Lord Speaker, Lords, Ladies and Gentlemen

It's a privilege to give this lecture — and I'd like to express admiration for Peter Hennessy, who's the moving spirit behind it.

We're at a juncture when the adage 'a week is a long time in politics' seems truer than ever. But I'll try to direct your gaze towards 2050. Even politicians need this perspective: decisions made now on our nation's infrastructure resonate that far ahead; the younger people here will still be drawing pensions more than 50 years from now.

Many in the House of Lords have though longer and harder about the 21st Century than I have. For instance, Chris Patten's recent book entitled 'What Next? Surviving the 21st Century' can be thoroughly recommended

Indeed, one of the Lord Speaker's predecessors ventured into such speculations. Lord Birkenhead (F.E. Smith) , Tory Lord Chancellor in the 1920s and crony of Churchill, published a book in 1930, entitled 'The World in 2030′. He'd soaked up the futurology of Wells, Haldane, and Bernal; he described human embryos being reared in flasks, and suchlike. But he was entrenched in the social mindset of his class and his time — especially regarding female emancipation:

'In 2030 women will still …… by their wit and charms, direct the activities of the most able men towards heights which they could never themselves hope to achieve'

We didn't have to wait till 2030 for a Margaret Thatcher! Nor for women on the Woolsack. The past record of scientific forecasters is dismal. Lord Rutherford averred that nuclear energy was moonshine; Thomas Watson, founder of IBM, thought there might be a world market for 5 computers; and one of my predecessors as Astronomer Royal said space travel was utter bilge. I won't add to this inglorious roll-call.

And in science, the most transformational advances, the real qualitative leaps, are hardest to predict. A still earlier Lord Chancellor, Francis Bacon realised this 400 years ago, adducing gunpowder, silk and the mariners' compass as examples.

Social changes are even harder to predict (though some have done better than Lord Birkenhead). We don't know what the social and geopolitical backdrop for people's lives in 2050 will be.

But there's one trend we can predict with confidence. There will then, barring a global catastrophe, be far more people on the Earth than today. Fifty years ago the world population was below 3 billion. It has more than doubled since then, to 6.7 billion today. And it's projected to reach 9 billion by 2050. By then, it will be in Asia — not Europe nor the US — where the world's physical and intellectual capital will be concentrated In most countries, fertility has now fallen below replacement level — the average woman has less than one female child. We all know the social trends that lead to this demographic transition — declining infant mortality, availability of contraceptive advice, women's education, and so forth. If the transition quickly extended to all countries, then the global population could start a gradual decline after 2050 — a development that
would surely be benign.

But the demographic transition hasn't occurred in Africa, where there could be a billion more people in 2050 than there are today. In 1950, Europe had 3 times the population of Africa. In 2050, Africa will have 3 times Europe's. That's where most of Paul Collier's 'bottom billion' now live — trapped in poverty. (It's good news in this context, incidentally, that the US has now reversed the Bush administration's constraints on support of family planning initiatives in Africa.)

Today's population couldn't be fed by yesterday's agriculture. A second green revolution may be needed to feed tomorrow's population. Failure to

achieve this would be a tragedy of continental proportions. It would also be a trigger for massive migration — from Africa into Europe — of unskilled people motivated by desperation.

The challenge of feeding a growing population is aggravated by climate change.

And a second firm prediction about 2050 is that the world will then be warmer than today. The consequent shifts in weather patterns (and rising sea levels) impact most greviously on those least able to adapt, and on countries that have themselves contributed minimally to global CO2 emissions.

The consensus on the science underlying climate change has firmed up: there are fewer ‘deniers’ and fewer ‘Day after Tomorrow’ doomsters.

To my mind, the debate about how much warming has already happened is secondary. The two key points are these:

First, it’s undeniable that the measured CO2 concentration has been rising for the last 50 years, is higher than it’s been for the last half million years, and is projected to reach around twice the pre-industrial level by 2050.

Second, it’s also incontroversial that carbon dioxide is a greenhouse gas — this was recognised by Sir John Tyndall 150 years ago.

Those two facts alone would in my view justify precautionary action – though we now of course have far more detailed models, codified in the IPCC reports.

Just today, incidentally, the Hadley Centre has taken a big step forward by publishing a range of predictions for the UK climate which for the first time have spatial resolution that’s fine enough to be useful to local planners. But the science, though intricate, is a doddle compared to the politics and economics of climate change — for two reasons.

Unlike more familiar pollution, any effective ‘polluter pays’ regime must be global. That’s because emissions from the UK and from Australia have the same effect.

And a second feature of global warming is the time-lag: the effects of enhanced CO2 aren’t immediate, but take decades to fully manifest themselves.

Nick Stern’s 2006 report argued that all developed nations should commit substantial resources now, to pre-empt much greater costs in future decades — and that equity to future generations renders a ‘commercial’ discount rate quite inappropriate.

There are of course precedents for long-term altruism in public policy. Indeed, in discussing the safe disposal of nuclear waste, experts talk with a straight face about what might happen more than 10000 years from now, thereby implicitly applying a zero discount rate. To concern ourselves with a remote ‘post-human’ era might seem bizarre. But history will surely judge us harshly if we discount too heavily what might happen when our grandchildren grow old. We’re mindful (especially in these historic surroundings ) of the heritage we owe to centuries pastm and should surely plan a century ahead.

As a digression, let me recall the Thames Barrier. This great project was advocated by a committee set up after the East Coast floods by a committee was chaired by Sir Hermann Bondi. Bondi was a cosmologist — but, more relevantly, he was a brilliant and persuasive man. A really catastrophic flooding of central London was expected much less than once per century. But such an event would cause damage of tens of billions of pounds — so huge that it was worth building the barrier even though it may never be needed (In fact, of course, it has been used repeatedly and has probably prevented minor damage. Moreover, climate change increases the risk so we’re even more glad to have the barrier.)

The debate that led to the barrier was a micro and localised version of the global issue that confronts us today.

It's still uncertain just how sensitive the climate is to the CO2 level, and what parts of the world will be affected most. What should make us specially anxious is the significant probability of a really drastic climatic shift — of triggering a grave and irreversible global trend: rising sea levels due to the melting of Greenland's icecap; runaway release of methane in the tundra, and so forth. The target espoused by the G8+ 5 is to reduce global CO2 emissions, by 2050, to half the 1990 level. This target corresponds to two tons of CO2 per year from each person on the planet. For comparison, the current US level is 20, the European figure is about 10, and the Chinese level is already 4 and the Indian 1.5. To achieve the global target without stifling economic growth is a huge challenge.

It's urgent to develop 'cleaner' and more efficient technology soon enough that the Asian per capita emissions never need to rise to ours, and ours go down to converge towards theirs. We in the UK have enshrined this target in the Climate Change Act

We can get part of the way with present technology. Indeed the UK can cut emissions substantially by measures that actually save money (energy-efficient buildings, for instance).

But to achieve an 80 percent cut by 2050, present technology isn't enough. R and D in energy should be funded –both publicly and privately — on the same scale as R and D in health and medicine. It's still far too low, worldwide.

I can't think of anything that could do more to attract the brightest and best into science than a strongly proclaimed goal to provide clean energy for the developing and the developed world. In the US, President Obama has done just this — he's appointed a dream team of science advisors, and declared

that energy R and D should have the same national priority that the Apollo programme had in the 1960s.

(Unless we in the UK respond to Obama's stimulus package, incidentally, there's a real risk that we'll lose our standing as one of the most attractive countries to mobile talent — a standing that we've acquired thanks to this government's genuine commitment to science over the last decade. )

The UK consumes only around 2 percent of the world's energy. We can't substantially abate global warming by cutting back our own emissions.

But we can exert disproportionately larger leverage on the world's climate by innovation. The UK has the expertise to spearhead the technologies the world needs, and it's in our economic interest to do so.

What are the 'clean energy' options?

Carbon capture and storage (CCS) is crucial. Coal, oil and gas seem set to dominate the world's every-growing energy needs for at least 30 years. Last year the Chinese built 100 coal-fired power stations. . Full-scale demonstrations at CCS at electric power plants can be delivered before 2020 if we start now.

And the UK could lead in wave and tidal energy. We have the geography — capes round our coast with fast-flowing tidal currents, and we have marine technology from the North Sea oil and gas.

And there's biofuels. There's rightly been ambivalence about first generation biofuels. But the prospects for converting cellulose, or intensively culture marine algae requires further investigation. Beyond that, genetic technology, where we're strong, may have a lot to offer.

Another need is for improved energy storage — lithium batteries and super-capacitors — for transport, and to smooth over peaks and troughs in

demand, and to complement unsteady power sources such as sun and wind.

What is the role of nuclear power in all this? I'd myself favour the UK having at least a replacement generation of power stations — and boosted R and D into 'fourth generation' reactors. But the non-proliferation regime is fragile, and before being relaxed about a world-wide programme of nuclear power, one would surely require the kind of fuel bank and leasing arrangement that has been proposed by the IAEA.

And nuclear fusion deserves to remains an important area of research that could have long-term potential.

But my favoured long-term bet for Europe is solar energy — huge collectors in the Sahara generating power that's distributed via a pan-European smart grid, Achieving this will require vision, commitment and public-private investment on the European Level.

I'm confident that the UK can, by 2050, develop a low-carbon economy which meet our 80 percent targets, and could enhance rather than impede our growth or quality of life, and give us energy security.

And politically we have leverage too. Through the UK's example and international leadership — at Gleneagles and thereafter — we have the credentials to exert substantial impact at the Copenhagen conference in December.

Any Copenhagen deal that's equitable and realistic will involve a transfer of funds from the developed to the fast-developing nations. These are estimated as 1 or 2 percent of the GNP for the developed world.

That seems manageable. But I admit to some worries. We're aware of the underfunding of overseas aid — below the UN's 0.7 percent target – and the failure to meet the Millennium Goals, despite the clear humanitarian imperative. This augers badly for the actual implementation of the measures

needed to meet the 2050 carbon emission targets where the payoff is less immediately apparent.

Some pessimists argue that the international community should, as a fallback, contemplate a ‘plan B’ — being fatalistic about the rise in CO2, but intervening to combat its warming effects by (for instance) putting aerosols in the upper atmosphere, or even vast sunshades in space. The Royal Society is studying some of these ideas at the moment. Such ‘geoengineering’ would not “solve” climate change –it would at best buy time, probably at inordinate cost. But if carbon abatement measures haven’t worked by 2050, I would expect geoengineering to be high on the agenda — though it would be yet another issue for international disputes and contention.

Some years ago I wrote a book which I entitled ‘Our Final Century?’ The publishers removed the ‘?’. The US publishers retitled the book as ‘Our Final Hour’ — Americans want instant (dis)gratification. The book addressed the issues I’ve just discussed — emphasising that this is the first century when the actions of one species — ours — can determine the planet’s future.

Human activities are severely ravaging the biosphere — by rapid changes in and use and deforestation. We’ve entered a new geological era — the anthropocene. There have been 5 great extinctions in the geological past; We’re causing a 6th. The extinction rate is 1000 times higher than normal, and increasing. We are destroying the book of life before we have read it.

Biodiversity — manifested in forests, coral reefs, and all Earth’s other ecosystems — is often proclaimed as a crucial component of human wellbeing and economic growth. It manifestly is: we’re clearly harmed if fish stocks dwindle to extinction; there are plants whose gene pool might be useful to us. And massive destruction of the rain forests would accelerate global warming. But for environmentalists these ‘instrumental’ — and anthropocentric — arguments aren’t the only compelling ones. For them,

preserving the richness of our biosphere has value in its own right, over and above what it means to us humans.

Overall, our lives are getting safer and healthier. In our everyday lives, we have a confused attitude to risk. We fret about traces of carcinogens in food, a one-in-a-million chance of being killed in train crashes, and so forth. But we're in denial about others that should loom much larger.

For instance, infectious diseases are a growing hazard. A global pandemic could kill tens of millions and cost many trillions of dollars. If we apply to pandemics the same prudent analysis that leads us to buy insurance — multiplying probability by consequences — we'd surely conclude that measures to alleviate this kind of extreme event need higher priority. And effective prevention and early warning has to be a fully international endeavour. Whether or not a pandemic gets global grip may hinge on how quickly a Vietnamese poultry farmer can diagnose or report any strange sickness.

In the coming decades there will be an 'arms race' between ever-improving preventative measures, and the growing virulence of the pathogens that could plague us — the latter augmented by risks of 'bioerror' or 'bioterror'. The spread of epidemics is aggravated by rapid air travel, plus the huge concentrations of people in megacities with fragile infrastructures.

And in our ever more interconnected world, there are new concerns. We're all precariously dependent on elaborate networks — electricity grids, air traffic control, the internet, just-in-time delivery and so forth. It's crucial to optimise the resilience of all such system.

In a future era of vast individual empowerment by bio-, cyber-, or nano-technology, where even one malign act would be too many, there are new reasons for concern.

. We're kidding ourselves if we think that technical expertise is always allied with balanced rationality: it can be combined with fanaticism –not just the traditional fundamentalism that we're so mindful of today, but new age irrationalities. I'm thinking of the Raelians, extreme eco-freaks, violent animal rights campaigners and the like. The global village will have its village idiots.

Overall, our world may now be safer. But something has changed. The 'old' risks were localised. If a boiler explodes, it's horrible but there's an 'upper bound' to just how horrible. In our ever more interconnected world, there are new risks whose consequences could be so widespread that even a tiny probability is disquieting.

Let me now inject some optimism — some good news. Obviously, health care is improving at a global level — indeed there's been a welcome rebalancing of effort. Traditionally the focus was on diseases of the rich — cancer and cardiovascular disease. But tropical diseases are now receiving more attention — and that's thanks largely to the Bill and Melinda Gates foundation.

And, mindful of where Bill Gates's money came from, let's recall that the silicon chip was perhaps the most transformative single invention of the last century. It's allowed miniaturisation, spawned worldwide reach of mobile phones and internet — promoting economic growth — while being sparing of energy and resources. Indeed, these developments surprise us by their rapidity — iPhones would have seemed magic 30 years ago.

Another safe prediction, I think, is that computer networks will continue to become ever more powerful and pervasive. Each mobile phone today has far more computing power than the whole of NASA had for the Apollo programme. If advances continue at the same pace, computers will by 2050 achieve human capabilities. Of course, in some respects they already have. The most basic pocket calculators can hugely surpass us at arithmetic. IBM's 'Deep Blue' beat Kasparov, the world chess champion.

But not even the most advanced robot can recognise and move the pieces on a real chessboard as adeptly as a five year old child – there's a long way to go before interactive human level 'robotic intelligence' is achieved. But when that happens, everyone's lifestyle and work patterns will surely be transformed.

(For scientists, incidentally, some kind ot mental prosthetics may become essential. A unified theory of physics, or a theory of consciousness, might be beyond the powers of unaided human brains, just as surely as quantum mechanics would flummox a chimpanzee.)

Another speculation — a real 'wild card' in population projections — is that the human lifespan could be greatly extended. Indeed some Americans, worried that they'll die before this nirvana is reached, bequeath their bodies to be 'frozen' on their death, hoping that some future generations will resurrect them or download their brains into a computer.

For my part, I'd still opt to end my days in an English churchyard rather than a Californian refrigerator.

But flaky futurologists aren't always wrong. I tell my students that they'll derive more stimulus from first-rate science fiction than from second rate science. We should keep our minds open, or at least ajar, to concepts on the fringe of science fiction. In this century, novel mind-enhancing drugs, genetics, and 'cyborg' techniques may start to alter human beings themselves. The posthuman era may beckon.

But, coming back onto firmer ground, I'd make one generic forecast that's important for parliamentarians. There will surely be a ever-widening gulf between what science enables us to do, and what applications it's prudent or ethical actually to pursue — more doors that science could open but which are best kept closed.

Opinion polls show a positive attitude towards scientists. They're among the most trusted professions — just below doctors and clergy. And way above other callings that it might be ungracious to specify here. But there's anxiety that science may 'run away' faster than we can
properly cope with it.

Scietists have an obligation to engage with policy-makers, and decisions need to be based on the best scientific advice. As President Obama acknowledged, such advice should be heeded "even when it is inconvenient — indeed especially when it is inconvenient" .

But such decisions — whether about energy, GM technology, stem cells, mind-enhancing drugs or whatever — are never solely 'scientific': strategic, economic, social, and ethical ramifications enter as well. And here scientists have no special credentials.

Everyone deserves to have a voice on issues like: Should we build nuclear power stations — or windmills? Should the law allow 'designer babies'? How much should computers take over our lives? What's the right tradeoff between surveillance and privacy?

But for public debate to get above the level of tabloid slogans, citizens all need a 'feel' for science and a realistic attitude to risk.

And that's not an unrealistic aim . Science seems forbidding because of the technicalities and jargon. Specialists need to master these — but it's the key ideas, not the details, that matter for everyone else. And I believe these can — if scientists make the effort to communicate well — be made accessible to everyone

These key ideas matter if one's to be a responsible citizen. But I'd like to conclude by speaking as a scientist — and to assert that they matter for another reason: they're part of our culture.

Indeed science is the one truly universal culture. Protons, proteins and Pythagoras's theorem are the same from China to Peru. All races throughout human history have gazed up at the same night sky and wondered at it .

It's an intellectual impoverishment not to appreciate the panorama offered by modern cosmology and Darwinism — the chain of emergent complexity leading from some still-mysterious beginning to atoms, stars, planets, biospheres and brains able to ponder the mystery of it all. This common vision should transcend all differences of nationality and faith — and give us all a cosmic perspective.

40 years ago, the Apollo 10 astronauts, orbiting the Moon, saw and photographed our planet rising above the lunar horizon, its delicate biosphere contrasting with the sterile moonscape where Neil Armstrong took his 'first small step'.

This image of 'spaceship Earth' has become iconic for environmentalists. I'd like to offer a cosmic vignette inspired by it. Suppose some aliens had been watching our planet for its entire history, what would they have seen? Over nearly all that immense time, 45 million centuries, Earth's appearance would have altered very gradually. The continents drifted; the ice cover waxed and waned; successive species emerged, evolved and became extinct.

But in just a tiny sliver of the Earth's history — the last one millionth part — the patterns of vegetation altered much faster than before. This signalled the start of agriculture. The pace of change accelerated as human populations rose.

Then there were other changes, even more abrupt. Within just one century, the carbon dioxide in the atmosphere began to rise anomalously fast. The planet became an intense emitter of radio waves (the total output from all TV, cellphone, and radar transmissions.) And something else unprecedented happened: small projectiles launched from the planet's surface and escaped

the biosphere completely. Some were propelled into orbits around the Earth; some journeyed to the Moon and planets.

If they understood astrophysics, the aliens could confidently predict that the biosphere would face doom in a few billion years when the Sun flares up and dies. But could they have predicted this unprecedented sudden fever — less than half way through the Earth's life — these human-induced transformations seemingly occurring with runaway speed?

If they continued to keep watch, what might these hypothetical aliens witness in the next hundred years? Will a final spasm be followed by silence? Or will the planet itself stabilise? And will some of the objects launched from the Earth spawn new oases of life elsewhere?

What actually happens — our planet's fate — will depend on whether science is applied wisely.

And (to focus finally closer to home) so will this nation's prosperity and security.

We don't know what will be the 21st century counterparts of the electron, quantum theory, the double helix and the computer — nor where the great innovators of the future will get their formative training and inspiration. But one thing seems clear: The UK's standing depends on sustaining our competitive edge as discoverers and innovators — on ensuring that some of the key creative ideas of the 21st century germinate and — even more – are exploited here in the UK.