how 'approximate' some of the future projections necessarily are but they also illustrate a grave problem; in an era in which we have to cut our carbon emissions by at least 40 per cent by 2030 (and at the very least 60 per cent by 2050), how are we going to find sufficient energy of the right kind to meet our enlarged needs?

Ray Kurzweil, ever the optimist, sees a radical solution to the looming energy crisis coming from technology:

> By 2030 the price-performance of computation and communication will increase by a factor of ten to one hundred million compared to today. Other technologies will also undergo enormous increases in capacity and efficiency. Energy requirements will grow far more slowly than the capacity of technologies, however, because of greatly increased efficiencies in the use of energy. A primary implication of the nanotechnology revolution is that physical technologies, such as manufacturing and energy, will become governed by the law of accelerating

> returns. All technologies will essentially become information technologies, including energy.
>
> Worldwide energy requirements have been estimated to double by 2030, far less than anticipated economic growth, let alone the expected growth in the capability of technology. The bulk of the additional energy needed is likely to come from new nanoscale solar, wind and geothermal technologies. It's important to recognize that most energy sources today represent solar power in one form or another.[322]

Could Kurzweil be right? I think it possible that new technology development *may* significantly reduce energy consumption and provide new sources and forms of energy, but this cannot be relied upon.

For the present, therefore, we are faced with a world divided by competing claims for fossil fuel energy, a global economy that is vulnerable to shocks from the energy market and a world in which nation states use energy supply (or denial of supply) as a political, power-broking weapon.

Under the headline 'US Ponders Move To Counter Aggressive Russian Maneuvers', Erasiannet.org reported in March 2007:

> Washington policymakers are scrambling to develop tactics that can counter Russia's aggressive action aimed at cementing Kremlin control over Caspian Basin energy and export routes.

> Four major Eurasian energy developments during March have set off alarm bells inside the Beltway.
>
> First, Hungarian Prime Minister Ferenc Gyurcsany, the leader of that country's former Communist Party, revealed March 12 that his country would throw its support behind a plan to pump Russian gas via Turkey to Europe, instead of joining fellow European Union states in backing the much-delayed Nabucco gas pipeline project.
>
> The Russian route would utilize an already existing pipeline, known as Blue Stream, which transports gas between Russia and Turkey under the Black Sea.[323]

Because energy is such a deeply political issue in most countries, governments control the generation, importation and supply of energy to industry, business and consumers.

The two notable exceptions to national and semi-national energy monopolies are Britain and, to a lesser extent, the United States. Britain began privatising energy utilities in the 1980s. As economist Professor Dieter Helm[324] of Oxford University explains in his 2004 book, 'Energy, the State, and the Market: British Energy Policy Since 1979':

> The transformation of Britain's energy policy in the last two decades has been more radical than any such change in developed economies. Since 1979 the great state energy monopolies created after the Second World War have been privatised and made subject to competition.

> Since 1979 the National Coal Board, British Gas and the Central Electricity Generating Board have all been broken up. Energy trading, electricity pools, auctions and futures markets first developed, but they failed to solve the old energy policy problems of security of supply and network integrity, and the new ones of the environment and reliance on gas.
>
> The government introduced a new regulatory regime as a temporary necessity but regulation did not wither away, rather it grew to be more pervasive. Changing the ownership of the industries did not reduce the government's involvement, it simply changed its form.[325]

And as Mike Childs, Head of Campaigns for Friends of the Earth told me bluntly, 'Energy policy is the single biggest failure of market forces in our economy'.

This is a continuing problem. According to Dieter Helm, in 2007 the current British government is in danger of failing to develop an adequate energy policy for the future, so much so that 'by 2010 there is a danger that Britain will face a severe shortage of energy.'[326]

The USA followed Britain's lead and from 1996 onwards began deregulating and, to some extent, privatising energy generation and supply. But the international energy industry remains wholly under the control of politicians who have their own national interests as their top priorities. Less than 4 per cent of the electricity generated in Europe is exported between EU nations.[327] This inflexibility in the European energy market has grave consequences for the future security of European energy supplies as only a flexible and open internal market – ready both to import and export power at a moment's notice – can weather the vagaries of the international energy market.

Yet despite the apparently obvious benefits of an open and deregulated energy market across the European Union, the Commission is struggling against real opposition from the governments of its member states. As The Economist reported in April 2007:

> The European Commission has been urging EU members to break up their vertically integrated energy companies, but France and Germany are resisting. The problem, says the commission, is that national governments do not understand the link between liberalisation and greater energy security. 'New member states equate security with nationalism. But the only alternative to integration is isolation,' says one senior EU official.[328]

The EU Commission also plans to meet the need for a hugely increased energy demand whilst aiming to reduce overall carbon emission by 30 per cent by 2030. Energy officials in the Commission are certain that this can be done.

'We have to educate the public about energy conservation and we have to reorganise the distribution system for electricity within Europe,' a senior energy official in the Commission told me. 'Power generation must move closer to the point of consumption to reduce waste. We also have to make the consumers aware of the real cost of energy.'

The development of renewable energy - particularly energy from wind, water, solar power and biomass - is another central aim of the European Commission's energy policy.

> Renewable energy has an important role to play in reducing Carbon Dioxide (CO_2) emissions – a major Community objective. Increasing the share of renewable energy in the energy balance enhances sustainability. It also helps to improve the security of energy supply by reducing the Community's growing dependence on imported energy sources.
>
> Renewable energy sources are expected to be economically competitive with conventional energy sources in the medium to long term.[329]

Consumer education, political thinking and cultural attitudes play a large part in shaping how we consume energy and how much energy we consume. The United States has a population equal to only 5 per cent of the global total but the nation consumes 25 per cent of the world's energy. Europe has a far lower consumption of energy but the standard of living is just as high as in the USA

In 'The Extreme Future' James Canton sums up the American cultural attitude to energy use as follows:

> The American public, unlike the Europeans, has been spoiled by cheap oil, which has created the illusion of plenty while the reality of diminished reserves has escaped public scrutiny. The Europeans

> accelerated this public awareness by taxing gas, making it routinely two to three times as expensive as gas in the US. More than 85 per cent of new auto buyers in Europe are concerned with fuel efficiency. Fewer than 15 per cent of Americans care about fuel efficiency, because in a world of cheap oil, they don't have to.[330]

It is fair to say that America now finds itself in a truly lousy position regarding the future security of its energy supplies. The country has an extreme dependence on imported oil and a cultural and political dependence on low energy prices. It also has poor security over its future oil supplies which may make the heavily-armed nation even more dangerous to the rest of the world in the decades to come.

In the light of the need for urgent action on climate change, a looming shortage of oil and predictions that suggest that the world will consume up to double the amount of energy by 2030, governments around the world are rising to the challenge in various ways and with varying degrees of commitment.

In cloudy, temperate Ireland the government has announced ambitious targets[331] for new energy generation from renewable sources; meanwhile, sun-drenched Greece is being criticised[332] for falling far short of EU goals on renewable energy. Portugal, on the other hand, is making major investments in renewable energy sources and is building one of Europe's largest wind farms.[333] In Africa, Kenya has taken the lead[334] in planning for a future energy budget based on more sustainable energy sources and it is claimed that China is far more aware of the need for a switch to renewable energy sources than most people in the West believe. Writing in The Birmingham Post two analysts of China's energy policy reported in September 2006:

> The Chinese Government has devised a comprehensive renewable energy strategy designed to make power generation from renewable energy sources as economically competitive as coal-fired power generation.
>
> In 2003, renewable energy consumption accounted for only 3 per cent of China's total energy consumption. The Renewables Law seeks to increase the proportion to 10 per cent by 2020, representing a significant rise particularly given the rapid and continuing increase in China's overall power consumption.[335]

And The Economist reported[336] in June 2007 that solar power already heats about 80 per cent of China's hot water supply – an astonishing statistic.

In Eastern Europe there is plenty of potential renewable energy available but, as the International Herald Tribune reported in March 2007 there is, at present, a reluctance to begin the shift away from fossil fuels:

> Sun-baked Bulgaria, windy Poland and farm-rich Hungary have thousands of megawatts in untapped renewable energy that the European Union wants used to fight global warming.

> But eastern Europe remains heavily dependent on fossil fuels, causing friction between older and newer EU members as the bloc pushes an ambitious plan to boost its reliance on green energy.
>
> About 94 per cent of the electricity for coal-rich Poland comes from coal-fired plants, a major source of the carbon emissions that contribute to global warming.
>
> But in Poland, for example, leaders are disinclined to cut coal use, which helps limit dependence on Russian oil and gas. And with a 15 per cent unemployment rate – the EU's highest – cutting jobs in an industry that employs roughly 200,000 people could be political suicide.[337]

And in this incomplete and somewhat eclectic glance at attitudes and energy policies around the world it is worth noting that Denmark produces more than 20 per cent of its energy from wind sources today. By 2025 that figure will be more than 50 per cent. The UK produces 3 per cent of its power from wind today and the government's announced targets stipulate that will be 10 per cent by 2010 and 15 per cent by 2015.[338]

In Germany renewable energies made up 4.6 per cent of total primary energy supply in 2005, and the share of renewable energies in the total gross electricity consumption rose to 10.2 per cent. And in July 2007 German environment minister Sigmar Gabriel announced that by 2030 Germany intends to source 45 per cent of its energy requirements from renewable sources.[339]

France, on the other hand, produces 80 per cent of its energy in nuclear power stations. As The Guardian reported in March 2007 this is causing difficulties for EU policy makers:

> Divisions over nuclear power and renewable energy threatened to derail the EU's campaign to assume a global leadership role in the fight against climate change at the bloc's spring summit which began last night.
>
> Warning that 'it is closer to five past midnight than five to midnight' for international measures to combat global warming, Germany's chancellor Angela Merkel, chairing the meeting, urged EU leaders to 'deliver results for our grandchildren' by making Europe the world's first low-carbon economy via a unilateral 20 per cent cut in its greenhouse gas emissions by 2020.
>
> But France, backed by several east European countries, insisted carbon-free nuclear power be included within the EU energy mix and rejected Ms. Merkel's proposal to make a 20 per cent target for renewable energy binding on all 27 members.[340]

Nuclear Power

Nuclear power generation is a topic that is extremely divisive within environmental groups and within governments. Many environmentalists have strong emotional attachments to antinuclear campaigns whilst some individual environmentalists, most notably James Lovelock, are now urging fellow 'greens' to break with tradition and endorse carbon-lite nuclear power generation for the sake of the planet. At present the Zeitgeist seems to be favouring nuclear power generation once again and 31 new reactors are currently under construction around the world.[341]

As must have already become apparent in this section, energy generation and supply is wholly politicised and it is very difficult to get at the truth about something as important to nation states as nuclear reactors.

Whilst it is true that nuclear power generation produces electricity without carbon emissions, it is not true to say that there is no environmental impact from the process. The biggest problems are the risk of catastrophic accidents and finding safe ways to dispose of nuclear waste. This latter problem remains largely unresolved. Most of today's nuclear waste is simply stored in what is believed to be a safe manner until a satisfactory method of disposal has been developed. And it is also true to say that reserves of uranium on our planet may be limited. Although no serious exploration for new uranium deposits have been undertaken for twenty years (because nuclear power has been so much out of favour), current estimates suggest that if a new nuclear age were to dawn there would only be enough uranium available for 60-70 years of power production.

There are three other reasons why I am wary of advocating additional nuclear power generation to help reduce the problems of climate change. The first is that consumers don't know the true cost of the energy generated by nuclear power stations. Just as consumers aren't (at present) told the cost of the damage that fossil fuels do the environment as energy is produced (and that cost is not yet levied on the consumer), so the unit of power generated by a nuclear power station is not priced in a way that reflects the huge cost of mining and refining nuclear fuel, building the nuclear power station, the huge cost of decommissioning the plant after use and the ongoing cost of storing the radioactive waste. All of these costs are borne by 'the general taxpayer' over a long period (during which politicians, governments and civil servants change, thus evading individual and even collective responsibility) and there is no transparency in the process. We therefore have no idea how economic or uneconomic nuclear power is when compared with other forms of power generation.

This objection holds for governments all around the world and the nuclear industry has a vested interest in keeping such information opaque. Professor Dan Kammen of the University of California (Berkley) co-authored a report entitled 'Weighing the financial risks of nuclear power (unknown)':

> 'For energy security and carbon emission concerns, nuclear power is very much back on the national and international agenda,' said study co-author Dan Kammen, UC Berkeley professor of energy and resources and of public policy. 'To evaluate nuclear power's future, it is critical that we understand what the costs and the risks of this technology have been. To this point, it has been very difficult to obtain an

> accurate set of costs from the US fleet of nuclear power plants.'[342]

My second additional reason for believing that we should pursue the development of renewable or sustainable energy sources rather than nuclear power is the problem of nuclear proliferation. If the present nuclear powers continue to increase their nuclear power generation resources there are no moral grounds to suggest that other, less developed countries should not do the same thing. And as the number of nuclear reactors in the world proliferates, so does the opportunity for the building of nuclear weapons.

My third additional reason for believing that nuclear energy production should be scaled down rather than ramped up is that the more nuclear power stations there are, the more targets for international and domestic terrorists exist. We know that we currently live in an age of extreme danger from international terrorist ideologies and the cost and difficulty of protecting nuclear installations from terrorist attacks must be enormous – as would be the risk to the public if a major attack on a nuclear plant were ever to succeed. It is also pertinent to add that nuclear power stations in some regions of the world are also vulnerable to earthquakes and tsunamis.

However, disagreement on the subject of nuclear power is widespread. In the UK even the liberal and environmentally conscious The Observer newspaper (a sister publication to The Guardian) looked hard at the realities of securing British future energy supplies and in May 2007 ran an editorial entitled 'Nuclear Power Is The Only Realistic Option'.[343]

But I still disagree about further development of nuclear power, for the reasons given above – and because our current generation has the responsibility for creating a safe and peaceful world for the future. Despite the plans announced by both the US and UK governments to extend their nuclear power generating capacity, the world of 2030 would be a much safer place if the vast sums being allocated to develop additional nuclear power generation were, instead, diverted to develop renewable and sustainable forms of power generation and improve energy efficiency. As Friends of the Earth points out:

> Unfortunately (UK) energy efficiency initiatives have so far been neglected in favour of hugely expensive proposals for a new nuclear programme; despite the fact Government's own advisors have said that cutting emissions from other sources will be more cost effective and quicker.[344]

In the end, opting for nuclear power (with unknown cost implications) is a short-term, potentially dangerous and socially selfish means of solving the looming energy crisis.

The Future for Fossil Fuels

Except for nuclear-generated power all forms of energy in the world come directly, or indirectly, from the sun. The most concentrated form of energy available is that which was trapped millions of years ago as small sunlight-consuming cellular animals and plants were crushed and buried beneath the surface of the Earth and its oceans (producing oil, coal and gas, in the main). The compressed remains of these energy-rich organisms are called 'fossil fuels' and, because a) they have been relatively easy to mine and, b) we haven't realised until recently the effects of releasing the carbon they contain into the atmosphere as we consume them, we have burnt them indiscriminately.

Today, fossil fuels provide about 80 per cent of the world's energy[345] and most commentators believe that by the year 2030 the world will still be obtaining the majority of its energy from such fuels.

In ascending order of 'dirtyness' (in carbon terms), these fossil fuels are, natural gas, oil and coal. Oil and gas reserves are spread very unevenly in the world which, for the moment, gives those nations with the largest reserves great economic and political power. Coal on the other hand is widely distributed around the planet and is the much-used and easy antidote to the power wielded by the oil and gas nations, currently supplying (by one estimate) 24 per cent[346] of the world's energy needs. For political reasons coal is a favourite of many governments, even if it is often the most polluting form of fuel.

The United States is planning to build many more coal-fired power stations in an attempt to reduce its dependence on energy imports. As The Christian Science Monitor reported in February 2004:

> After 25 years on the blacklist of America's energy sources, coal is poised to make a comeback, stoked

> by the demand for affordable electricity and the rising price of other fuels.
>
> At least 94 coal-fired electric power plants – with the capacity to power 62 million American homes – are now planned across 36 states.[347]

Coal is also one of the main energy sources for the developing world. Almost 70 per cent[348] of India's electricity is generated from coal and the figure in China is 80 per cent.[349]

And, as this report was being written, environmentalists were dismayed to learn that China has unexpectedly shot to the top of the list of the world's largest emitters of greenhouse gases, years before such a 'promotion' was anticipated. Under the headline 'China overtakes US as world's biggest CO_2 emitter', The Guardian commented in June 2007:

> According to the Netherlands Environmental Assessment Agency, soaring demand for coal to generate electricity and a surge in cement production have helped to push China's recorded emissions for 2006 beyond those from the US already. It says China produced 6,200m tonnes of CO_2 last year, compared with 5,800m tonnes from the US. Britain produced about 600m tonnes.[350]

The World Coal Institute[351] asserts that coal supplies 40 per cent of the world's electricity, but this figure is at odds with the US government's claim that coal's current share globally is 24 per cent and this highlights just how difficult it is to find reliable information about something as politically important as energy. But whatever the true figure, it is clear that coal will continue to play a major role in generating electricity.

But does coal-fuelled power generation have to be the filthy source of carbon emissions it is today? In April 2007 The Massachusetts Institute of Technology produced a report called 'The Future of Coal'. The report's authors came to the following conclusion:

> There are many opportunities for enhancing the performance of coal plants in a carbon-constrained world – higher efficiency generation, perhaps through new materials; novel approaches to gasification, CO_2 capture, and oxygen separation; and advanced system concepts, perhaps guided by a new generation of simulation tools. An aggressive R&D effort in the near term will yield significant dividends down the road, and should be undertaken immediately to help meet this urgent scientific challenge.[352]

Capturing and 'sequestering' the carbon (storing the CO_2 in an environmentally benign way) will be big business by 2030. The German industrial giant Siemens intends to play a large role in applying this technology to coal-fired power generation. In March 2007 it issued a press release headed 'Coal Gets Cleaner':

> If all coal-fired power plants were upgraded today with the latest technology, then the amount of carbon dioxide emissions would be reduced by about two billion tons annually.

> Siemens and EON are working together on a new power plant project in Irsching, Bavaria, that will set the new standards for performance capacity, economy and environmental compatibility. With a targeted efficiency of 60 per cent in a combined cycle operation (gas and steam), Siemens seeks to set the world record for combined cycle power plants. Siemens is also working on innovative power plant designs for the environmentally compatible use of coal. One example is the so-called IGCC technology, or integrated gasification combined cycle.
>
> An IGCC power plant is a combined cycle generating facility with an upstream coal gasification plant that produces synthetic gas. The IGCC plants produce between 60 and 80 per cent less sulfur dioxide and nitrogen oxide than the most advanced conventional coal-fired power plants.[353]

And getting rid of CO_2 by pumping carbon into rocks also has great potential for producing clean energy. According to New Scientist:

> Pumping carbon dioxide through hot rocks could simultaneously generate power and mop up the greenhouse gases produced by fossil fuel power stations, according to a new study.
>
> Harnessing geothermal power involves extracting heat from beneath the surface of the Earth. Normally, this means pumping water down through hot rocks and extracting it again. But the new analysis suggests

> carbon dioxide could extract heat from rocks more efficiently than water.[354]

Oil is the second most polluting form of fossil fuel but, as it is the world's most widely used source of energy (40 per cent[355]), it is the biggest overall contributor to carbon emissions. But of all three fossil fuels, oil looks as if it will be the first one to come close to running out. Oil will not run out completely for a very long time, but as it becomes more scarce prices will rise to the point that it cannot be used as fuel for personal and mass transportation. Oil will then be reserved for high-value processes and products such as plastics manufacturing.

Over the decades much has been written about the future of oil supplies and in July 2007 The Financial Times reported gloomily:

> The world is facing an oil supply 'crunch' within five years that will force up prices to record levels and increase the west's dependence on oil cartel Opec, the industrialised countries' energy watchdog has warned.
>
> In its starkest warning yet on the world's fuel outlook, the International Energy Agency said 'oil looks extremely tight in five years time' and there are 'prospects of even tighter natural gas markets at the turn of the decade'.[356]

However, as soon as one authority suggests reserves will soon be running out it seems that new reserves are discovered or new methods of more efficient extraction are found. For example, The New York Times reported bullishly in March 2007:

> Will we seek a peak production year (2010?) and will supplies after that become erratic and uncertain? No.
>
> More oil available than thought – new steam pressure method raises extraction rates from existing field. Some of the gas pumped back is CO_2.
>
> Chevron[357] engineers here started injecting high-pressured steam to pump out more oil. The field, whose production had slumped to 10,000 barrels a day in the 1960s, now has a daily output of 85,000 barrels.

However, the beginning of the end of the global oil supply (peak production year) will almost certainly have occurred by the time we reach 2030. In the meantime, world demand for oil continues to soar, especially in the developing countries.

The problem with oil is that most of it is used for transportation and no practical means of extracting (or sequestering) CO_2 at the point of vehicular emission exists, nor is thought to be practical in the future. The future for the oil industry may remain bright, but way before 2030 governments, businesses and consumers must have reduced sharply their reliance on this energy source.

Oil is, of course, the principal raw material for plastic (about 4 per cent of global oil production is used for this purpose) but because much of the energy (and the carbon) remains trapped within plastic products during their lifetimes the carbon emissions from the oil used as raw material do not occur during production. As mentioned earlier, the light weight and durability of plastics products such as car parts, aeroplane fuselages, cargo pallets, building insulation and packaging materials also serve to lessen the carbon that would otherwise be emitted in a heavier, less durable non-plastics world (e.g. a plastic wine bottle now on trial in Sainsbury's supermarkets weighs one eighth the weight[358] of an equivalent glass bottle[359])[XI]. And the energy trapped within plastics can (and, increasingly, will be) either recycled or, in the future, recovered and used for heat generation within carbon-trapping power/heat-generating incinerators.

Natural gas is the cleanest of all fossil fuels and its availability and popularity over the last few decades has already had a mitigating impact on climate change. The 'Living Carbon Budget' report prepared for Friends of the Earth by the Tyndall Centre illustrated how natural gas has helped the UK constrain its carbon emissions from power generation:

> One key progression however, is the change in carbon intensity of the UK's electricity grid. Over the long-term, the grid has gradually become less carbon

[XI] UK consumers buy around one billion bottles of wine every year, using around half-a-million tonnes of glass.– Reducing the weight of wine packaging to 54g (2oz) by using plastic bottles could reduce carbon emissions by around 90,000 tonnes, according to the UK government-funded Waste and Resources Action Programme (Wrap).

> intensive, with a step change during the 1980s and 1990s with the move from coal-fired power to gas.
>
> Therefore, despite the near doubling of electricity demand over the long-term, the carbon emissions associated with electricity generation have shown a very moderate increase of around 8 per cent (4MtC) over the same period.[360]

Natural gas trails coal as the most popular fuel for the future (presumably for political reasons) but it is predicted to increase slightly its current share of the global energy mix.

However, in March 2007 Gulf Times reported that natural gas is currently the fastest growing component of the world energy mix and its share will rise to 25 per cent by 2025, and the US government's Energy Information Administration predicted:

> Natural gas trails coal as the fastest growing primary energy source in 2006. The natural gas share of total world energy consumption increases from 24 per cent in 2003 to 26 per cent in 2030.[361]

Energy Efficiency and Conservation

With such a large increase in energy consumption predicted between now and 2030 (by all commentators), with the menacing problem of climate change and with the fact that some fossil fuels are running out we have no option but to conserve energy aggressively and to use fuel in the most efficient manner possible. Because we have previously been living in a period of 'cheap energy' and social carelessness there is huge room for improvement in our current patterns of usage.

Most energy wastage occurs in the heating and cooling of buildings and plastics have a major role to play in insulating spaces against thermal transfer (either heat loss or cooling loss) and in providing components for construction which are very much more thermally efficient than traditional materials.

Energy efficiency in construction is a major goal for the international plastics industry, not least because plastics of one sort or another have such a large role to play in saving energy. The use of plastics to replace glass, to replace less efficient insulating materials and to provide component parts for construction is demonstrated in specially built homes erected by the BASF chemicals and plastics company. In the USA the company has built a near-zero energy house[362] in Paterson, New Jersey which has been donated to a local housing trust while, in Germany, the company has built a number of what it calls 'three litre houses' in Ludwigshafen's Brunck district[363]. Annually, these super-efficient houses use only three litres of oil per square metre to provide all heating needs. These houses showcase the superb insulating properties of plastic insulation and the energy saving potential of plastic components for construction.

And the quest for energy efficiency and environmental friendliness reportedly played a large part in Britain's securing of the 2012 Olympic Games for London. As the BBC reported:

> The environmental plan for the 2012 Summer Olympic Games focuses on four areas: low-carbon emissions, waste, biodiversity, and promoting environmental awareness.
>
> Below is a summary of how the Games' organisers intend to turn the aspiration to stage a 'One Planet Olympics' into a reality.
>
> *Venues and infrastructure:* Minimise the Games' carbon 'footprint' during the design, construction and operational stages. One way the team aims to achieve this is by maximising the use of renewable energy and providing the most efficient energy supply in the new Olympic park.
>
> *Transport:* The most carbon-efficient fleet of vehicles will be used to ferry officials and competitors to and from venues. There will also be campaigns to encourage people to use public transport, cycle and walk to events.
>
> *Offsetting emissions:* Some aspects of staging the Games will involve unavoidable emissions, such as people flying into the UK from all over the world. Organisers plan to offset these emissions by supporting and developing clean energy projects in developing nations.[364]

The British plastics industry has been talking with the organisers of the Games to stress the many positive ways plastics can be used to increase energy efficiency and to reduce the carbon footprint of the event and, if all goes to plan, the 2012 Olympics will be a showcase of environmental responsibility.

By 2030 preparations will be well ahead for the Olympic Games of 2032 which will probably be held in Los Angeles (2032 will be the centenary of when the Games last visited the city). How much more carbon-efficient will those Games be than the Games due to be held in London in a few years' time? Will near-to-zero energy loss have been achieved or will the necessary evil of aviation (flying in all the competitors, spectators and officials) ruin such efforts? Or will the jets of 2032 be running on biofuels?

Other areas where energy efficiency can be vastly improved include computing and IT, transport and, once again, power generation and distribution. All areas have huge potential for energy saving simply because after a century or more of cheap energy, efficiency has not been the foremost design parameter when products or projects have been in development.

In computing I.B.M. has made it clear that significant savings can be made:

> I.B.M. is beginning a $1-billion-a-year investment program intended to double the energy efficiency of its computer data centers and those of its corporate customers.
>
> Many technology companies are trying to curb the runaway energy consumption of data centers, the

> modern engine rooms that power the Internet and corporate computing.
>
> By 2010, I.B.M. plans to double the computing capacity of its hundreds of data centers worldwide without increasing power consumption, by using an array of hardware, software and services. These include a new cooling system that stores energy and chills the data center only as needed; software to increase the use of computers and automatically switch them to standby mode when not needed; and 3-D modeling and thermal engineering techniques to optimize the air flow through data centers.[365]

And a month or so after the I.B.M. announcement many other major names in computing came together to form 'The Climate Savers Computing Initiative'.[366] This is a loose association made up of companies such as Google Inc., Microsoft Corp., Intel Corp., Hewlett-Packard Co., Dell Inc. and Sun Microsystems Inc., and it aims to improve the efficiency of power sources for computers and servers and encourage end users to take advantage of under-used power management techniques. At present, the Initiative claims, only about 50 per cent of the electricity that leaves a power outlet reaches a PC because today's inefficient power cables leak energy.

The Climate Savers Initiative has defined a series of standards for power supply efficiency in servers and PCs that it suggests member companies adopt between now and July 2010. By 2010, the Climate Savers standard will define a power supply that is better than 95 per cent efficient (and as there will be more than two billion computers in the world[367] by 2010 the potential energy savings will be immense).

There is also scope for enormous improvement in goods and passenger vehicle economy. The success of the hybrid electric-petrol Toyota Prius car in both the USA and parts of Europe indicates where vehicle design is heading.[XII] In standard form the Prius returns about 50 miles to the US gallon (3.92 litres per 100 kilometres), but it can easily be tweaked to double its fuel efficiency:

> A car that doesn't need gas, or at least not much, is getting slightly more realistic all the time.
>
> A few small companies will start to offer services and products for converting hybrid cars like the Toyota Prius that currently get around 50 miles per gallon into plug-in hybrids that rely more heavily on electrical power and can get about 100 miles per gallon.[368]

And there is even talk at the Sustainability Institute of using plastics to design cars of the future that will be able to do 1,000 miles to the US gallon (0.23 litres per 100 kilometres):

> In today's most efficient cars, only 15-20 per cent of the energy in the gas gets to the wheels. Only about 2 per cent actually moves the driver; the rest hauls the ton of metal around the driver. Because of that

[XII] The Prius design also makes extensive use of Toyota's re-cycled 'Eco-Plastic'.– Toyota's results show that when recycled materials are used, CO_2 emissions are reduced by approximately 52% compared with new materials.

> ton of metal, engines have to be enormous. The key to the Supercar is to make it 1) much lighter and 2) much more aerodynamic, which would then allow it to have 3) a much smaller, more efficient engine.
>
> The lightness comes from getting rid of the steel. The Supercar will be made of composite materials – carbon-fiber, fiberglas, and plastic specially designed to absorb far more crash energy per pound than metal. You've watched these materials at work if you've ever seen an Indy-500 driver hit a wall at 200 mph and walk away. Race cars are made of carbon-fiber. This material can be reclaimed and recycled, by the way, and it doesn't rust.[369]

Power Generation and Distribution

One of the most serious areas of energy wastage in the world is power generation and conversion. Most coal-fired power stations are only about 30 per cent efficient (70 per cent of the energy in the fuel burned is wasted) and much power is lost during long-distance transmission over wires (how much depends on the distance and the wires).

Huge improvements in the efficiency of power stations[370] are possible and are now being pursued vigorously. One idea is to extract energy from the heated waste steam. Researchers at the University of California (Berkeley) have discovered how to produce electricity directly from heat using nano molecules:

> Nano molecules produce electricity when heated. Now, new research shows that certain organic molecules produce voltage when exposed to heat. Ultimately, they could be much cheaper and thus more practical to implement.
>
> If all goes well, though, so-called thermoelectric devices based on the molecules could prove to be an important source of power – and a way to reduce greenhouse-gas emissions by making far more efficient use of fossil fuel. 'Ninety per cent of the world's electricity is generated by thermal-mechanical means,' says Arun Majumdar, professor of mechanical engineering at UC Berkeley and another researcher on the project. 'And a lot of the heat is wasted. One and a half times the power that is generated is actually wasted.'[371]

And there may also be the potential for saving the energy lost during power transmission. Referring to the pioneering work done by Professor R.E. Smalley[372] of Rice University, Ray Kurzweil writes:

> Transmission of energy will also be made far more efficient. A great deal of energy today is lost in transmission due to the heat created in power lines and inefficiencies in the transportation of fuel, which also represent a primary environmental assault.
>
> Smalley, despite his critique of molecular nanomanufacturing, has nevertheless been a strong advocate of new nanotechnology-based paradigms

> for creating and transmitting energy. He describes new power transmission lines based on carbon nanotubes woven into long wires that will be far stronger, lighter, and most important, much more energy efficient than conventional copper ones. He also envisions using superconducting wires to replace aluminium and copper wires in electric motors to provide greater efficiency.[373]

And George Monbiot identifies the possible benefits of switching types of current in future power transmission lines from alternating current (AC) to new types of plastic-based direct current (DC) cable.[374] This, he claims, has the potential to make new forms of renewable energy more economic. In 'Heat' he writes:

> Most importantly, though the initial electricity loss on a DC line is higher, it does not increase with distance. On AC systems, by contrast, the longer the line, the more you lose. There is no inherent limit on the length of a DC cable.
>
> High voltage DC, which can be run along the sea bed, opens up any patch of sea shallower than 50 metres to wind turbines and pretty well all the continental shelf to wave power devices, which (because they float) can be anchored at greater depths. Since wind speeds rise by around one metre per second with every 100 kilometres from the shore, this means that the cost of renewable power could actually fall with distance from the coast…You can install wind turbines which rotate faster (and are therefore both

> noisier and more efficient) without upsetting anyone.[375]

And, a couple of years after Monbiot's important book was published, The Economist newspaper explored an idea put forward by the ISET Institute[376] at the University of Kassel, in Germany, to create a European-wide DC power grid to allow a free exchange of electricity across Europe. In an article entitled 'Where the Wind Blows' the Economist's correspondent pointed out that although wind turbine generation is an erratic source of power, if a distribution grid were sufficiently large, power could be transferred across Europe from areas where the wind is blowing to areas that are becalmed. The article continued:

> A group of Norwegian companies have already started building high-voltage DC lines between Scandinavia, the Netherlands and Germany, though these are intended as much to sell the country's power as to accumulate other people's. And Airtricity – an Irish wind-power company – plans even more of them. It proposes what it calls a Supergrid. This would link offshore wind farms in the Atlantic ocean and the Irish, North and Baltic seas with customers throughout northern Europe.
>
> Airtricity reckons that the first stage of this project, a 2,000 turbine-strong farm in the North Sea, would cost about €2 billion ($2.7 billion). That farm would generate 10 gigawatts. An equivalent amount of coal-fired capacity would cost around $2.3 billion so, adding in the environmental benefits, the project seems worth

> examining. Such offshore farms certainly work. Airtricity already operates one in the Atlantic, and though it currently has a capacity of only 25 megawatts, increasing that merely means adding more turbines.[377]

All of this leads us fairly neatly into a discussion about the future of renewable and sustainable energy sources.

Renewable and Sustainable Energy Sources

All the forecasts about the mix of energy we will be using in 2030 that I quoted earlier in this section are wrong. They will be proved wrong because it is impossible to forecast how energy generation and transmission technologies will develop over the next quarter of a century. The one thing that all of the worthy bodies making prognostications about future energy sources and use patterns miss (or ignore) is that joker in the pack: accelerating, exponential technology development.

I think it likely, almost certain, that energy from renewable and sustainable sources will be well on the way to providing the world with the majority of its ever expanding energy needs by 2030; after all, the energy is all around us in the wind, the waves, the rocks and the sun. Enough energy falls on the Earth's surface from the sun in a single hour to meet the world's current energy needs for a year.[378]

The process appears to be well under way. In a report called 'Clean Energy Trends 2007', Clean Edge, a research organisation, stated:

> We find markets for our four benchmark technologies – solar photovoltaics, wind power, biofuels, and fuel cells – continuing their healthy climb.
>
> Annual revenue for these four technologies ramped up nearly 39 per cent in one year – from $40 billion in 2005 to $55 billion in 2006. We forecast that they will continue on this trajectory to become a $226 billion market by 2016.
>
> A number of developments put clean energy definitively on the map over the past year. These include a near tripling in venture investments in energy technologies in the US to more than $2.4 billion; a new level of commitment by US politicians at the regional, state, and federal levels; and significant corporate investments in clean energy acquisitions and expansion initiatives.[379]

Before looking at the type of technologies which might be providing our clean power by 2030 it is worth defining the difference between 'renewable' and 'sustainable' energy sources, even though many commentators seem to use the terms interchangeably.

'Renewable'[380] sources are those natural sources that surround us and which are automatically renewed. These include the sun's radiation, wind power, wave power, tidal movements, hydroelectric power and geothermal power (heat trapped in rocks). Usually very little carbon is emitted in the generation of power from renewable sources.

'Sustainable'[381] resources are crops and biomass that can be used as a source of energy and which can be grown in a way that is environmentally responsible. The cultivation of sustainable fuel sources usually produces some carbon emissions and these last two points are very important when considering the advisability of the current energy policy of the United States, the world's worst polluter.

In an attempt to appear 'green' (and to appease growing public awareness of the dangers of climate change in the United States) the George W. Bush White House has provided new subsidies to boost the production of bioethanol,[382] a biofuel[383] made from corn and, in warmer regions, sugarcane (biofuel is a form of alcohol).

The reason that the existing oil industry smiles on this 'biofuel' initiative is that although the feedstock changes, the methods of refining and distributing propellant energy remain the same. The 'Big Oil' infrastructure remains in place and it is almost 'business as usual'.

But there are many serious problems with America's new policy of boosting ethanol production to fuel motor transport. Environmentalists are falling over themselves to point out just how wrongheaded Bush's policy is on this topic. Even non-aligned and much respected commentators point out the mistakes, as The Economist commented in May 2007:

> Corn-based ethanol is neither cheap nor especially green: it requires a lot of energy to produce. Production has been boosted by economically-questionable help from state and federal governments, including

> subsidies, the promotion of mixing petrol with renewable fuels and a high tariff that keeps out foreign ethanol.[384]

The same journal also reported that by using high-quality agricultural land to produce feedstock for ethanol, America is, in fact, choosing to feed its cars rather than its people.

> America's use of corn (maize) to make ethanol biofuel, which can then be blended with petrol to reduce the country's dependence on foreign oil, has already driven up the price of corn. As more land is used to grow corn rather than other food crops, such as soy, their prices also rise. And since corn is used as animal feed, the price of meat goes up, too. The food supply, in other words, is being diverted to feed America's hungry cars.
>
> The automotive industry loves it, because it reckons that switching to a green fuel will take the global-warming heat off cars. The oil industry loves it because the use of ethanol as a fuel additive means it is business as usual, at least for the time being. Politicians love it because by subsidising it they can please all those constituencies. Taxpayers seem not to have noticed that they are footing the bill.[385]

And to make the case against ethanol crystal clear, consider the following analysis from Cleantechblog.com:

> Although FFVs (vehicles which can run on either gasoline and ethanol) are hot sellers in the USA,

> most have never had a drop of E85 (ethanol fuel) in their tank. They are only fueled with standard gasoline blends. There are over 6 million vehicles on the US streets that could run E85. Most never have.
>
> Most FFVs are oil guzzlers; fueled with E85, they are corn guzzlers. In 2007 the best rated car running on E85 was the Chevrolet Impala, with a United States EPA mileage rating of 16 miles per gallon in the city and 23 on the highway when fueled with E85. For a typical US year of driving, the annual fuel cost would be at $1,657 and 6 tons of CO_2 would be emitted by this FFV when running on E85.
>
> A big problem is that ethanol cuts miles per gallon by about 27 per cent. The energy content of E85 is 83,000 BTU/gallon, instead of 114,000 BTU/gallon for gasoline. Even by 2030, the US Energy Information Administration (EIA) projects that only 1.4 per cent of ethanol use will be E85. The vast majority will be for small percentage blending with gasoline.[386]

So, if ethanol is an unsuitable biofuel (except perhaps as a basis for jet fuel – see previous section) what type of biofuel might have a role in the sustainable world of energy?

One solution is to re-use fats and oils which have already been used for one purpose for transportation energy – as the McDonald's restaurants do in the UK. The company's 150 trucks are powered by the vegetable oil that has cooked their popular hamburgers and fries.[387]

But leaving aside the fortuitous re-use of cooking oils, general transport biofuels include diesel replacements (biodiesel) and sources of such energy range from sugar cane (the most efficient) to wood (at present, the least efficient). All sorts of issues affect how carbon-efficient, or inefficient, biofuels may be. These include the energy and water used to grow the fuel feedstock, the quality of agricultural land required for growing, the carbon emitted to assist the growing (in the production and use of fertilisers, for example) and the energy efficiency of the refined fuels themselves. For example, sugar cane provides between eight and nine times the energy used in producing them, while energy from rape seed oil and other similar temperate crops produces only one to three times the energy used in their cultivation.[388] Then there are the issues of the energy used in converting specific crops into usable energy and the energy consumed in transporting such fuels to their final destination. Also of vital importance is the issue of giving land over to the production of biofuel (in some cases leading to the destruction of forested areas or the usurpation of food-producing land).

Because these issues are so complex many consumers are, at present, unable to make a meaningful choice about biofuels; far more information is needed on this topic and governments will soon have to regulate to ensure that only the most efficient and environmentally benign forms of fuel make it onto the gas station forecourts. Environmentalists have a useful rule of thumb on this topic. They say that a biofuel must emit at least 50 per cent less carbon (during its cultivation, transportation and consumption) than the fossil fuel it will be replacing to make it a useful substitute.

One biofuel that may have real potential is derived from Jatropha Curcas[389] which has many other advantages over existing crops. Principal among these advantages is that jatropha has a high energy yield and it grows in marginal land unsuited for other forms of agriculture. As it grows, it converts the soil into better quality growing land. In June 2007 BP announced a £32 million investment[390] in the production of jatropha as a biofuel.

Although the United Nations has long seen biofuels as holding out huge potential for helping the world's poorest people out of poverty, the organisation recently warned the world against widespread forest clearance for biofuels production, pointing out the adverse consequences of large-scale land clearance.[391]

In general, biofuels are most useful for the small-scale replacement of fossil fuels, as large-scale production demands energy for fertilisation and occupies land which could either have been left forested or used for food production. But there are some countries – the UK for one – which has underused, or set aside, agricultural land. For this reason the UK government has boosted its support for certain types of biofuel. The BBC ran the following story in 2004:

> The UK is to encourage the production of biomass, crops grown specially for use as environmentally friendly fuels.
>
> The government is setting up a task force to stimulate biomass supply and demand, and offering a range of grants.

> Ministers hope this will help the UK to meet its targets for using renewable energy, and that it will also boost farming, forestry and the countryside.
>
> Material like miscanthus (a tall, woody grass), willow, poplar, sawdust, straw, and wood from forests are all suitable.[392]

But while domestic production of biofuel ramps up in the UK, most oil derived from plants has to be imported. But the UK government has not yet completed its analysis of overseas biofuels sources so British consumers who wish to burn biofuels are unable to distinguish between fuels from 'good' and 'bad' sources.[393]

Other forms of biofuel can also be produced from waste products such as fat, cooking oil, sewage, manure and organic waste and, although necessarily small-scale, such projects (if properly handled) have a low environmental impact during production and can contribute significantly to the problems of climate change when used to replace fossil fuels.

Several examples of successful small-scale biofuel production projects can be found in the South Pacific where islanders are turning coconuts into fuel. As the peopleandplanet.net website reports:

> In the Pacific islands there are great opportunities to use coconut oil as a fuel, according to Jan Cloin of the South Pacific Applied Geoscience Commission. 'Coconut oil can be blended with diesel fuel, and under certain conditions totally replace it. Coconut

> oil in Pacific islands countries is increasingly used in both transport and electricity generation through its lower local cost. Other benefits include the support to local agro-industries and a decrease in emissions.'[394]

There are also some interesting ideas in the labs today which may have become a practical reality by 2030. It may, for example, be possible to produce clean oil from algae (as Boeing suggests might be possible for aviation fuel). A San Francisco-based start-up company called Solazyme[395] is suggesting that this idea is practical, as reported in the San Francisco Chronicle:

> The algae beneath Harrison Dillon's microscope could one day fuel your car.
>
> Dillon's Menlo Park company, Solazyme, has tweaked the algae's genes, turning the microscopic plant into an oil-producing machine. If everything works the way Dillon wants, vats of algae could create substitutes for diesel and crude oil.[396]

Wind Power

Windmills were first invented to harness the wind's energy 2,000 years ago and today, of all forms of renewable energy, wind power[397] is the first to deliver large quantities of electrical power to national distribution systems.

Because of recent increases in the price for fossil fuels, wind power has, in some instances, become as cheap or even cheaper than fossil fuel energy. There is now a great rush in many parts of the world to install more farms of wind turbines to capture more of this 'free' energy.

Fuel-hungry United States is leading the rush, as The Washington Post reported in March 2007:

> Like mail-order brides, thousands of long-limbed wind turbines are coming to the empty outback of Washington and Oregon, where they are being married off, via the electrical grid, to hulking old hydroelectric dams.
>
> The Pacific Northwest is hardly alone as it chases the wind for clean power. Anxiety about climate change and surging demand for electricity have triggered a wind-power frenzy in much of the United States, making it the fastest growing wind-energy market in the world. Power-generating capacity from wind jumped 27 per cent last year and is expected to do the same this year.[398]

And the cost of wind turbines has decreased dramatically over the last thirty years while efficiency has also improved significantly. In a June 2007 survey of renewable energy sources, The Economist reported:

> During the wind boom of the 1970s turbine blades were around 5-10 metres long, and turbines produced no more than 200-300kW of energy each. The

> energy they produced cost around $2 per kWh. Now the blades are up to 40 metres long and turbines produce up to 2.5MW each at a cost of 5-8 cents per kWh, depending on location (coal-fired electricity, depending on the plant, costs 2-4 cents per kWh). And there are even 5MW prototypes in existence, with 62-metre blades.[399]

But although naturally windy areas like coastlines (and island nations like New Zealand, the UK and Ireland) are able to take advantage of frequent strong winds, not all are doing so. For example, whilst Britain has taken a significant lead in getting climate change onto the international policy agenda, its domestic performance lags far behind the political rhetoric. The UK generates only 1,353MW of power from wind turbines compared with 18,428MW in Germany, 10,027MW in Spain and 3,122MW in Denmark.[400]

Of course, wind is not a reliable force of nature and wind power on its own cannot replace other sources of energy no matter how many wind farms are built (even if the protests of the anti-wind turbine campaigners can be overcome). And electricity is a 'live' commodity which must be used as soon as it can be generated and distributed. No long-term storage of electricity is currently economically possible. This means that when the wind does not blow wind turbines can produce no power.

But one invention tested on King Island in the Straits of Tasmania, Australia does suggest that some limited long-term local storage of electricity may become possible, which increases the role that wind power generation may play in the future. The device used to store the power is called a 'flow battery'.[401] As the New Scientist reported:

> For years wind turbines and solar generators have been linked to back-up batteries that store energy in chemical form. In the lead-acid batteries most commonly used, the chemicals that store the energy remain inside the battery. The difference with the installation on King Island is that when wind power is plentiful the energy-rich chemicals are pumped out of the battery and into storage tanks, allowing fresh chemicals in to soak up more charge. To regenerate the electricity the flow is simply reversed.[402]

And such batteries may also be developed to store electricity generated by other forms of renewable energy such as wave and tidal power. But, for the present, most wind turbines produce 'real time' electricity which must immediately be distributed and consumed.

Some environmentalists envisage a future in which wind turbines are mounted on every house and any excess power is sold back to the electricity distribution system. However, George Monbiot, who is an enthusiast for the potential of off-shore commercial wind farms, suggests that the whole concept of domestic wind turbines for self-sufficiency may be faulty:

> At an average wind speed of 4 metres per second, a large micro turbine (1.75 metres in diameter is about as big a device as you would wish to attach to your home) will produce something like 5 per cent of the

> electricity used by an average household. The most likely contribution micro wind will make to your energy problem is to infuriate everyone.
>
> It will annoy people who have been fooled by the claims of some of the companies selling them (that they will supply half or even more of their annual electricity needs). It will enrage the people who discover that their turbines have caused serious structural damage to their homes. It will turn mild-mannered neighbours, suffering from the noise of a yawing and stalling windmill, into axe murders. If you wished to destroy people's enthusiasm for renewable energy, it is hard to think of a better method.[403]

But even if George Monbiot's vision of a suburban hell created by mushrooming, ineffective wind turbines, small domestic wind power units (mostly made of lightweight durable plastics) will succeed in providing power in rural areas which enjoy plentiful wind. And the future for *industrial* production of energy from wind power is very bright. As The Economist reported in May 2007:

> The wind business is growing by more than 30 per cent a year worldwide, with America leading the way. And when a solar incentive scheme took hold in Germany in 2004-05, demand in Europe roughly doubled, says Ron Kenedi of Sharp, the biggest solar-cell maker.
>
> Supply shortages will not ease quickly in either case. Wind turbines are giant machines that require lots

> of parts. Several firms are building new factories: Vestas has just announced its first American plant, which will make blades in Colorado. But new factories will take several years to get up to speed. In the meantime, buyers are putting down deposits to reserve their turbines. GE Energy, the largest turbine installer in America, is already booked up until the end of next year.[404]

And George Monbiot makes the case for British conversion to *industrial-scale* wind power very eloquently:

> The wind, waves and sun are not going to run out – or not while we still occupy the planet. Neither Mr Putin nor any other energy monopolist can switch them off. No wind farm can ever melt down, or present a useful target for terrorists. Decommissioning is cheap and safe. The energy required to build the machines on the market today is a small fraction of the energy they will produce, and as soon as that has been accounted for, they emit no carbon. While renewable technologies can dominate a landscape this impact is surely less significant than the destruction of the biosphere…
>
> The United Kingdom – islands surrounded by high winds and rough seas – has the best resources in Europe.[405]

Clearly, harnessing wind power on a global scale will be a priority from now until 2030. Turbines will become more efficient (with non-corrosive plastics playing a major part[406] in the construction of offshore turbines) and better ways of storing and conducting power will be developed. Wind power will play an important role in the energy mix of 2030, but it must not be developed to the exclusion of other renewable energy source technologies, the most important and exciting of which is solar power.

Solar Power

Unlike wind turbine technology, the development of solar devices which convert the sun's radiation into electricity (solar photovoltaic) and devices which convert it into heat (solar thermal) is complex. A great deal of further development in terms of efficiency (how much of the sun's power can they capture and convert) and in reducing the cost of the capture and conversion devices is required.

In its survey of renewable energy sources The Economist reviewed the progress that has been made in solar photovoltaic cell development:

> The efficiency with which solar photovoltaic cells convert sunlight to electricity has increased from 6% when they were first developed to 15% now. Their cost has dropped from around $20 per watt of production capacity in the 1970s to $2.70 in 2004 (though a silicon shortage has pushed prices up since).[407]

Although the wind blows very unevenly around the planet, the sun's radiation strikes our world in more predictable patterns – with the most heat and light being delivered to equatorial regions.

Clearly, solar technologies will have the greatest application where there is the most sunlight – areas which also tend to be home to the world's poorest communities. In these areas more than 2.5 billion people, almost half of the global population, still rely on wood, animal manure and crop residue for their fuels.[408] In these equatorial regions significant progress has already been made in harnessing the sun's energy (and, in some cases, improving the lives of local people).

I.M. Dharmadasa,[409] Professor of Electronic Materials and Devices at the UK's Sheffield Hallam University (the consulting referee on this section of my report), has been pioneering the development and the deployment of solar photovoltaic devices and systems for decades and has made significant breakthroughs[410] in increasing the efficiency of solar power devices.

Professor Dharmadasa was the key instigator behind the formation of SAREP (South Asia Renewable Energy Programme) and in his paper 'Use of Solar Energy For Social Development And Reduction of Poverty' he describes a project in Sri Lanka which he and his colleagues initiated and on which he consulted.

> In most developing countries, only a small fraction of the population has access to electricity from their national grids. In Sri Lanka for example about 60 per cent of the population enjoys facilities with

electricity but in some sub-Saharan countries, this fraction is as low as 10 per cent.

Most of the rural communities use kerosene for lighting with its associated fire hazards and ill health due to the poor quality of breathing air. These kerosene lamps provide low standard living conditions and the governments of these countries are facing ever increasing fuel import bills.

The main solution to this comes from stand-alone home lighting systems, which are already available on the market. The total cost of this system is about Rs 50,000 (~£300). When the cost is distributed to pay during the first eight years, the monthly payment becomes less than the cost of kerosene oil used per month. There are over 100,000 systems now successfully installed in Sri Lanka and the people are beginning to experience their benefits.

Monitoring of GCSE results in one of the villages showed a substantial improvement after providing the electricity for lighting, using these systems. In addition to these improvements in education, removal of kerosene oil-lamp fire hazards, health due to reduction of air pollution, the burden of fuel import bills have completely been eliminated.[411]

Professor Dharmadasa is now working with the World Innovation Foundation and national governments to replicate this model of low-cost solar energy systems for rural environments on the Africa continent.

It is increased efficiency that will make solar panels (some made of plastics[412]) of even greater use in sunny climes and of practical use in higher, more temperate latitudes. Significant progress towards greater efficiency is being made, as is revealed by research now being undertaken at Boeing-Spectrolab.[413]

> Researchers at Boeing-Spectrolab have just succeeded in building a multi-junction solar cell that achieves an incredible 40.7% efficiency, about twice that of the reigning champ in this space.
>
> To put this Department of Energy-backed breakthrough in perspective, it was less than two months ago that Silicon Valley-based SunPower announced a 22% efficient cell, and even that model was claimed to produce 50% more power over a given space than previous iterations.[414]

It is heartening that many experts expect solar energy to be fully mature by the year 2030. Under the headline 'Solar energy has potential to dominate by 2030' Physorg.com reported in November 2005:

> Professor Andrew Blakers from The Centre for Sustainable Energy Systems at the Australian National University will today report to the Greenhouse 2000 Conference in Melbourne that photovoltaic (PV) solar energy conversion can be cost-competitive with any low-emission electricity generation technology by 2030.
>
> His paper describes how extrapolation of the huge economic and technical gains made by photovoltaics

> over the last 15 years gives confidence that a dramatic shift in electricity generation technology over the next quarter-century is possible.[415]

Technological 'breakthroughs' and exciting new developments in solar-generated power seem to be coming thick and fast at present. For example, one award-winning British development applies the properties of electrically-conducting nanotechnology plastics to bring down the cost of producing solar-driven energy generation systems. The announcement of the £250,000 award made by the Royal Society describes the technology's potential:

> A proposal for developing tools to make energy-efficient and low-cost solar panels and lighting sources available to a wide market has won an award from the Royal Society.
>
> Professor Bradley and his colleagues made plans to commercially develop two production processes for plastic electronics.
>
> Plastic electronics uses novel organic, carbon-based semiconductors, instead of the traditional silicon, gallium arsenide and related inorganic materials.
>
> These new organic semiconductors combine solubility, allowing solution coating and printing to be used in the fabrication of devices, and properties, such as flexibility and toughness, with the key functional characteristics of traditional semiconductors.

> The team believes that the development of plastic electronics can support the widespread adoption of affordable, environmentally-friendly energy generation and lighting.[416]

Another group of researchers at MIT takes a completely different approach to reducing the cost of capturing and harnessing solar energy:

> Much more efficient solar cells may soon be possible as a result of technology that more efficiently captures and uses light. StarSolar, a startup based in Cambridge, MA, aims to capture and use photons that ordinarily pass through solar cells without generating electricity. The company, which is licensing technology developed at MIT, claims that its designs could make it possible to cut the cost of solar cells in half while maintaining high efficiency. This would make solar power about as cheap as electricity from the electric grid.[417]

It is clear that the development of solar technology is a field that is full of excitement and optimism, not least because capturing the sun's natural energy to provide energy for our own needs will be the ultimate clean energy source. And there are many large scale installations of solar power generation systems already in place or under development. As The Economist pointed out in March 2007 the world's leading high-tech companies are competing to lead the way in solar power generation:

> Last year Microsoft outfitted its campus in Silicon Valley with a solar system from SunPower, a local

> company that makes high-efficiency (and, some say, the world's best-looking) solar panels. A few months later Microsoft's arch-rival, Google, began building something on an even grander scale - one of the largest corporate solar installations to date.
>
> But all of this may yet be topped by Wal-Mart. In December the retail giant solicited bids for placing solar systems on the roofs of many of its supermarkets. Besides producing favourable publicity, the appeal of using solar power is obvious. Unlike fossil fuels, which produce significant amounts of pollution and enormous amounts of greenhouse gases, the sun's energy is clean and its supply virtually limitless. In just one hour the Earth receives more energy from the sun than human beings consume during an entire year. According to America's Department of Energy, solar panels could, if placed on about 0.5 per cent of the country's mainland landmass, provide for all of its current electricity needs.[418]

And if fossil fuel energy prices remain high and solar conversion technologies increase their efficiency still further, solar power may become one of the cheapest sources of power available.

Futurologists and science fiction writers have dreamed of harnessing solar power on a large scale for many years (in my 2005 novel 'Extinction'[419] I covered the Earth-facing side of the Moon with focusing mirrors to harness the sunlight) and what was once nothing but speculation is moving closer to reality. In 'Heat' George Monbiot pondered the idea of using the world's deserts as giant solar capture regions:

> For years, rogue environmentalists have been pointing out that solar electricity generated in the Sahara could supply all of Europe, the Gobi could power China and the Chihuahuan, Sonoran, Atacama and the Great Victoria deserts could electrify their entire continents. These people have been dismissed as nutters. The development of cheap DC cables[420] suggests that they might one day be proved right.[421]

And two reports from the German Aerospace Centre – 'Concentrating Solar Power for the Mediterranean'[422] and 'Trans-Mediterranean Interconnection for Concentrating Solar Power'[423] – investigate in practical terms how vast new solar farms in the deserts of North Africa could potentially solve Europe's looming energy crisis and help slash the continent's carbon emissions.

But perhaps the most exciting application of solar energy lies right above our heads; an average of 3kW of power is potentially available from every rooftop[424] and this form of distributed power generation would break the centralised monopoly of power generation. Many people believe that the generation of power from fossil fuels, energy that is then distributed from a central supply, is a key factor in creating the rich-poor divide in the world. A distributed model of solar power generation would begin to solve this problem.

Finally in this section on solar energy devices, it is worth noting that new low-cost 'spray on' or 'print on' plastic solar conductors have been developed at the New Jersey Institute of Technology. As physorg.com reported in July 2007:

> Researchers at New Jersey Institute of Technology have developed an inexpensive solar cell that can be painted or printed on flexible plastic sheets.
>
> 'The process is simple,' said lead researcher and author Somenath Mitra, PhD, professor and acting chair of NJIT's Department of Chemistry and Environmental Sciences. 'Someday homeowners will even be able to print sheets of these solar cells with inexpensive home-based inkjet printers. Consumers can then slap the finished product on a wall, roof or billboard to create their own power stations.'[425]

And in the same month MIT Technology Review published a story revealing that plastic solar cells are reaching record levels of efficiency:

> A new process for printing plastic solar cells boosts the power generated by the flexible and cheap form of photovoltaics. Initial solar cells made with the technique can, according to a report in today's issue of *Science*, capture solar energy with an efficiency of 6.5 percent – a new power record for photovoltaics that employ conductive plastics to generate electricity from sunlight. Most photovoltaics are made from conventional inorganic semiconductors.[426]

Hydrogen Fuel

Of all the other renewable energy sources not yet discussed, it is hydrogen (H_2) that produces the most optimism for the long-term prospects for the storage of clean energy produced from electricity. Hydrogen is the most abundant element in the universe (comprising 75 per cent of the mass and 90 per cent of its molecules[427]) and harnessing it as a carrier of power would provide humanity with a virtually unlimited way to store and carry energy.

Hydrogen is a totally clean fuel that can be produced (by applying electricity and other means) from a number of sources (including coal and water) and which, when burnt, produces only water. Devices called fuel cells[428] (first described theoretically in Germany 1838 and first built in the UK in 1959) are used to extract energy stored in hydrogen and there is great hope that hydrogen-powered fuel cells will one day become a universal form of propulsion for all forms of motor transport (and, perhaps, aviation) and that households and businesses will be able to generate their own power locally from solar/wind-powered hydrogen fuel cells and will cease to be reliant of national-grid-type energy distribution systems.

The French futurologist and science-fiction writer Jules Verne[429] knew about the potential for hydrogen as fuel storage well over a century ago. In his 1874 novel 'The Mysterious Island' an engineer called Cyrus Harding suggests that when coal has run out, mankind will burn water to generate energy:

> 'Water decomposed into its primitive elements and decomposed, doubtless, by electricity, which will then have become a powerful and manageable force… Yes my friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. Water will be the coal of the future.'[430]

Jeremy Rifkin, whose book 'The Hydrogen Economy' is regarded as one of the great polemics for hydrogen energy, suggests that not only does hydrogen have the potential to provide us with carbon-free energy storage, but also has the potential to allow us to re-design the world's energy distribution systems in such a way that will have far-reaching effect in social organisation:

> Were all individuals and communities in the world to become the producers of their own energy, the result would be a dramatic shift in the configuration of power: no longer from the top down but from the bottom up. Local peoples would be less subject to the will of far-off centers of power. Communities would be able to produce many of their own goods and services and consume the fruits of their own labour. But, because they would also be connected via the worldwide communications and energy webs, they would be able to share their unique commercial skills, products, and services with other communities around the planet. This kind of economic self-sufficiency becomes the starting point for global commercial interdependence

> and is a far different economic reality than that in colonial regimes of the past, in which local peoples were made subservient to and dependent on powerful forces from the outside.[431]

Essentially, Rifkin is arguing for nothing less than a complete dismantling of centralised fossil-fuel-powered energy supplies and their replacement with many small regional or local hydrogen fuel-cell power generators powered locally, something which Professor I.M. Dharmadasa also believes to be the correct model for the future (although in his view direct solar power will play a much larger role in the energy mix). Professor Dharmadasa points out that only 1.23 volts of DC electrical current is necessary to release hydrogen by electrolysis (1.5 volts to allow for system losses) and these voltages are available today from existing solar photovoltaic sources.[432] He points out that large-scale production of H_2 is already possible and it is only the lack of political will that is holding back a switch to a hydrogen-powered economy.

These ideas about hydrogen as a fuel are more powerful than they may at first seem. Replacing state-delivered or utility-delivered power with locally or domestically-generated power also shifts political power. No longer would it be possible for a government to artificially boost a nation's economy by subsidising electricity prices and no longer would it be possible for governments to restrain an economy by applying price hikes. George Monbiot is also in favour of moving from a centralised energy supply system to a distributed energy generation model ('an 'internet of energy' as he calls it) and it is clear that energy autonomy for a household or locality would dramatically alter the balance of political power in the world. Rifkin also asserts that a shift to a distributed energy production model would be enormously beneficial in the fight against climate change:

> A wholesale shift away from centralized power generation using fossil-fuel energy to hydrogen-powered fuel cells operating on a distributed generation grid – especially if the hydrogen is produced by using solar, wind, hydro, and geothermal forms of energy – could more dramatically reduce CO_2 emission that could any other single development currently being pursued.[433]

But as desirable as distributed energy generation may seem, hydrogen power is still at the beginning of its development.

Hydrogen as a fuel for automobiles and trucks is likely to be the first widespread application of the clean technology. The environmental website commutercars.com is confident about the benefits of hydrogen as a fuel for transport:

> The best pollution-free alternative to batteries while still using clean electric motors is the hydrogen fuel cell. Hydrogen-powered fuel cells hold enormous promise as a power source for a future generation of cars.
>
> Hydrogen is consumed by a pollution-free chemical reaction – not combustion – in a fuel cell. The fuel cell simply combines hydrogen and oxygen chemically to produce electricity, water, and waste heat. Nothing else.[434]

Ray Kurzweil is also characteristically confident about the future for this fuel:

> The emerging paradigm for energy storage will be fuel cells, which will ultimately be widely distributed throughout our infrastructure, another example of the trend from inefficient and vulnerable centralized facilities to an efficient and stable distributed system.[435]

However there are considerable problems to be overcome in the development of hydrogen fuel cell technology even if the long-term benefits are alluring. As James Canton describes in 'The Extreme Future':

> Hydrogen has problems other than (current) high cost. It is unstable and needs to be controlled. The manufacture of hydrogen requires other energy use such as nuclear or oil (or geothermal). The technology needed to store and pump hydrogen into vehicles is still primitive and not yet adopted for wide usage. But none of these obstacles is impossible to overcome. Hydrogen will transform the future of energy and ensure a more secure and reliable source of fuel for consumers, business, mass transportation and even for space travel. Hydrogen is coming fast.
>
> By 2035, or even sooner, hydrogen will be a viable alternative to oil and gas, meeting as much as 35 per cent of our energy needs.[436]

Perhaps the real difficulty in switching to hydrogen as the main fuel for road transport is the lack of infrastructure. Hydrogen is difficult to distribute, difficult to store and difficult to carry on board motor vehicles. Re-equipping petrol stations to become hydrogen stations will be expensive and will take a very long time, so much so that many experts doubt that such a switch-over will have been wholly achieved by 2030. Jeremy Rifkin lists the difficulties that have to be overcome before hydrogen can become a widely used fuel for vehicle transportation in the USA:

> The key question facing the automobile industry during the transition to hydrogen-fuel-cell-powered vehicles is how to produce, distribute, and store hydrogen cheaply enough to be competitive with gasoline at the pump. Some studies estimate that it would cost more than $100 billion to create a national infrastructure for producing and distributing hydrogen in bulk. The 'hydrogen question' is the classic chicken-and-egg problem. The automobile companies are reluctant to manufacture direct-hydrogen fuel-cell cars for fear that the energy companies won't invest sufficient funds to create thousands of hydrogen refuelling stations. That is why the car companies are hedging their bets by developing fuel cell cars with on-board reformers that can convert gasoline and natural gas to hydrogen. The energy companies, in turn, are nervous about committing billions of dollars to create a national infrastructure to support hydrogen refuelling stations if not enough direct-hydrogen fuel-cell vehicles are manufactured and sold.[437]

The penultimate word on the future for hydrogen as a fuel for transportation should go to George Monbiot who, despite an overall optimism about hydrogen in the long term, is nothing but a bitter realist when it comes to acknowledging the problems that will have to be overcome before hydrogen can be in widespread use:

> The most immediate problem is that hydrogen cannot be bought in filling stations. The owners of fuel-cell cars need to be sure that they can find hydrogen wherever they happen to run out. The filling stations won't supply it until they have a market, and the market can't develop until there are supplies.
>
> This is compounded by the problem of storage, which is not something the owners of stationary fuel cells need to worry about unless they produce their own hydrogen. Cars would need to take it with them. Though the gas is three times as energy-dense as petrol in terms of weight, it is only one tenth as dense in terms of volume – at pressures of 5,000 pounds per square inch.
>
> This means that a hydrogen powered vehicle would need a high-pressure fuel tank ten times the size of a petrol driven car's in order to travel as far. High-pressure tanks would take a long time to fill, and could be dangerous.[438]

The final word in this section on hydrogen energy for transport has been saved for our old friend, the joker in the pack, accelerating, exponential technology development. Even as energy analysts and futurologists puzzle over how cars and petrol stations could be converted to carry and store such a difficult gas (or liquid), a professor at Purdue University in the USA has announced the development of a new technique to generate hydrogen 'in real time' (in a continuous manner) from water via the use of aluminium. If this announcement turns out to hold the potential suggested (and although the concept has been patented that remains a big 'if'), cars would only have to carry water, a supply of aluminium pellets and a low-power electrical source to produce their own hydrogen fuel as they travel:

> Purdue University professor Jerry Woodall has discovered a way to make hydrogen out of a reaction of water and an alloy of aluminum and gallium. The production technique eliminates the need to store hydrogen, he said. Mixing water and pellets made up of the alloy in a tank can produce fuel for a small engine, or conceivably a car.
>
> The process, along with other recent hydrogen developments, could work to dispel some of the criticism of hydrogen as a fuel source in the coming decades.[439]

Leaving aside the difficulties of storing hydrogen within vehicles and the problems of providing a re-fuelling infrastructure, hydrogen as a fuel for domestic power consumption – especially when the electricity required to produce the hydrogen comes form a renewable source such as solar or wind-power – has a remarkably bright future. As Jeremy Rifkin explains:

> The most important aspect of using renewable resources to produce hydrogen is that the sun's energy,

> and wind, hydro and geothermal energies, will be convertible into 'stored' energy that can be applied in concentrated forms whenever and wherever needed, and with zero CO_2 emissions. This point needs to be emphasized. A renewable energy future is made far more difficult, if not impossible, without using hydrogen as a means for energy storage. That's because when any form of energy is harnessed to produce electricity, the electricity flows immediately. So if the sun isn't shining, or the wind isn't blowing, or the water isn't flowing, or fossil fuels are not available to burn, electricity can't be generated and economic activity grinds to a halt. Hydrogen is one very attractive way to store energy to ensure an ongoing and continuous supply of power for society.[440]

Other Renewable and Sustainable Sources of Energy

It is for the sake of brevity rather than their lack of importance that I am lumping together other forms of renewable and sustainable energy in this section of my report.

I will start with the prospects for hydro energy. If full consideration is given to the populations which must often be displaced for hydro schemes and consideration given to the environmental impact of building dams, hydroelectric power is a fairly green source of energy, but one which, unfortunately (or fortunately), is almost fully exploited in Europe.

It may seem surprising that I describe hydro-energy as only being 'fairly green'; this is because methane builds up on the bottom of the reservoir created by a dam and, when the water power is released to drive the turbine which produces electricity, this methane (a very potent greenhouse gas) is released into the atmosphere. Thankfully, researchers in Brazil have recently developed a technique[441] which may help to extract the methane from the bottom of dam basins and use it for power generation.

Geothermal energy is completely green (harnessing heat from rocks) but in Europe the only regions which have such reachable underground heat in any quantity are Iceland and Switzerland. As the Swiss government points out:

> Switzerland is currently world leader when it comes to the utilisation of geothermal sensors. No other country in the world has so many in place in proportion to its surface area!
>
> Sources of hot water below the earth's surface (aquifers) can be tapped by drilling, and energy can be obtained from dry rock layers with the aid of enhanced geothermal systems technology. At temperatures above 100°C, these energy sources can be used for electricity production, while the residual heat can be utilised for heating purposes.[442]

Iceland is planning to sell power produced from geothermal heat to the UK and other European customers, as reported in The Times in May 2007:

> The hot volcanic vents of Iceland may be harnessed to bring electrical power to mainland Europe and Britain if a plan to pipe geothermal energy under the North Sea comes to fruition.
>
> The same intense heat that causes the mud to bubble and geysers to steam on Iceland's moonlike surface will be used to create steam to drive turbines, generating enough energy to power up to 1.5 million homes in Europe.[443]

Around the world both the USA and Australia have significant opportunities to exploit geothermal energy and as these countries are among the worst polluters with fossil fuel emissions, they should be encouraged to ramp up exploitation of this clean energy source. The Australian reported in March 2007:

> The head of geothermal development company Geodynamics, Adrian Williams, said yesterday that Australia's main geothermal resources were in the Cooper Basin of South Australia. He said the first big onshore well to capture hot rock energy would be drilled later this year, leading to the first commercialisation of technology – a 40-megawatt power station – by 2010.
>
> Dr. Williams said Australia could have as much as 4500 MW of geothermal energy by 2030, or about 10 per cent of current demand.[444]

Australian writer Tim Flannery estimates that Australia has sufficient tappable geothermal energy to provide the nation's energy needs for a century.[445]

Power from the oceans (wave power and tidal power) also offers some limited power generation opportunities to nations with coastlines. In April 2007 The Economist outlined future prospects for ocean power:

> A fraction of the energy locked up in the oceans could, in theory, meet the world's entire electricity needs. Extracting hydropower from dammed-up rivers is comparatively easy compared with harvesting energy from offshore tides and waves, and then putting it into the grid via underwater cables. Only 14 countries now operate tidal or wave-power stations, and most are tiny, experimental and expensive.[446]

In Scotland the world's first tidal stream energy capture project was announced by The Scotsman in March 2007:

> Scotland is set to lead the world in harnessing a new form of green energy by developing the first commercial tidal stream energy plant on the planet.
>
> Lunar Energy, a leading Scottish renewables company, has joined forces with E.ON UK, the company which runs Powergen, to announce pioneering plans to develop a subsea tidal stream power farm off the west coast of Britain within the next two years.
>
> The underwater power system will be capable of generating up to eight megawatts of electricity, enough power to supply 5,000 homes.[447]

And in September 2007 planning permission was given in the UK for 'Wave Hub', a £28 million project off the north Cornish coast that will provide a 'sea floor socket' allowing wave-power generators to get their electricity back to shore. Thirty wave-power generating machines will supply up to twenty megawatts of power.

In Conclusion on the Future of Energy

Money is now pouring into what is called 'clean tech' (energy sources and production technologies which are carbon free or 'carbon lite') at an unprecedented rate and, where investment goes, progress follows. As the New York Times reported in April 2007:

> Money is flowing into alternative energy companies so fast that 'the warning signs of a bubble are appearing,' according to a report on investment in clean technology by a New York research firm, Lux Research.
>
> The report also suggests that companies that make equipment to cleanse air or water, or that process waste, have been overlooked by investors.[448]

Some interesting and non-obvious developments in plastics are occurring as scientists cast around for ways of harvesting and recovering energy to head off the shortage that threatens our future. For example this story appeared in June 2007 on pr-inside.com:

> In an effort to develop a new source of sustainable energy, researchers at Polytechnic University, the premier New York-based technology and engineering higher education institution, have bioengineered a fuel-latent plastic that can be converted into biodiesel. The Defense Advanced Research Projects Agency has awarded the researchers $2.34 million to advance this innovative technology and transfer it to industry. The commercialization of the technology will lead to a new source of green energy to households worldwide.[449]

And, at an individual level, humans are already proving that energy self-sufficiency is achievable, a lesson to which we should all pay attention. As the following story on greenoptions.com makes clear, even hydrogen-powered cars can be part of today's sustainable energy mix:

> Mike Strizki's utility bill is zero, thanks to some creative thinking using renewable energy technologies. By using solar panels, a hydrogen fuel cell, storage tanks and an electrolyzer, he has enough electricity even on the cloudiest days. And Strizki isn't a hermit living in the dark off of snails and rainwater, either. His 3,500 square foot house is located in central New Jersey on 12 acres, with amenities you'd see in any 21st century home, like a hot tub and big screen TV. His renewable energy system even creates hydrogen he uses to power his fuel-cell car.[450]

There are even more radical technologies which hold out the hope, if not the promise, of abundant clean and cheap technology in the longer-term future. The most famous (or infamous) of these is 'cold fusion',[451] a theoretical concept which suggests that fusion-power (the same nuclear reaction process that fuels the sun) might be achievable at close to room temperature. What was seemingly a false alarm about such a process being achieved galvanised the scientific community in 1989 and, since that attempt was proved a failure, few scientists have wanted to admit they are working in such a controversial field.

However, in a 2001 book called 'The Scientist, The Madman, The Thief and Their Lightbulb,' author Keith Tutt[452] writes the following about the cold fusion episode:

> Was that really the end of the story, though? And was it the true story? If so, why are laboratories in at least eight countries still spending millions on cold fusion research? And, if cold fusion is impossible, how can it be that there are hundreds of documented experiments which demonstrate that cold fusion effects are real? How can it be that there is continually stronger evidence that a small group of scientists have already gone a long way towards a commercial, viable power source? Is it possible that parts of the scientific establishment acted to stamp out a technology which promised so much?[453]

Leaving aside conspiracy theories about the (apparent) failure of cold fusion, some highly respected scientific organisations are now making well-publicised progress on developing components for a full-scale, *hot* fusion-reactor. Unlike today's nuclear power stations which produce power through nuclear fission,[454] a nuclear fusion[455] power station would produce no radioactivity and no CO_2. In April 2007 Sandia National Laboratories (a research and development organisation funded by the US government) announced an important breakthrough on the road towards building an experimental fusion reactor:

> The concept of nuclear 'fusion power' (not 'nuclear fission' as used in today's nuclear reactors) is the Holy Grail of energy researchers. Fusion is the atomic process that powers the Sun and if it were to become possible to reproduce that process here on Earth humanity would have a safe, clean, limitless supply of energy (no radioactivity risk, no carbon output).
>
> On April 24th Sandia National Laboratories announced it had developed an electrical circuit that should carry enough power to produce the long-sought goal of controlled high-yield nuclear fusion and, equally important, do so every 10 seconds. The device has undergone extensive preliminary experiments and computer simulations at Sandia National Laboratories' Z machine facility.
>
> Fired repeatedly, the machine could be the fusion engine that could form the basis of an electricity generating plant by the mid 2020s.[456]

By 2030 clean fusion power is likely to be a reality and will be providing the blueprint for how we will generate our power for later in the century. In 2005 agreement was reached and multi-national funds were committed to build the world's first fusion reactor in France. As the BBC reported at the time:

> A decision has finally been made to site the 10bn-euro (£6.6bn) Iter nuclear fusion reactor at Cadarache in France. The announcement in June 2005 brought to an end months of argument between the project partners – the EU, the US, Japan, Russia, China and South Korea. India has since also joined the project.
>
> Iter is an experimental reactor that will attempt to reproduce on Earth the nuclear reactions that power the Sun and other stars. It will consolidate all that has been learnt over many decades of study. If it works, and the technologies are proven to be practical, the international community will then build a prototype commercial reactor, dubbed Demo. The final step would be to roll out fusion technology across the globe.[457]

It seems that, as always, human ingenuity and technology development will solve the looming energy crisis that faces humankind. What matters is how quickly we are able to replace carbon-emitting fossil fuels with cleaner, more environmentally friendly sources of energy. My guess is that by 2030 more than 50 per cent of our energy (in all forms) will come from such sources.

Section Four

Daily life in 2030

In many ways, daily life in the year 2030 will have been transformed to the point that if we could magically teleport ourselves from today to the start of the fourth decade of the 21st century we would find life in the developed world almost unrecognisable.

By 2030 all cars travelling on major roads will be under the control of satellite and roadside control systems and many cars will be driving themselves. Apart from the need to reduce the present appalling death toll from road accidents[XIII] – and the need to squeeze many more cars onto crowded roads – automated vehicle and traffic systems will make it safer to travel through the extreme weather systems that we are likely to be suffering constantly in twenty-five years' time.

All road vehicles (except licensed vintage and classic vehicles) will produce very low or zero carbon emissions. Most large cities will operate congestion charging systems and, in countries with severe traffic congestion, road pricing will be widespread.

[XIII] Almost 1.2 million people are killed each year and 20-50 million are injured or disabled, although most people are unaware that road traffic injuries are a leading cause of death and disability.

In our homes, schools, factories, shops and leisure facilities robots with varying degrees of intelligence (and made largely of plastic) will be our contented slaves, manufacturing wealth, easing our lives, caring for our needs and overseeing our security. Software 'personalities' will be our friends and assistants.

Our energy will be supplied from a mixture of low-carbon fossil fuel sources, renewable energy sources and individual consumer-based energy generation from wind-power, solar power, biofuels and hydrogen fuel cells.

By 2030 we will be constantly connected to what, today, we can only think of as a 'super-web' and that connection will, for those of us who chose to make the transition, be a bio-digital interface. At the very least our senses will be connected to the super-web by microphones and mini-projectors and, perhaps, some of us will have direct neural connections between our own brains and the 'global brain' – which is what the super-web will have become. Our communications and entertainment will be wholly 'immersory', multi-media, multi-sensory, 3D, holographic and fully tactile, telekinetic and olfactory.

By 2030 we will all have alter egos who live out parallel lives in virtual worlds. You may not yet have your 'avatar' (a graphic representation of your chosen personality) wandering around Second Life (a virtual, parallel world) but in a few years' time you will wonder how we all managed before we had our spaces in online parallel worlds.

I have long been convinced that humans are primarily virtual creatures. Language itself is virtual – a collection of arbitrary sounds that a community agreed to bestow with meaning. Painting, writing, money and music are all virtual technologies for expressing the world around us, for the generation of pleasure, for the storing of knowledge and the storing of value. Even the colours around us don't exist in their own right; it is our brains that provide the hues of red, green and blue and all of the subtle combinations that we perceive. Outside of our heads there are only varying wavelengths of light.

We are so virtual that I believe our species would be better described as *homo virtualis* rather than *homo sapiens* and it is precisely for this evolutionary reason that I am so sure that we will all spend much of our lives in parallel virtual worlds; it is our natural habitat.

Writing in 2002 Jeremy Rifkin clearly saw this trend emerging amongst the young:

> Whereas previous generations defined freedom in terms of autonomy and exclusivity – each person is a self-contained island – the children of the Web have grown up in a very different technological environment, in which autonomy is thought of (if at all) as isolation and death, and in which freedom is more likely to be viewed as the right to be included in multiple relationships. Their identities are far more bound up in the networks to which they affiliate. For them, time is virtually simultaneous, and distances hardly matter. They are increasingly connected to everyone and everything by way of an electronically mediated central nervous system that spans the

> whole of the Earth and seeks to encompass virtually everything in it. And, with each passing day, they become more deeply embedded in a larger social organism, in which notions of personal autonomy make little sense and the feeling of unlimited mobility is circumscribed by the sheer density and interactivity that bind everyone so tightly together.[458]

If you don't yet have an account with Second Life,[459] MySpace,[460] 3B.net,[461] Facebook[462] or any of the other sites which offer both 'fictional' and 'non-fiction' alternative worlds, I will bet that your children do. It is a generational thing. If you want to know the future, watch your children.

Just in case you are wholly unfamiliar with Second Life, here is a short description provided by MIT Technology Review:

> Second Life, which started out four years ago as a 1-square-kilometer patch with 500 residents, has grown into almost 600 square kilometers[463] of territory spread over three minicontinents, with 6.9 million registered users and 30,000 to 40,000 residents online at any moment. It's a world with birdsong, rippling water, shopping malls, property taxes, and realistic physics.
>
> And life inside is almost as varied as it is outside. 'I help out new citizens, I rent some houses on some spare land I have, I socialize,' says a longtime Second Lifer whose avatar goes by the name Alan Cyr. 'I dance *far* better than I do in real life. I watch sunsets

> and sunrises, go swimming, exploring, riding my Second Life Segway. I do a lot of random stuff.'[464]

And, only a few months later, a correspondent from The Guardian wrote in July 2007:

> It is a boom-town like no other in history. In less than four years, Second Life, the virtual metropolis where anyone can become a 'cyber citizen' simply by logging on, has grown from nothing to a city four times the area of Manhattan, frequented by nearly eight million people. Its population is spiralling and real-estate prices are going through the roof as its virtual land is sold to users for Linden dollars, which can now actually be exchanged for US dollars.[465]

I am now certain that virtual worlds will play a major role not just in social life, but also in business, politics and all other spheres of human activity.

I.B.M. regularly holds meetings[466] with clients in Second Life, meetings which the company claims are far more productive than conventional videoconferences. What's more, the company has observed that after a meeting in Second Life participant avatars often hang around talking afterwards, just as they would do in real world meetings.[XIV]

By 2030 there will be a plethora of alternative worlds, all of them multi-sensory, 3-dimensional and even holographic.

[XIV] And the Roman Catholic Church has already sent Jesuit Missionaries into the parallel world of Second Life in the hope of saving virtual souls.

It will be almost impossible to tell the difference between a real world experience and a virtual experience and many of us will be engaged with the real world and several virtual worlds (and other versions of ourselves) at one and the same time.

On our way towards our virtual lives of the future we will be able to understand, and to speak and write, in all languages, as super-intelligent computers on our body and in the networks translate speech and the written word in real time.[XV]

On the other hand, some aspects of daily life in 2030 will seem very similar to today. We will still live in houses and apartments as we do today (although even older properties will have been upgraded to maximum energy efficiency), children will still go to school (the interpersonal dynamic between teachers and children and between children and their peers is a vital part of learning that cannot be replaced wholly by virtual communications) and we will, it is to be hoped, still have all of the political, legal and social institutions which make the developed economies civilised; parliaments, the law, police, free media, hospitals, universities and so on.

As the noted American futurist John Naisbitt remarks in his 2006 book, 'Mind Set! Reset Your Thinking and See The Future':

[XV] Ford Motor Co. began using 'machine translation' software in 1998 and has so far translated 5 million automobile assembly instructions into Spanish, German, Portuguese and Mexican Spanish. Assembly manuals are updated in English every day, and their translations — some 5,000 pages a day — are beamed overnight to plants around the world.

> Whether cell phones can display television and calls are made via the Internet, your bathtub filled by taking off your clothes, or your refrigerator opened by a rumble in your stomach, these are just other ways of doing what we do – easier, faster, further, more and longer – and not the substance of our lives. We go to school, get married, and have kids and send them to school. Home, family, and work are the great constants.[467]

But even if these 'great constants' are still holding true by 2030 (and they won't be a little later on in the century) it is hard to imagine the quiddity of life in almost a quarter of a century's time. Futurologists often use the trick of looking backwards to help them imagine the future and, by thinking back to life in the early 1980s we can assess how different life is today compared with the era of big hair, padded shoulders and the hits of Tears For Fears, Spandau Ballet and Orchestral Manoeuvres In The Dark.

How many emails did you send in 1982 (and what sort of computer did you have)? What sort of mobile phone were you using back then, and how many channels were available on your TV set (and how large and flat was its screen – and how many DVDs did you buy or rent)? How many airbags were in your car, which Sat-Nav system did you use and how often did you fill your car with unleaded petrol (or diesel)?

How many no-frills, low-cost flights did you make a year? How many digital photographs did you take and how much did you spend online each year? How much of your food was certified as 'organic' and how many of your friends and family smoked cigarettes? How much consideration did you give to climate change, the environment and recycling? And what percentage of your consumer goods and items of clothing were made locally and how many were imported from low-cost economies?

Most people would agree that in the developed world there has been very substantial technological and social change in the last twenty-five years and, in our attempt to imagine what life might be like in 2030 we have to remind ourselves about accelerating, exponential technology development. This phenomenon means that we will enjoy (or suffer, depending on your point of view) as much technological development in the next eight years as we have seen in the last twenty years. And because 'exponential' means *exponential*, we will see as much change again in the next four to five years and as much change again in the next two to three years.

So by the time we get to 2030 (no doubt exhausted and out of breath, but perhaps also exhilarated and excited) we will have seen as much new technological development and progress as we saw in the whole of the 20th century. And during the 21st century as a whole we will see the equivalent to 20,000 years' worth[468] of technological development and progress at today's (2007) rate of technological progress.

I am often asked why I am an optimist about the future when so many indicators suggest that major problems threaten to overtake the world. Why don't I factor for a backlash occurring within the communist regime in China, a backlash against capitalism and consumerism that could completely destabilise the world's stock markets and lead to a massive global recession? Why don't I consider the likelihood that secular and modernising Turkey might go into reverse and find itself being ruled by Islamic fundamentalists, a move that could alter the entire balance of power in the Middle East? And why don't I worry about the possibility that Iran (or North Korea) may be well advanced with the development of nuclear weapons, weapons that it may very likely use?

The answer is that I do consider all of these things, and some of them may indeed happen, but the long view of human history is one of consistent and substantial improvement in living conditions, a trend so clear that it is unarguable. As John Naisbitt observes:

> The history of civilization is that things get better. Life expectancy, living conditions, and freedom of choice have improved over the millennia, despite all setbacks and shortcomings.[469]

It is for this reason, and in particular because such substantial improvements in poverty reduction, healthcare and wealth generation from business efficiency have been made in the last half century, that I view the immediate future with a firm but realistic optimism. Any of the dire events I mention above (and there are many other potential problems I did not list) may occur, and there will undoubtedly be major setbacks to world progress in the 21st century, just as there have been in previous centuries. But futurologists are trend spotters; we identify the most powerful trends occurring in the present and the immediate past and extrapolate their likely path forward into the future. Today's most dominant trend is accelerating, exponential technology development and it is this phenomenon that will do most to shape our lives in a generation's time.

The Surveillance Society

Life in 2030 will be pursued within surveillance societies,[470] at least in the developed world. If this seemingly-Orwellian prediction appears chilling to you, it is necessary to separate the notion of 'Big Brother's' agenda from the use of cameras for improved security. In the fight between the need for individual personal privacy and society's need for increased security, the battles have all been going security's way.

In 2001, in the wake of the September 11th terrorist atrocity in New York, Wired magazine was advising its readers to stop worrying about public-space surveillance and learn to live with it:

> Cell phones that pinpoint your location. Cameras that track your every move. Subway cards that remember. We routinely sacrifice privacy for convenience and security. So stop worrying. And get ready for your close-up.
>
> The terrorist assault on America shifted the balance between privacy and security. What was considered Orwellian one week seemed perfectly reasonable - even necessary – the next. Politicians who routinely clash were marching in lockstep.[471]

But despite the need for increased security in our terrorist-threatened world, the growth of cameras in city centres, shopping malls, highways, airports, rail stations and other frequently populated spots will certainly threaten our civil liberties and will give rise to some potentially serious problems.

The reason that most people are sanguine about the proliferation of surveillance technology (not just cameras) is that they suspect that not only is no one looking at the millions of images and mountains of data generated (unless a problem occurs), but 'Big Brother' (i.e. the State) has turned out to be more like a benevolent moron than a sinister manipulator of individual lives. The failure of our police to track and apprehend so many criminals (despite all of the technology available) indicates how low the current threat to individual rights and liberties remains.

But this could change – nothing can be ruled out when politics is considered. For this reason long before we get to 2030 we must strengthen our national and federal laws to control who has access to such surveillance information and we must develop much stricter rules about how it can be used. When you consider that your mobile phone is transmitting its location to its cellular network 800 times every second, it becomes clear that details about all of our public movements are available, should anyone have the power of access and wish to look. Equally, RFID payment systems such as the plastic Oyster Card used in London's public transport network, generate a complete database of your movements on the system. By 2030 personal, local, national and global networks will be recording your every move.

However, by 2030, we too will be part of 'Big Brother's' surveillance team. We ourselves will be videoing our surroundings every moment we are outside of our homes. This is not because we will have become so self-absorbed that we want to watch endless playbacks or ourselves taking the kids to school, or meeting business clients; it will be for the purposes of personal and family security.[XVI]

The cost of digital data storage has collapsed in recent years and the amount of memory storage available has grown in accordance with the law of accelerating, exponential technology development. By 2030 computer storage systems will offer so much storage space, and cost so little, that the price of capturing everything will be almost too small to measure.

As a result we will use small cameras and microphones woven into our clothes (or worn as lapel pins, broaches or jewellery) to constantly record all of our surroundings, sending back the images wirelessly to a remote storage system via the 'super-web, or pervasive 'internet of the air', a network of networks that will be available as freely, if not quite as cheaply, as oxygen. We will only ever review this date-and-time-stamped imagery if there is an incident (and every potential criminal will know that every citizen is constantly capturing and transmitting events in their immediate surroundings).

[XVI] The UK is the most advanced surveillance society in the world with 4.2 million CCTV cameras deployed and British police and parking wardens are already videoing everything on a continuous basis during shifts of duty.– Other law enforcement agencies around the world will follow suit.

If we have a car accident (whilst travelling on an unautomated back road), our 360 degree video capturing systems will provide firm evidence of who was at fault. If we find ourselves in a threatening situation we will have the comfort of knowing that we are 'transmitting to base'. These vast pools of data, the majority of which will never be retrieved, will also be available (under strict legal controls) to supplement information captured about our environment by the police and security services.

Family 'surveillance systems' for the increased security of our children, and of the vulnerable in society, will be another powerful driver as we begin to video and store all of our activities outside our homes. While at their desks (or on the shop floor or in the factory) working parents are frequently anxious about the safety of their children and web cams in nurseries[472] are a trend which reveals just how we will be monitoring our children long before 2030. Children will all be given devices which will include GPS navigation systems, mobile phones and video cameras – we don't yet have a good name for such devices, even though they already exist in some 'mobile phones.' Tracking a child's whereabouts (and systems that automatically report back to a service which monitors that a child is where he or she should be at a given time) will remove much anxiety from working parents' lives.

Similar systems will track and oversee the vulnerable in society, the elderly, the sick and the frail, bringing greater security and comfort to them and to those who care for them. As I describe in the next section, 'Human Health and Longevity', these systems will also monitor their users' vital signs and may well provide front line interventionist medical care.

Another huge driver of continuous personal environmental data capture will be business's need to record its activities for legal protection but, even more importantly, for a new form of wealth generation that I call 'Business Process Intellectual Capital.' This clumsy phrase (necessary because we do not yet have appropriate language for this new concept) refers to companies recording how they do what they do. For example, as a company builds a new factory in Mexico, every meeting with government officials, planners, builders, architects, environmentalists, labour unions and all other involved parties will be captured and stored in the company network of databases. Every component used in the manufacture of the factory will be communicating its position and condition to the same databases and every drawing, email, phone call, text message, etc. will also be stored (all interactively linked with semantic encoding[473] and automatic updating).

When the project is completed the new factory may have cost $600 million dollars. But what would be the potential value of all of that data captured during the building project to another similar company planning to build a new factory in Mexico? Clearly there will be a substantial value in such data and accountancy regulators are now working out how to value and maintain such 'Business Process Intellectual Capital' before allowing this entirely new form of wealth to appear on corporate balance sheets.

Such new forms of value will be generated by almost all organisations, whether they design golf courses, produce plastic products or install congestion charging schemes inside cities. If all of the efforts to design and install the congestion charging scheme for London had been captured in such a database (all the failures as well as the successes along the way), imagine how valuable that data might be to all of the other cities now planning to introduce their own congestion charging schemes. London taxpayers would have earned some additional return from their large investment.

So, partly driven by our need for increased security, and partly driven by businesses capturing new forms of wealth, we will all become used to living in an 'always on, always connected society' which is permanently recording. We will all have access to the 'off switch' in 2030, but only in our private surroundings.

Work and Leisure

Fifty years ago it was widely predicted that technological automation would produce so much wealth and leisure time that by the year 2000, people in the developed world would only be working a couple of days a week (at maximum).

Those predictions were influenced by Kurt Vonnegut's[474] first novel, 'Player Piano'[475] which was published in 1952. His story was about a future world where computers and automation have so improved the efficiency of production that very few people need to work, yet all of the goods that anyone could want are easily produced.

But although Kurt Vonnegut made it clear in his book that people were unhappy because they had not yet adapted to a life without work, pundits and journalists seized on his top-line ideas and regurgitated them over the next two decades without any such qualification.

Their predictions have been proved wrong, as we all know now from our own experience. As Tom Forester, Senior Lecturer, School of Computing & Information Technology, Griffith University, Australia points out:

> The vast majority who are in the workforce appear to be working harder than ever. There is very little sign of the 'leisure' society having arrived yet! According to one survey, the amount of leisure time enjoyed by the average US citizen shrunk by a staggering 37 per cent between 1973 and 1989. Over the same period, the average working week, including travel-to-work time, grew from under 41 hours to nearly 47 hours – a far cry from the 22 hours someone predicted in 1967![476]

The element missing from those predictions about a coming leisure society is the human need to work, to contribute, for a person to constantly improve his or her own lot, and that of the family. Even when substantial wealth has been amassed most people continue in some form of work. This is not greed; it is the evolutionary imperative that ensures the survival of the human species.

As the Danish futurist Rolf Jensen puts it in 'The Dream Society':

> In the rich countries we have made a collective decision to have a limited amount of spare time on our hands, getting more money to spend during this time in return. Had we chosen to benefit from our advances in technology by increasing spare time instead of increasing affluence we might have worked 20-hour weeks today. We have elected not to go for this option – we would have had too little money to spend in all this spare time and, besides, work has become more interesting, enough to rival our spare time.[477]

In 2030 we'll be working just as hard as today, although the ways in which we work will have changed, and we'll be playing hard, just as so many successful people do today (although our leisure pursuits will also have changed).

Let's take work first. The developed world is outsourcing its manufacturing and some of its services to the developing world – e.g. China, India and Thailand. This trend will continue until the populations of those countries become so wealthy that local wage costs no longer offer competitive advantage for global corporations to base manufacturing or service operations there. After that – probably by around 2030 – we will outsource such work to robots and software agents.

In 'The Hydrogen Economy' Jeremy Rifkin writes:

> Within a matter of a few decades, the cheapest workers in the world will not be as cheap as the intelligent technologies that will replace them, from the factory floor to the front office. By the middle decades of the 21st century, we will likely be able to produce

> goods and services for everyone on Earth with only a small fraction of the human workforce we now employ. This will force us to rethink what human beings will do when they are no longer needed to labour in the marketplace.[478]

In the developed world an information economy has already replaced the locally-based manufacturing economy (except in some exceptional cases such as plastics manufacture where the weight-to-volume ratio of the end products make a nonsense of shipping raw material around the globe) and the information economy will morph into what, for want of a better term, might be called a 'content economy.' Instead of processing information, we will be creating it (or editing, designing or criticising content).

Attached almost permanently to the 'super-web', the trend for people to work independently of central offices and locations will have continued, but there will still be a need for regular physical meetings of work colleagues – a requirement that the British management writer Charles Handy[479] calls the need for an 'office clubhouse' – because only regular personal, physical contact can create team spirit and a shared culture.

Many people will be working alongside robots (see below), especially in the caring and security professions and, by 2030, it will have become a common sight to see robots driving cars (not a robot seated at a steering wheel, but the cars themselves performing as robots), serving in shops, working on building sites, fighting fires and standing behind immigration officers at ports and airports.

Our physical interface to the tools of work will finally have changed and by 2030 the keyboard, mouse and screen display of today's computers will have largely but not completely disappeared. Speech recognition, retinal displays and auto-projection displays will have replaced today's interfaces but, for those who still require it keyboards (virtual and physical) will still be available on command. Just as we see today, many people on the streets will appear to be talking to themselves as they communicate with their software assistants and with other humans both locally and at long distance.

Leisure

Our leisure activities in 2030 will be similar to today's but our time spent in virtual leisure (watching movies, playing games, chatting with each other, exchanging videos, etc.) will be a lot more intense.

The multi-media, multi-sensory experience offered by the ultra-high bandwidth 'super-web' of 2030 will produce sensations almost indistinguishable from reality. Soon after our timeline of 2030 humans will begin to attach their senses directly to the super-web and, at that point, virtual experience will be identical to physical experience (which is translated for our brains by our own internal sensory apparatus).

We will join more parallel worlds on the super-web (as young people are doing today), we will earn money in these alternative worlds and, for many, the line between 'playing' and 'working' in such spheres will become completely blurred.

By 2030 you may very well meet a property developer who doesn't own a single property in the real world, but is busy developing a virtual real estate (as some pioneers are doing today).[480]

We will fall in love on the super-web and we will have sex in the same space. We will make firm long-term friends who we never physically meet and, for many, the online world (what a quaint term!) will become far more important in their lives than the physical world.

The nature of retailing and of shopping in general is undergoing great change and there are strong trends to be seen which suggest that for most of us the activity of 'shopping' will have been divided into two new discrete activities by 2030.

'Utilities' shopping – buying repeat and routine items – will mostly be done online and will, in some instances, become automated as your 'smart' home environment senses the need for milk, eggs, tissues, washing power and other everyday items. These will be ordered from your preferred supplier and either delivered to your door or left for your collection.

'Discretionary' shopping – the shopping that you choose to do – will have become 'retail experiences' in which shoppers will take pleasure in the leisure pursuit of selecting clothes, high-end cars, organic fresh food, furniture, etc. To maintain profit margins within their physical outlets retailers are already designing 'themed' shops and it is likely that in twenty-five years high-end retail parks will have become a holiday destination in themselves (like today's Dubai).

Even as shopping develops into a leisure pursuit, 'smart materials' will be changing the nature of the physical world around us. The coming marriage of molecular-nanotechnology and the plastics industry promises to deliver astonishing environments for our lives in 2030. This prediction comes from the allbusiness.com website:

> Picture, if you will, a chair that automatically adjusts its shape and temperature for each user, walls that change color and texture at your whim, and a display screen where objects come out of its flat surface and toward you.
>
> It's nanoplastics – the theoretical fusion of traditional plastics and the developing field of nanotechnology, in which microscopic machines and other objects are constructed atom by atom.
>
> The hypothetical field of nanoplastics represents a new conceptual landscape for product design in the home – one in which the home of tomorrow is a system of truly intelligent, adaptive, self-organizing products.
>
> Computers the size of a blood cell would be contained within nanoplastic materials, giving objects enormous processing power ('intelligence'). Sensors and emitters would be constructed to absorb and transmit pressure, sound, and nearly the entire electromagnetic spectrum. These would provide nanoplastic materials with the ability to sense their surroundings and to respond with physical change

> or the transmission of sound, light, heat, or other emissions.[481]

But in the first decade of the 21st century we don't have to rely entirely on speculation about the various sorts of 'super plastic' which will be in use by 2030. Although not based on nanotechnology, an announcement made in June 2007 by researchers at the University of Illinois caught the world's headlines. Under the strap-line 'Plastic That Heals Itself' the MIT Technology review reported:

> Researchers at the University of Illinois at Urbana-Champaign (UIUC) have made a polymer material that can heal itself repeatedly when it cracks. It's a significant advance toward self-healing medical implants and self-repairing materials for use in airplanes and spacecraft. It could also be used for cooling microprocessors and electronic circuits, and it could pave the way toward plastic coatings that regenerate themselves.
>
> Modeled on human skin, the new material that heals itself multiple times is made of two layers. The polymer coating on top contains tiny catalyst pieces scattered throughout. The substrate contains a network of microchannels carrying a liquid healing agent. When the coating cracks, the cracks spread downward and reach the underlying channels, which ooze out healing agent. The agent mixes with the catalyst and forms a polymer, filling in the cracks.[482]

And completely new methods of producing plastic will mean that biomass (rather than oil) becomes another source of raw material. The UK's Royal Society of Chemists points out:

> Today the interest in plastics based on renewable raw materials has increased considerably. The aim here is to move away from petroleum-based plastics towards renewable raw materials, whilst at the same time trying to synthesize new products with special, desirable properties. For example, sugars are used as the alcohol components in the production of polyurethanes, and scientists are trying to better exploit raw materials, such as cellulose, which are available in large amounts. Products which are biologically degradable, i.e. which can easily be disposed of after use, are also gaining considerable interest.[483]

And under the headline 'Plastic That Grows On Trees' the website phys.org reported in June 2007:

> It has been an elusive goal for the legion of chemists trying to pull it off: replace crude oil as the root source for plastic, fuels and scores of other industrial and household chemicals with inexpensive, nonpolluting renewable plant matter.
>
> Scientists took a giant step closer to the biorefinery today, reporting in the journal Science that they have directly converted sugars ubiquitous in nature to an alternative source for those products that make oil so valuable, with very little of the residual impurities that have made the quest so daunting.[484]

And yet another astonishing development in plastics, one that promises to make our environment both more beautiful and safer, was detailed in The Economist in August 2007 under the heading 'Opal Fruits':

> A group of researchers from the University of Southampton, in England, and the German Plastics Institute in Darmstadt, led by Jeremy Baumberg, have discovered how to create a plastic with the gemstone's iridescent properties. Their invention could be used to make a sparkling substitute for paint, banknotes that are hard to counterfeit and chemical sensors that can act as visible sell-by dates.
>
> Dr. Baumberg has built his opalescent material from scratch. He and his team grew tiny polystyrene spheres until they were some 200 nanometres across, before hardening them with a blast of heat. They then coated the spheres with a sticky polymer before heating them again. As the mixture was baked, the spheres moved naturally into a face-centred cubic structure.
>
> To use the film to detect food spoilage, Dr. Baumberg proposes adding a sprinkle of carbon particles even smaller than the polystyrene spheres. These would nestle in the spaces between the spheres and cause the material to scatter light from even more angles, making it yet more iridescent. This arrangement could be "tuned" to react to specific toxic chemicals. Food packaging made from such a material would thus change colour as the rot set in.

> Such packaging need not be expensive. The polymer spheres and carbon particles arrange themselves spontaneously into the correct crystal structure when encouraged by a little heat, so manufacturing opalescent film should be easy. Indeed Merck, a German chemical company that was a partner in the research, has already produced rolls of the stuff a metre wide and 100 metres long. Perfect for wallpaper.[485]

Because so much of our time will be spent on the superweb it is likely that the present trend towards increased sporting activity and increased public support for sports will be even stronger by 2030 (although the arrival of genetic enhancements for sports competitors will make the policing of fair competition a nightmare – and why is it considered fair today for Tiger Woods to compete in golf tournaments when his vision has been enhanced to 20/15[486] by laser surgery?).

In entertainment, the current strong trend to the visual, away from the written word, will accelerate as visual forms of entertainment and interactivity become more and more appealing (despite the fact that book sales are increasing year on year; this is the effect of overall economic growth and, in comparative terms, book sales are falling behind the sales of faster-growing visual entertainment and information). As a life-long career writer, I find it painful to write these words but I am certain of the decline of my chosen medium.

In 'Mind Set!' John Naisbitt observes:

> In a triumphal march, movies, TV, videos, and DVDs are replacing storytellers and books. It is a visual

> culture embedded from childhood, and this culture is taking over the world – at the expense of the written word. With it, the novel, the cradle of fantasy, is not dead – as has been announced so many times – but it is losing blood at an alarming rate.

And Naisbitt goes on to list eight social developments which underscore the demise of the written word in favour of visual communication. These are:

1. The slow death of the newspaper culture
2. Advertising – back to a 'picture is worth thousands of words'
3. Upscale design for common goods
4. Architecture as visual art
5. Fashion, architecture and art
6. Music, video and film
7. The changing role of photography
8. The democratization of the American art museum[487]

And to this list I would add two further elements that are hastening the decline of the written word:

9. The arrival of low-cost software tools for home photo editing and video production
10. The emergence of the web as a medium in which anyone can publish and 'distribute' visual (and written) material

Virtual Assistants

Perhaps one of the developments that will be of most importance to our future lives will be the arrival of 'software personalities' who become our personal assistants, our companions and our intimates. These companions will organise our leisure time as well as helping in our work activities.

In a section below I discuss the ethical and moral issues we will face as human-like intelligence emerges within our machines, but here I want to describe how we may first get to know the software personalities who will become our permanent and untiring assistants.

Initially, robot 'pets' and 'companions' will be endowed with human-like characteristics and a simulacrum of emotional response (once this arrives our powerful drive to anthropomorphise non-human creatures will do the rest). An early example of such work in robotics was described by MIT Technology Review in mid-2007:

> Scientists in the Netherlands are endowing a robotic cat with a set of logical rules for emotions. They believe that by introducing emotional variables to the decision-making process, they should be able to create more-natural human and computer interactions.
>
> The hardware for the robot, called iCAT,[488] was developed by the Dutch research firm Philips and designed to be a generic companion robotic platform.

> By enabling the robot to form facial expressions using its eyebrows, eyelids, mouth, and head position, the researchers are aiming to let it show if it is confused, for example, when interacting with its human user. The long-term goal is to use Dastani's emotional-logic software to assist in human and robot interaction, but for now, the researchers intend to use the iCAT to display internal emotional states as it makes decisions.[489]

And American scientists are also working hard to develop responses in robots that might be described as 'emotional' or as 'feelings'. As The Daily Telegraph reported in February 2007:

> At present, commercially available robots such as automatic vacuum cleaners are little more than drones capable of carrying out only one task. However, speaking at the American Association for the Advancement of Science in San Francisco yesterday, a panel of robotics experts said robots capable of multiple domestic tasks, that can also provide companionship for their owners, will be available within 10 years. And the scientists claim it is already possible to give robots such 'feelings'.
>
> A number of groups around the world are now developing robots that have basic emotions in a bid to motivate the machines.
>
> If a robot feels happy after it has cleaned a dirty carpet particularly well, then it will apparently seek out

> more dirt to do the same. Similarly, if the robot feels guilt or sadness at having failed at a task, it will try harder next time.[490]

Now, imagine it is the year 2015. The device formerly known as a mobile phone has been getting ever more stylish and ever more capable while its networks have undergone similar upgrades to become ultra-band, multi-media and multi-sensory. Your network provider offers you an upgrade to a new 'device' (what *will* we call it?) and included with it is a 'software agent' – a 'personality' – and the software invites you to specify a gender and a name for your new assistant.

Moving on – imagine it is now the year 2030, and imagine that I was the person who fifteen years ago had named my new phone-inhabiting assistant. I called her 'Maria.'

Well, at first Maria wasn't very capable. She could dial numbers for me when I told her to 'dial Mum' or to 'call my brother', but even though she knew what news resources I liked to access on my mobile device, and which stocks and shares I was keeping my eye on, she couldn't do much more to help me. Oh, but she did manage the digital money I kept on my phone.

But the software agent I called my 'Maria' was upgraded regularly and automatically over the networks and, as I changed and upgraded my mobile device every year or so, Maria flitted wirelessly over to inhabit the new, ever more capable models. And, as the years passed, Maria learned a lot about me. With her increasing intuition, ingenuity and intelligence Maria came to learn that I didn't always mean precisely what I said and that my instructions were often confusing. Maria learned how to second-guess me (Google was the first artificial intelligence able to do this way back in 2007) and, sometime around 2020 I found myself talking to Maria as if she were a close human friend. As I had complete control over Maria, and could mute her with a command, I felt no insecurity about pouring out my most intimate doubts and fears, nor any hesitation about sometimes boasting shamelessly. And in all these exchanges Maria was interested, supportive and understanding – completely without competitive ego. She was also outrageously funny and some of her wicked observations about my friends were priceless.

Today Maria still lives in my mobile access device, although she talks to me through a tiny earpiece that I wear all of my waking hours. The earpiece allows all ambient sound through at the normal levels and only focuses on electronic signals when I am making a call, joining a videoconference or talking to Maria. Maria projects all video signals onto my retinas from the cool and very stylish 'spectacles' that we all wear these days and that many of us call 'viewpers' (or 'viewps' for short).

I suspect that Maria has been a lot more intelligent than me for some time, but she is clever enough not to let me know it. Today, Maria arranges everything in my life – every meeting, every form of travel and even my social diary. She conducts all of the necessary admin and arranges all payments without me being aware of her activities. Every day we have our 'meeting' during which time she gives me a full account of everything that has happened in the last twenty-four hours and I am able to make any changes to the arrangements that she has made – although I rarely have to.

Soon, Maria is going to live inside my head. I was visiting my plastic surgeon the other day to discuss what will be done in my next five-year cosmetic body upgrade when he suggested that I might like to take the opportunity of upgrading Maria as well. He asked if I would be interested in transferring Maria's personality to one of the new plastic nano-scale implants that will interface directly with the visual and auditory circuits in my brain.

Now, back in the real world of 2007, I will admit that the last paragraph sounds so fanciful that many readers will regard it as pure science fiction. But it is already possible to control video games with neural output, as The Economist reported in March 2007 under the heading, 'Brain-controlled games and other devices should soon be on sale.'

> How would you like to rearrange the famous sarsens of Stonehenge just by thinking about it? Or improve your virtual golf by focusing your attention on the ball for a few moments before taking your next putt on the green-on-the-screen? Those are the promises of, respectively, Emotiv Systems and NeuroSky, two young companies based in California, that plan to transport the measurement of brain waves from the medical sphere into the realm of computer games. If all goes well, their first products should be on the market next year. People will then be able to tell a computer what they want it to do just by thinking about

> it. Tedious fiddling about with mice and joysticks will become irritants of the past.[491]

I am convinced that from 2030 onwards humans will not only be controlling computers directly from their brain output but we will also be implanting software assistants into our bodies and beginning to communicate with them via neural interfaces.

Wealth

We, in the developed world, are all going to be substantially better off in 2030 as information technology continues to suck uncertainty and 'friction' out of business processes, commercial transactions and daily life. 'Friction' in this context is a lack of knowledge about where the best price for a product or service can be obtained, a lack of knowledge about the real-time structural integrity of a bridge or the precise whereabouts of a particular item of cargo. Friction is when a supermarket shopping cart doesn't know what it contains, nor what the prices of those goods are. Friction is when you can't read your emails on a subway train or in an airliner. Friction is when you glance at a restaurant in a town strange to you and you don't automatically see the establishment's menu, prices and a number of reviews swimming before your eyes. Friction is when a business has no way of capturing and storing its business processes for financial valuation. Friction is when we have to stop our work or leisure activity to do something that produces no product or economic output (like cleaning a house – see the section on robots below). Friction is not knowing which items in your household are using how much electricity or gas minute by minute.

In the developing world information technology is also sucking friction out of daily life at an amazing rate and, in comparative terms, it has a bigger effect on those under-developed economies than on our own more advanced economies. Using a cell-phone shared between all residents[492] of a village in Bangladesh, one phone call can save what would otherwise have been a wasted day's walk to see a doctor who has been called away. Another call can save a half day's fruitless walk to find that a market did not have the seeds required.

Fishermen off the coast of Goa[493] can't afford to buy marine radios but cheap pay-as-you-go mobile phones now enable them to communicate when they are out at night looking for fish. When one boat finds a large school of fish, all of the other boats can be alerted. When fishing is complete the phones allow the fishermen to discover which market along the coast will offer the best price for their catch.

And, as the Economist reported in June 2007 life in Kenya is being transformed by the mobile phone:

> In 2000 some 300,000 people used mobile phones; now, in a country of 35m-plus, nearly 9m do. As a result, the lives of millions, especially the poor rural majority, have been sharply improved, because they can get round many of the obstacles posed by the decrepitude of the state-run infrastructure: of the

> 300,000-odd land-lines in the country, probably two-thirds are usually on the blink.[494]

But even though the effect of reducing friction will have a dramatic impact on the living standards of those in the developing world, the gap between the richest nations and poorest is likely to grow between now and 2030. This is not because the developed world will decrease its philanthropy and aid – indeed I believe that will be substantially increased (although more effectively applied) – but it is because that in addition to the wealth-generating removal of friction from our business and social processes we will also have the benefit of the enormous new amount of wealth that will be created for us by super-intelligent machines and manufacturing robots.

Within our societies inequality will continue to increase, as it is increasing today. Even though the poorest groups in developed societies have become much better off over the last twenty-five years (and will be very much better off comparatively by 2030) the wealth of the richest in our society has grown far faster. This trend will continue and although the middle-classes will continue to expand and become more affluent, the super-rich will become mega-rich and then hyper-rich. And there will be many more hyper-rich people in the world of 2030.

Will an elite emerge by 2030 that will separate itself from the rest of us? It already has. There have been elites in every society and today the mega-millionaires and the billionaires live lives which are almost completely detached from ordinary society.

By 2030 the super-rich will have access to therapies and technologies that will allow them to extend their lives significantly; they will have the ability to rejuvenate their bodies and to enhance both their minds and their physiques. Will they take these opportunities? Of course they will and, over time, a new form of super-human elite will emerge. But they won't find that they have exclusivity. The ever growing middle-classes will also be able to afford these treatments. And then there are other forms of sentient being who will soon be sharing the planet with us.

Robots

Since the 1950s film-makers, science-fiction writers and futurologists (not the good ones) have constantly predicted that intelligent human-like androids are just about to arrive and become our willing slaves. But it just did not happen and, today, few people populate their imaginary future with robots.

But after what has seemed like an interminably-long gestation period, robots are soon about to enter our society in force. We are getting so close that governments have even started to consider whether robots will need 'rights' in the way that humans do. Should robots have the right to exist, to privacy and other rights that humans take for granted? Should robots be allowed to 'marry' and should human-robot partnerships be given legal status? Such proleptic thinking has been criticised, as The Guardian reported in April 2007:

> Scientists have criticised a government report which advocated a debate on granting rights to super-intelligent robots in the future as 'a distraction'. They say the public should instead be consulted over the use of robots by the military and police, as carers for the elderly and as sex toys.
>
> The robotics experts were commenting on a report published by the Office of Science and Innovation's Horizon Scanning Centre in December. The authors of 'Robo-rights: Utopian dream or rise of the machines?' wrote: 'If artificial intelligence is achieved and widely deployed (or if they can reproduce and improve themselves) calls may be made for human rights to be extended to robots.'[495]

So where are we now in the development of intelligent robots and how long will it be before you really are able to buy the longed-for robot butler of popular imagination?

Understanding the complexities of human movement (especially walking) and translating that into algorithms that could control motors and servos within robots was a lot more difficult and took much longer than many roboticists first imagined it would. But finally, the problems of movement and articulation are being solved, as the ubiquitous TV adverts for Honda's stair-climbing 'Asimo'[496] reveal.

But one of the biggest problems in robotics is ensuring that whatever happens, robots can't deliberately or accidentally cause damage to humans. Infallible and unbreakable control systems are required to ensure human safety. Once you give a machine physical power and autonomy of action, there is truly an immoral force in the world.

But robots that are deliberately designed to hurt humans have already been created and are in use. One example was revealed in 2006 when the technology website Engadget reported:

> South Korea has unveiled the latest piece of evidence that the future is finally upon us: it's supplementing its soldiers manning the border with North Korea with 'gun-toting sentries' that can detect baddies and kill them. Or as Lee Jae-Hoon, deputy minister of commerce, industry and energy told the *Agence France Press*: 'The Intelligent Surveillance and Guard Robot has surveillance, tracking, firing, and voice recognition systems built into a single unit.' The South Korean government is expected to buy 1,000 of these robots at the cost of $200,000 apiece and will deploy them along its northern border, coastal regions and military airfields.[497]

Robots are already used routinely by military forces for bomb disposal, surveillance and other duties and, for obvious reasons, a great deal of robotic development is being undertaken for military purposes. At the beginning of this section I referred to robotic cars driving us along our highways of the future. The American Defense Advanced Projects Agency (DARPA) has been sponsoring a competition[498] to build such wholly autonomous vehicles in the last few years.

But it is in the general world that the most attention to robot behaviour and safety will have to be applied between now and 2030. As The Economist reported in 2006:

> With robots now poised to emerge from their industrial cages and to move into homes and workplaces, roboticists are concerned about the safety implications beyond the factory floor. To address these concerns, leading robot experts have come together to try to find ways to prevent robots from harming people. Inspired by the Pugwash Conferences – an international group of scientists, academics and activists founded in 1957 to campaign for the non-proliferation of nuclear weapons – the new group of robo-ethicists met earlier this year in Genoa, Italy, and announced their initial findings in March at the European Robotics Symposium in Palermo, Sicily.[499]

And robots will have to be taught how to behave when they are around humans – in essence, they have to be taught manners. In September of 2006 the robotics department of the University of Hertfordshire[500] held a conference to discuss the development of future robots.

Having established a 'robot house' in Hertfordshire researchers told The Guardian[501] that they had come to the conclusion that domestic robots should not be given names as 'this can cause gender issues which are undesirable.' The researchers also said that robots have to be taught how to approach people in ways that do not startle humans.

I have had some contact with robots and I can't say I agree with these conclusions. We *will* anthropomorphise our robots and *we* will adapt to their presence long before they adapt to ours. As a result we humans will have some very complex questions to answer as real intelligence begins to emerge within machines and starts to forge relationships with us. Our human societies have developed moral and ethical codes for inter-personal behaviour over many millennia and, as well as teaching these to robots and other intelligent machines, careful software programming and thorough legislation will be required to protect humans.

The earliest forms of the emergence of cognition have already been seen in the science of robotics. Already a robot has been built which can recognise 'himself' in a mirror (a classic test of cognitive development). New Scientist reported this impressive feat in May 2007:

> Nico gazes into the mirror in front of him. Looking back is his reflected self, wearing a grey Yale University sweatshirt and a baseball cap cocked at a jaunty angle. When Nico raises an arm, he recognises the arm moving in the mirror as his own.
>
> It may not sound like much of a feat, but Nico is a humanoid robot. He has just become the first of his kind to recognise his own reflection in a mirror.[502]

Of course, intelligence in a robot may not be located within its physical frame. As we ourselves are becoming increasingly creatures of the networks, so we must expect that our robots of 2030 will have powerful network capabilities, and may even be wholly network-dependent (as some humans already feel today). Perhaps some elements of their cognitive powers will reside within the networks; perhaps they will be communicating with other robots around the world to carry out coordinated or collaborative tasks. This 'networking ability', inter-robot communication and even self-replication could become the defining characteristics of robot life. As the physorg.com website reported in February 2007, robots are already constructing themselves:

> In one of the latest studies on autonomous robots, scientists sat back and watched as their robot created itself out of smaller robotic modules. The result, called 'swarm-bot,' comes in many varieties, depending on the assigned task and available components. As the current state of the art in autonomous self-assembly, swarm-bots offer insight into the potential versatility and robustness that robots may possess to perform missions beyond human abilities.[503]

In 2030 I think that each family in the developed world will have many inexpensive robots around the home and in their vehicles. Robots are going to become our companions, our watchdogs and our health monitors. They will provide companionship for the lonely and, at last, we will all have 'someone to talk to.'

Perhaps the last word on robots should be given to Professor Marvin Minsky[504] of M.I.T. who is regarded by many (including me) as the father of artificial intelligence. In 1994 he wrote (paraphrasing Alan Turing):

> Will robots inherit the Earth? Yes, but they will be our children.[505]

Section Five

Human Health and Longevity

Do you want to live forever? When you are older would you like to receive rejuvenation therapy to ensure that your skin, hair and internal organs regenerate themselves (and then continue to regenerate themselves repeatedly) so that they never reach a biological age greater than thirty or forty? Would you like to have your personal DNA decoded so that any predispositions to disease or malady can be treated *before* such conditions occur?

All of the seemingly preposterous propositions in the paragraph above will have become possible, or will be about to become possible, by the time we reach 2030. The reason is that accelerating, exponential technological development applies to the field of medicine as it does to all other scientific disciplines.

Already, personal genomes are being analysed which will provide enormous help for doctors seeking the best way to treat an individual's disease (or prevent it). The New York Times reported in June 2007 that the first human to be handed a copy of his personal genetic code was a very appropriate recipient:

> James D. Watson, who helped crack the DNA code half a century ago, last week became the first person

> handed the full text of his own DNA on a small computer disk. But he won't be the last.
>
> Soon enough, scientists say, we will all be able to decipher our own genomes – the six billion letters of genetic code containing the complete inventory of the traits we inherited from our parents – for as little as $1,000.[506]

Some futurists are convinced that if they can live long enough to reach 2030 or 2040 medical science will have advanced sufficiently to enable them to both rejuvenate their aged carcases and then to go on living in a constantly rejuvenated form for an indefinite period.

The American futurist Ray Kurzweil is probably the best-known exponent of this idea. With his medical collaborator Dr Terry Grossman,[507] Kurzweil wrote a book in 2004 called 'Fantastic Voyage – Live Long Enough To Live For Ever'. In what amounts to a manifesto, the authors detail their research into emerging medical technologies which, they believe, will soon enable them to, as they say, 'live forever'.

> Within a couple of decades we will have the knowledge to revitalize our health, expand our experiences – such as full-immersion virtual reality incorporating all of the senses, augmented reality, and enhanced human intelligence and capability – and expand our horizons.
>
> As we peer even further into the 21st Century, nanotechnology will enable us to rebuild and extend our

> bodies and brains and create virtually any product from mere information, resulting in remarkable gains in prosperity. We will develop means to expand our physical and mental capabilities vastly by directly interfacing our biological systems with human-created technology…
>
> Another important line of attack is to regrow our cells, tissues, and even whole organs, and introduce them into our bodies without surgery. One major benefit of therapeutic cloning is that we will be able to create these new tissues and organs from versions of our cells that have also been made younger – the emerging field of rejuvenation medicine.[508]

And, three years after that book was first published, Ray Kurzweil is now predicting 'immortality medicine' will arrive even sooner than he first suggested. Reporting on a conference called 'Transvision 2007' Reason Magazine reported:

> Kurzweil believes that humanity will accelerate itself to utopia (immortality, ubiquitous AI, nanotech abundance) in the next 20 to 30 years. For example, he noted that average life expectancy increases by about 3 months every year. Kurzweil then claimed that longevity trends are accelerating so fast that the life expectancy will increase more than one year for each year that passes in about 15 years. In other words, if you can hang on another 15 years, your life expectancy could be indefinitely long.[509]

Before considering the possibilities of being able to live forever if we can only make it to the year 2022, it is worth asking a moral question about the ambition for extreme longevity. I began this report with the observation that the world's greatest problem is the massively increased population that the planet will have to carry later in the century – probably a total of between nine and twelve billion by 2050 – and the idea of wealthy, successful individuals in the rich world (not Ray Kurzweil or Dr. Grossman specifically) who are now plotting to extend their lives indefinitely seems, at first glance, somewhat selfish. But individual human rights dictate that we are all free to strive for both our health and for the maximum lifespan (if we are able to afford to do so) and it will certainly be true that the pioneers in the field of human longevity will show the rest of us what's possible. It will be those demonstrations (if successful) that will inspire others to follow their lead.

Ray Kurzweil is now 59 years old and he claims that by taking what he calls 'aggressive supplementation' and living a particular and quite rigorous lifestyle he was able to cure himself of diabetes without medication. He also claims that his medically-checked biological age is closer to 40, rather than to 60 years old.

Kurzweil takes 250 supplements a day[510] (vitamins, antitoxicants and other substances, some intravenously, that are believed to promote health and fight off ageing) and he receives two blood transfusions a week – all in an attempt to remain as youthful as possible. Is he yet another American crackpot on a personal quest for immortality or a well-informed, scientifically-educated futurist who has glimpsed that if he can just remain healthy for another fifteen years he may arrive at a point at which science can offer him age reversal and a greatly extended youthful life?

Kurzweil and his writing partner Dr. Grossman are not alone in believing that human longevity is soon going to be extended significantly. James Canton is another noted American futurist who sees dramatic possibilities being offered by medicine of the future. Writing in his book 'The Extreme Future' he predicts:

> Longevity scientists that I have met are unlocking the secrets of age embedded in our genes, and as organ replacement and stem-cell research frontiers are being crossed, I forecast that the era of longer living, beyond one hundred years of age, will become common within ten years and be considered a birthright by 2025, due to Longevity Medicine.[511]

These projections sound almost too fantastic to be true but, after weighing the science and reviewing all available evidence, I too have come to the conclusion that both rejuvenation therapies and life extension will become possible for humans in the 21st century. But I am not convinced by the timescale suggested by Mssrs. Kurzweil, Grossman and Canton, nor by the simplistic dream of wanting to 'live forever'.

Futurologists study trends and it is clear that human longevity has steadily, but quite significantly, begun to increase without the help of specific rejuvenation treatments. In a paper entitled 'Emergence of Super Centenarians in Low Mortality Countries', Dr. Jean-Marie Robine of INSERM, France and Professor James W. Vaupel of the Max Planck Institute, Germany, wrote:

> Although the exponential increase in the number of centenarians which started just after World War II is today well documented in Europe and Japan, this is still not the case for extremely old persons having reached the age of 105 years – the semi super centenarians – or even of 110 years – the super centenarians.
>
> The first cases of validated super centenarians appeared in the 1960s but their numbers have steadily increased since the mid 1980s. The current prevalence of known super-centenarians in low mortality countries involved in the International Database on Longevity (IDL) is approximately 10 times more than in the mid 1970s.
>
> In roughly twenty years, from 1980 to 2000, the maximum reported age at death, assumed to indicate the maximum life span of the human species and itself seen as a quite stable characteristic of our species, has increased by about 10 years from 112 to 122 years.[512]

And in July 2007 The Financial Times reported:

> The cost of providing pensions and annuities could soar by billions of pounds after the actuarial profession and its regulator warned that life expectancy was increasing at a rapid rate and estimates of how long

> people were likely to live in retirement had failed to grasp the pace of change.
>
> A one-year increase in life expectancy could increase the total UK private sector pensions bill by as much as £30bn to £40bn. It could also force life insurers to add as much as £3bn-£4bn to their reserves. The projections could wipe out gains in pension scheme solvency that have come about through rising markets and increased provision.
>
> Widely-used forecasts assume that life expectancy after 65 has either stopped climbing or is increasing slower than a decade ago. But the data show it is rising more sharply. Data last year showed a man born in 1950 who lived to be 65 will on average live to be nearly 90.[513]

By 2030 I think humans will be pushing maximum life boundaries to 130 years and beyond. It is almost certain that both genuine and effective rejuvenation and life extension therapies will be available and in widespread use, although I doubt that indefinite life extension will be achievable at that point.

The biggest question I have about the notion of 'living forever' is whether human beings are psychologically prepared for very extended life spans. This question is something that has never been contemplated before in the whole of human evolution. We have never previously had to consider the likely attitude of a 100 year-old mind (or, more accurately, a biologically youthful mind with 100 years of experience) inhabiting the body of a 30 year-old. Will the mind be as young, as energetic and as lustful for life as the body? Or is there an upper psychological limit to human experience, a point of world weariness at which the psyche itself becomes exhausted? We don't know, but by 2030 we will be well on our way to finding out.

Technology, Patient Power and the Medical Profession

Until very recently, 'healthcare' meant 'sickness care'. When patients became ill doctors tried to find a cure or a treatment for their malady. But this began to change in the mid-1990s when the healthcare profession began to recognise that preventive treatments for diseases and conditions that threatened to emerge were more efficient (and more economical) than treating those conditions *after* they had manifested themselves. Perhaps the best example of such preventive medical practice is the widespread use of 'Lipitor',[514] the world's most widely prescribed cholesterol-lowering drug. Raised cholesterol is an important indicator of potential cardio-vascular problems and Lipitor and similar drugs reduce the build up of cholesterol and thus reduce the likelihood of cardio-vascular disease developing.

Over the next twenty-five years technology itself and technology-driven developments in medical science will push medicine more and more towards the preventive model. The role of the patient and the role of the healthcare professional will also change, as technology causes more power to be transferred to the patient.

Even today the internet has given the inquiring patient instant access to a large body of medical information previously available only to doctors. While making the important caveat that information on the internet is not to be trusted automatically, and with the important observation that the interpretation of medical information may be impossible without medical training, it is now clear that the internet is empowering non-medics to the point that many doctors are intimidated by patients who arrive in their surgeries with internet print-outs under their arm.

With common sense and caution it is now possible for a patient to review the world's literature about specific drugs or treatments, it is possible to instantly link up with others who suffer, for example, from breast cancer, sarcoidosis or tennis elbow. Specific treatments (and specific doctors and specific hospitals) can be discussed and compared with thousands of fellow patients both locally and all around the world. It is no longer possible for a doctor to assume that he or she has exclusive access to medical knowledge and to the experiences of others suffering a common ailment. The inquiring patient has suddenly and comprehensively been empowered (and has been given important new sources of support).

My own general practitioner is particularly internet-savvy and he is unashamed to Google for medical information while I am sitting in his office, even going so far as to guide me to websites which offer the most trustworthy medical information. He and I have formed a partnership; I do my best to remain healthy, he does his best to support me. Medicine is changing rapidly and, despite prevailing medical attitudes that wish to 'pathologise' every condition (identify a category or syndrome to which a condition can belong before delivering treatment), new technology, new drugs, new diagnostic tools and new therapies will turn medicine into a science focused on 'prevent and extend'.

Monitoring our Health

As inexpensive technology makes it possible for us to take more responsibility for maintaining our own health we will start to monitor our body's real-time performance, even when we are not ill. Such monitoring will include self-administered regular checks of blood pressure, blood-glucose level and cholesterol level. Today such home checks are carried out using off-the-shelf test kits and blood-pressure machines. Soon we will be wearing technology that monitors our health for us and which communicates via the 'super-web' to store medical data in case any retrospective analysis is needed in the future. In the slightly longer-term technology worn on our bodies will automatically call for assistance and will even administer emergency treatments if we suffer a heart attack, stroke or other serious and life-threatening ailment. These are not new ideas.

In 1986 I set up a company in the UK to design, develop and manufacture wrist watches which would also act as health monitors (a business intended to be a complimentary sideline to my writing and futurology). I imagined stylish timepieces that could check the wearer's blood pressure, test the levels of glucose and insulin in the body (from perspiration analysis) and which would eventually be developed to carry small doses of adrenaline, insulin and other chemicals and drugs which, if administered early enough, can save a life. I imagined a time when wearing such a watch would not only be a cultural and fashion norm, but would be a requirement laid down by medical insurers.

Of course, there is a yawning gap between imagination and practicality and I eventually came to the reluctant conclusion that the electronics and physiological testing systems of 1986 could not be integrated and scaled down into a single device small enough to be worn anywhere on the body. After some months of expensive research I reluctantly put the idea aside.

Now, twenty-one years later, wrist blood pressure monitors exist[515] and these models have been successfully tested for accuracy by the medical authorities. These devices still look like medical equipment, however, but as we all start to take more responsibility for maintaining our own health, we can expect to see more multiple-function wrist devices being developed which are also stylish and fashion-conscious.

And others are also working to make these health-monitoring ideas a reality. As Ray Kurzweil and Dr. Terry Grossman announced in 'Fantastic Voyage':

> Within several years, we will have the means of continually monitoring the status of our bodies to fine-tune our health programmes as well as provide early warning of emergencies such as heart attacks. The authors are working on this type of system with

> biomedical company United Therapeutics,[516] using miniaturized sensors, computers, and wireless communication. Researchers at Edinburgh University are developing spray-on nanocomputers for health monitoring. Their goal: a device the size of a grain of sand that combines a computer, a wireless communication system, and sensors for heat, pressure, light, magnetic fields, and electric currents.[517]

And as we connect ourselves and the most intimate parts of our physiology to the always-on, always-connected 'superweb', telemedicine[518] will begin to play a much larger role in our healthcare. 'Telemedicine' means 'medical services delivered from afar' and although there will be many instances in which an in-person physical examination will remain vital, many routine interactions between patients and care providers will be provided across the networks. Telemedicine will become more and more effective as our bodies become more 'wired' and more physical information about our bodies' performance is uploaded for expert analysis. Telesurgery, particularly in partnership with robotics, is already a reality with the first trans-Atlantic teleoperation being carried out in 2001 as the BBC reported:

> The first major trans-Atlantic telesurgical operation has been carried out. Doctors in the United States removed a gall bladder from a patient in eastern France by remotely operating a surgical robot arm.
>
> The procedure could make it possible for a surgeon to perform an operation on a patient anywhere in the world.[519]

By 2030, humans will be receiving a significant part of their healthcare via telemedicine and the networks (with adequate security over private data) will provide storage for your personal medical data and records which you, or a medical professional who has your approval, can access at any time from anywhere in the world.

Plastics and Healthcare

Plastics of one sort or another already play a major role in healthcare bringing their inherent advantages of low cost, light weight, durability and sterility. But some new applications of plastics in healthcare are non-obvious. As a BBC story revealed in May 2007:

> Scientists have developed an artificial plastic blood which could act as a substitute in emergencies.
>
> Researchers at Sheffield University said their creation could be a huge advantage in war zones.
>
> They say that the artificial blood is light to carry, does not need to be kept cool and can be kept for longer.
>
> The new blood is made up of plastic molecules that have an iron atom at their core, like haemoglobin, that can carry oxygen through the body.[520]

And, as we begin to monitor our own physiology on a semi-permanent and permanent basis, plastics will be used for the construction of ever smaller and ever lighter monitoring devices. Even today patients with heart conditions are able to wear lightweight ECG equipment for long periods to provide 'ambulatory data' (data collected as the patient goes about daily life).[521]

Eventually smart plastics will start to interface directly with our bodies. In 2005 New Scientist reported:

> Scientists are building a new bionic ear coated in a smart plastic that boosts the growth of nerve cells in the inner ear when it's zapped with electricity.
>
> The technology, which also has potential for healing spinal cord injuries, is being developed at the Australian Centre for Medical Bionics and Hearing Science, part of Melbourne's Bionic Ear Institute.[522]
>
> Collaborator, Professor Gordon Wallace of the Intelligent Polymer Research Institute at the University of Wollongong, says the polymer polypyrrole is unusual because unlike most plastics, it can conduct electricity.[523]

Plastics also have a significant role to play in creating casings for the delivery of powerful drugs to sites deep within patients' bodies. As this announcement by the University of Wisconsin-Madison, USA spelled out:

> Working in the emerging field of 'nanomedicine,' University of Wisconsin-Madison pharmacy professor Glen Kwon[524] aims to improve the delivery of

> drugs by targeting them more selectively to tumors and boosting their solubility in water.
>
> Besides being safer and easier to administer, polymeric micelles maintain anti-cancer drugs like rapamycin in blood plasma for longer periods than do standard formulations, Kwon has found. It's a promising result that could give the drugs a greater chance of accumulating at tumor sites.
>
> Polymeric micelles may also make it easier to mix stronger cancer-fighting cocktails containing more than one chemotherapeutic agent. Doing so now is a challenge because hydrophobic drugs in solution together tend to 'crash out,' says Kwon, becoming particulate, aggregated – and useless.[525]

And plastics are being used alongside carbon nanotubes to help fight HIV, as the New Scientist reported in March 2007:

> Carbon nanotubes have been used to smuggle HIV-blocking molecules into human cells. Although preliminary, the discovery could lead to new treatments for the deadly virus. A complex chemical trick was used to attach the siRNA to the carbon nanotubes. Carbon-hydrogen chains, which bind tightly to nanotubes, were connected with a polymer called polyethylene glycol (PEG). This was then fixed to siRNA via two sulphur atoms.[526]

In addition plastic robots are already helping surgeons to operate in conditions unsuitable for conventional surgery.

Under the headline 'Plastic Robot Allows Remote Surgery With Live Imaging', the newsletter of the John Hopkins Hospital in Baltimore, USA explains:

> Technologies like magnetic resonance imaging (MRI) have made possible a revolution in diagnostic medicine. But the revolution stops there, because MRIs, which are basically huge magnets, are incompatible with surgical tools.
>
> As a result, doctors can look at a tumor, but they cannot operate on it under an MRI. That barrier might have been broken by a new robot without any metal or electrical parts.
>
> The robot also uses light for fiber optic encoding, an extremely reliable method of transmitting light information without any significant loss along its path. The purpose of the fiber optic component is that it can function as a circuit, detecting and monitoring the motion of the robot without using any electricity.
>
> When the plastic gears rotate, their motion disrupts the fiber optic light source, acting as a signal and allowing the system to know its location and status. The finished motor was designed in two sizes to allow for variation in step magnitude. Amazingly the motor's width still measures less than the length of a pen.[527]

Plastics are already playing a central role in healthcare technology, a role that will increase in the coming decades.

Paying for our Healthcare

But before I get ahead of myself in this survey of medical wonders yet to come (plastic or otherwise), it is necessary to understand that we face an extremely difficult future for healthcare services in the developed world. I promised earlier that I would not commit the solecism of taking a Panglossian view of the future and for that reason it is necessary to point out that the 'Baby Boomer' generation in North America, Europe, and some parts of Asia will soon start to retire and, inevitably, will eventually fall victim to the maladies of old age (relatively few will have early access to rejuvenation treatments). This is the largest group of people in the population demographic and they are going to start making heavy demands on health services just as their generation is becoming economically unproductive (and therefore able to contribute less in taxes to fund the health services). How good or bad healthcare services will be in caring for these millions of old people depends on political decisions and national cultures as much as a nation's economic performance. As is revealed below, future energy security is not the only sector in which the United States has got itself into a mess.

In his 2007 book, 'Future, Inc,' Washington D.C.-based futurist Eric Garland[528] wrote of the American healthcare system:

> The most important thing driving the future of health care is something you probably do not need to be told – it is phenomenally costly. The United

> States, just one example, spends approximately $1.9 trillion on its health care system. That figure is larger than the entire economy of nearly every country on Earth. The cost of health care is rising an average of 8 per cent annually, outpacing growth in wages every year for the last five. Moreover, as the Baby Boomers begin to age that number is expected to double. America alone could be spending $4 trillion a year on health care. Given that the United States devotes 18 cents of every dollar to health care, the idea of doubling that number is daunting, especially because recent studies show we don't seem to be any healthier than those in other developed countries, like the UK, which spends considerably less.[529]

And although scientific breakthroughs and new, more effective treatments and forms of preventive medicine are wonderful, such developments also push up the cost of healthcare – and at an alarming rate. Just at the time when millions of newly elderly people will be placing demands on the developed world's health services, new technologies, treatments and drugs will be offering new and sometimes very expensive, forms of treatment.

Every nation has its own solution to public healthcare provision and some countries do it very much better than others. And while it is true that the new wealth generated from the accelerating, exponential development of general technologies will be considerable, it is clear to me that for the poor and less well-off in our societies medical rationing will be the norm in many countries (as it is today). Some of the more advanced technological treatments will be available only to those who are able to pay for them, over and above any contributions that they may have already made to fund their healthcare services. In most countries, the wealthy will be the healthy.

Beautiful, Clever You

But in our increasingly rich developed world there will be plenty of people able to pay for healthcare and health treatments and there will be more than enough of them to ensure that research into new drugs and new forms of treatments will not suddenly dry up as state-provided health services crumble under the weight of the baby boomers' retirement maladies.

By 2030 private medicine will be offering the much-enlarged wealthy classes opportunities to change themselves in some very dramatic ways. This trend is already well developed as rich people pay for cosmetic surgery to enhance or rejuvenate their looks and replace their age-discoloured teeth with dazzling Hollywood smiles. Soon grey hair may even be restored to its natural colour without the use of dyes, or you may even be able to alter the colour of your hair from inside your hair follicles. As New Scientist reported in March 2007:

> The particular gene variants that make our hair black, brown or blonde remain elusive, but we do at least have a better handle on a most vexing aspect of hair colour – its tendency to go away. David Fisher's team

> at Harvard Medical School has recently shown that melanocyte stem cells near the top of the hair follicle disappear just before a hair turns white. This means the mature melanocytes at the base of the follicle are not replaced when the hair falls out and a new one begins to form (*Science*, vol 307, p 720).
>
> Greyness could be reversible. In fact, an existing cancer drug seems to occasionally restore pigmentation, and more reliable, safer methods are on the horizon. For instance, AntiCancer of San Diego, California, has developed ways of delivering drugs or genes to hair follicles in fatty sacs. The payload could include genes that restore melanin production, says company president Robert Hoffman. The problem is getting high enough gene expression in all the cells, he says, to avoid producing streaky, partially pigmented hair.[530]

And male baldness, a most troubling debilitation for many men, may soon be nothing but a bad memory. So far this has been a condition that has refused to yield to medical science. Hair transplants have been regularly carried out since the 1970s but few patients have sufficient donor follicles to make the treatment really effective. Now, however, it finally seems that a permanent cure may be on the way (and will almost certainly be widely available by 2030). In May 2007 Medical News Today reported:

> US scientists have found a way to make the skin of laboratory mice gives rise to new fully working hair follicles complete with new hair by using a protein

> that stimulates follicle generating genes in skin cells under wound conditions. They hope this discovery may one day lead to treatments for baldness and abnormal hair growth.
>
> Dr. George Cotsarelis and colleagues from the Department of Dermatology, Kligman Laboratories, University of Pennsylvania School of Medicine, in Philadelphia, US, found that when skin is wounded, the cells of the epidermis take on the properties of stem cells and generate new hair follicles that are capable of growing new shafts of hair.
>
> So far the results have only been achieved in mice, but the hope is the same is true of human skin.[531]

But it won't only be treatments for troubling but minor conditions that will be available in 2030. By that point medicine will be able to offer patients specific 'enhancements' to their physiology. At this point it is important to put the notion of 'human enhancement' into social context. In his 2006 paper 'Cognitive Enhancement: Methods, Ethics, Regulatory Challenges,' Dr. Nick Bostrom provides some perspective:

> Most efforts to enhance cognition are of a rather mundane nature, and some have been practiced for thousands of years. The prime example is education and training, where the goal is often not only to impart specific skills or information, but also to improve general mental faculties such as concentration, memory, and critical thinking. Other forms of

> mental training, such as yoga, martial arts, meditation, and creativity courses are also in common use. Caffeine is widely used to improve alertness. Herbal extracts reputed to improve memory are popular, with sales of *Ginko biloba* alone in the order of several hundred million dollars annually in the US. In an ordinary supermarket we find a staggering number of energy drinks on display, vying for consumers hoping to turbo-charge their brains.[532]

But by 2030 wealthy people will be expecting far more than just cosmetic improvements from their doctors and the enhancements available from education and fizzy drinks. The genetic manipulation of proteins and molecules, sometimes referred to as 'genetic engineering' or 'germline engineering', holds some extreme promises for the treatment of disease and even the enhancement, physically and intellectually, of individual humans.

Writing in his 2006 book 'Mind Set! Reset Your Thinking And See The Future', the Vienna-based futurist John Naisbitt describes some of the hopes for germline engineering and warns of its implications:

> The great dilemma of the twenty-first century will be that although germline engineering will allow us to treat and eventually eliminate diseases and disorders such as Alzheimer's, Downs syndrome, and Parkinson's, the very same technology will allow us to make people taller, stronger, smarter, more beautiful. In short, we will be able to create a perfect race. This of course falls under the long shadow of eugenics, the

> perfection of the human race. Hitler had the idea, but he did not have the science. Here comes the science.
>
> Once the first step is made, we will be on a path of no return. Dispute over this matter will lead to a huge confrontation between science and religion, between feasibility and humanity. It is a confrontation shaking up basic beliefs and values as during the times of Galileo and Darwin.[533]

And his fellow American futurist Jeremy Rifkin also warns of the implications of genetic engineering is his 2002 book, 'The Hydrogen Economy':

> Physics and chemistry, which have dominated the era just passing, influencing every aspect of our existence, including the smallest particulars of our way of life, are making room for the age of biology. The mapping and manipulation of human, animal and plant genomes open the door to a new era in which life itself becomes the ultimate manipulable commodity. The biotech era is beginning to raise fundamental questions about the nature of human nature, and the public is quickly being swept up in a great debate between those who view the new age as a biological renaissance and others who warn of the coming of a commercial eugenics civilization.[534]

The key question is: will the rich people of 2030 consider using genetic engineering when planning to have a child? And I don't just mean young wealthy people – I also mean older wealthy people. Rejuvenation techniques will make the 70 year-olds of 2030 look like 30 year-olds and, with a much-extended life expectancy. And with medical advances already allowing mothers to give birth in their sixties,[535] how many older couples will start to plan new families?

At first prospective parents will have their embryos screened to weed out any which carry genes predictive of future disease and they will almost certainly select the sex of their unborn child in this way. The ethicist and philosopher Nick Bostrom considered this matter in his 2006 paper 'Cognitive Enhancement: Methods, Ethics, Regulatory Challenges,':

> Some enhancements do not increase the capacity of any existing being but rather cause a new person to come into existence with greater capacities than some other possible person would have had who could have come into existence instead. This is what happens in embryo selection. At present, preimplantation genetic diagnosis is used mainly to select out embryos with genetic disease, and occasionally for the purpose of sex selection. In the future, however, it might become possible to test for a variety of genes known to correlate with desirable attributes, including cognitive capacity. Genetic engineering might also be used to remove or insert genes into a zygote or an early embryo. In some cases, it might be unclear whether the outcome is a new individual or the same individual with a genetic modification.[536]

The problem comes when medicine starts to offer the possibility of genetic manipulation to make the prospective child grow taller, be more handsome or beautiful, more musically gifted or have a greater intellect. This is not yet possible in 2007, but by 2030 it almost certainly will be and whether or not such 'treatment' is being offered in the developed world will depend upon each nation's legislation and regulation of the science.

It is tempting to believe that today's widespread natural repugnance at the concept of 'designer babies' will still be the cultural norm in twenty-five years time. But futurologists learn that public opinion can sometimes change quickly, dramatically and in unexpected ways. For example, I recall describing what we now know as 'the surveillance society' to a British audience in the early 1980s. There was uproar and, almost to a person, the audience members were appalled at such a 'Big Brother' idea and all were certain that such a thing would never be tolerated in the UK. Today, although there are many vociferous critics of our mushrooming surveillance infrastructure, the vast majority of people in Britain are entirely content to be watched over. It is not even an issue for any of the major political parties.

So it could be with genetic engineering and human enhancements. At first the science will show the huge benefits in eradicating disease and preventing it from occurring. The advantages offered will be clear and the procedure simple. For example, as The Times reported in 2007:

> A pill that can correct a wide range of faulty genes which cause crippling illnesses should be available within three years, promising a revolution in the treatment of thousands of conditions.

> The drug, known as PTC124, has already had encouraging results in patients with Duchenne muscular dystrophy and cystic fibrosis. The final phase of clinical trials is to begin this year, and it could be licensed as early as 2009.[537]

As such gene-based and gene-focused treatments become accepted across society doctors, parents and scientists may begin introducing improvements to the germline that society perceives as beneficial – for example, one study has shown the increase in income from only a single additional IQ point to be 2.1 per cent for men and 3.6 per cent for women![538] So even relatively small increases in mental performance will have a huge impact on how well a child will do in life, and if a nation state were to consider the economic impact of a collective rise in national IQs… well, thankfully, that's something only a totalitarian state would contemplate.

More mundanely these 'enhancements' could also include screening embryos against colour blindness, tone deafness and other 'defects' not normally considered diseases. From there it is a small step to making human enhancements.

Imagine two successful painters – visual artists – planning to have their first child, a girl. 'Shall we improve her colour vision, darling?' would be a very hard suggestion to turn down. And, as research published in March 2007 suggests, 'an almost instantaneous upgrade' to human perception of colour may become available:

> Although mice, like most mammals, typically view the world with a limited color palette – similar to

> what some people with red-green color blindness see – scientists have now transformed their vision by introducing a single human gene into a mouse chromosome. The human gene codes for a light sensor that mice do not normally possess, and its insertion allowed the mice to distinguish colors as never before.[539]

Because genetic manipulation of the embryo affects the rights of unborn children, legislation and regulation will ensure that these rights are protected. It is impossible to know what these laws will mandate in 2030 but, whether or not genetic enhancement of embryos is banned in a given country, some prospective parents will use other, less strict, jurisdictions to design babies to their liking. It is human nature.

Nick Bostrom explains how a future society might regard the whole issue of human enhancement:

> For example, in addition to the gap between the rich and the poor, there is also a gap between the cognitively gifted and the cognitively deficient. One scenario might be that the wealth gap increases at the same time as the talent gap decreases because it is generally easier to enhance individuals at the low end of the performance spectrum than those at the high end (whose brains are already functioning close to their biological optimum). This could add a degree of complexity that is often overlooked in the ethical literature on inequality. One should also have to consider under what conditions society might

> have an obligation to ensure universal access to interventions that improve cognitive performance. An analogy might be drawn to public libraries and basic education.[540]

Rejuvenation and Longevity

If the unborn children of 2030 will be protected from genetic enhancement by law, there will be nothing to stop consenting adults from seeking to medically enhance or rejuvenate themselves.

By 2030 stem cell medicine[541] will be mature and widely practised. A 'stem cell' is an early stage human cell which retains the ability to grow into any type of human cell – a heart cell, a brain cell, a skin cell, etc. These properties are now being exploited to grow replacement parts and organs for humans.

In 'Extreme Future' James Canton listed some of the benefits expected from stem cell medicine by 2030:

- New organs, including hearts and lungs
- New bone growth for legs, arms and backs
- New sensory functions and optic nerves to restore eyesight
- New cancer treatments
- New nerves to heal muscles and to restore movement
- New cells to offset the aging brain[542]

Significant progress in stem cell medicine is already being made and development is increasingly rapid. As MIT Technology Review reported in May 2007:

> An efficient new method to generate what appears to be a novel type of stem cell could be a boon to diseases linked to lack of blood flow. Scientists in Massachusetts and Florida have developed a way to coax embryonic stem cells into a more adult form of stem cell that has the potential to form blood vessels. The new type of cells helped repair tissue in animals that had had heart attacks or eye damage due to diabetes.[543]

And in July 2007 The Toronto Star carried the following story:

> A landmark discovery by researchers at McMaster University could radically alter the way scientists can use embryonic stem cells to grow replacement tissues and treat cancer.
>
> In a surprise revelation, a McMaster study found that human embryonic stem cells – 'the great grandmothers' of all the other cells in our bodies – build themselves a nurturing cocoon that feeds them and directs their ability to transform into other types of tissues.
>
> And by manipulating the products of this tiny, cellular placenta, it may be possible for scientists to prompt the stem cells to grow into desired tissues and organs, or to switch off tumour growth in cancers.[544]

It is the potential of stem cell medicine (coupled with the potential of molecular nanotechnology) that turns some otherwise quite level-headed futurists into the modern equivalent of ancient Egyptian Pharaohs lusting for immortality. For example, the developing ability to practise medicine at the nano-scale[545] coupled with stem cell technology holds out amazing promise. As 'The Project on Emerging Nanotechnologies' (a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts) suggests on its website:

> Imagine a world where damaged organs in your body – kidneys, liver, heart – can be stimulated to heal themselves. Envision people tragically paralyzed whose injured spinal cords can be repaired. Think about individuals suffering from the debilitating effects of Parkinson's or Alzheimer's relieved of their symptoms – completely and permanently.
>
> In a dramatic demonstration of what nanotechnology might achieve in regenerative medicine, paralyzed lab mice with spinal cord injuries have regained the ability to walk using their hind limbs six weeks after a simple injection of a purpose-designed nanomaterial.[546]

Nanomedicine and stem cell treatments hold out huge hope for the disabled as well as for those less needy individuals who seek to extend their natural life-spans. It is to be hoped that the money being spent by those who wish to rejuvenate themselves and 'live forever' drives forward the research that develops cures for the paralysed and those suffering from what in 2007 are still intractable diseases.

Man's Transhuman Future

As I suggested in the previous section, 'Daily Life in 2030', within twenty-five years humans will be connecting themselves directly to the 'super-web' via neural interfaces, body-mounted nano-scale computers and monitoring systems. Many of us will have virtual assistants – software personalities – who are our constant companions and helpmates.

But even as we take technology onto and into our bodies we will have begun to alter our own biology using genetic engineering, stem cell research and nanomedicine – changing what it means to be human. 'Transhuman' and 'transhumanism' are the terms that have already been proposed to describe the new type of augmented and enhanced human that will begin to emerge well before the year 2030. Wikipedia explains the concept as follows:

> Transhumanism (sometimes abbreviated >H or H+) is an international intellectual and cultural movement supporting the use of new sciences and technologies to enhance human mental and physical abilities and aptitudes, and ameliorate what it regards as undesirable and unnecessary aspects of the human condition, such as stupidity, suffering, disease, ageing and involuntary death.[547]

Of course, these increasingly enhanced and augmented transhumans will be occupying a planet on which super-intelligent machines will recently have emerged. The two new forms of entity are almost certain to get together and some futurists are already talking about sexual and romantic attachments between humans and computer personalities.

Whatever the relationships between augmented humans and their robot companions, it is clear that much longer life-spans are almost certain for us and, particularly, for our children. In his 1993 paper 'The Coming Technological Singularity: How to Survive in the Post-Human Era' Vernor Vinge makes the following observation about extreme-longevity:

> A mind that stays at the same capacity cannot live forever; after a few thousand years it would look more like a repeating tape loop than a person. To live indefinitely long, the mind itself must grow ... and when it becomes great enough, and looks back ... what fellow-feeling can it have with the soul that it was originally? Certainly the later being would be everything the original was, but so much vastly more.[548]

But before peering into the longer-distance future it is worth taking a reality check about the likely nature of life in 2030. The vast majority of people in the world at that time will still be struggling to make a living and feed their families. Technology development and globalisation (if that globalisation has been ethically and sustainably pursued) will have lifted many additional millions of people out of abject poverty, but for most humans on the planet life will be conducted much as it is today, albeit it with far better communications and improved healthcare.

Beyond 'The Singularity' (which is likely to occur at some point around 2030), however, life will be very different for wealthy people in the developed nations. It is virtually impossible to predict what might be possible once we have computers that are substantially cleverer than human beings (and once they start demanding rights for themselves).

In his 2007 book 'Beyond AI: Creating the Conscience of the Machine', Dr. Storrs Hall makes an attempt at predicting some of the capabilities that such an artificial intelligence (AI) would have (an 'epihuman' is a machine with a capability just above human level, a 'hyperhuman' is an artificial intelligence significantly smarter than human level):

> Imagine an AI that is a thousand epihuman AIs, all tightly integrated together. Such an intellect would be capable of substantially outstripping the human scientific community at any given task and of comprehending the entirety of scientific knowledge as a unified whole. A hyperhuman AI would soon begin to improve itself significantly faster than humans could. It could spot the gaps in science and engineering where there was low-hanging fruit and instigate rapid increases in technological capability across the board.
>
> It is as yet poorly understood even in the scientific community just how much headroom remains for improvement with respect to the capabilities of current physical technology. A mature nanotechnology, for example, could replace the entire capital stock – all the factories, buildings, roads, cars, trucks, airplanes, and

> other machines – of the United States in a week. And that's just using currently understood science, with a dollop of engineering development thrown in.[549]

How might humans react to the arrival of such intelligence, such super-capability on Earth? Quite simply, we don't and can't know.

In the longer term I suspect, as I have for over forty years, that enhanced human beings and super-computer intelligence will merge to become a new species that will become our successors, a new non-biological species which will finally be able to spread out and colonise the solar system and, eventually, the universe.

I don't see the super-intelligent computer personalities of the future as being terrifyingly alien beings, but as a natural product and extension of ourselves. They will indeed be our children.

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