Address delivered by Lord Rees of Ludlow, OM in the House of Lords
27 February 2019

ON THE FUTURE: TECHNOLOGY AND ENVIRONMENTAL STRESSES IN 2050 AND BEYOND

A few years ago, I met a well-known tycoon from India. Knowing I had the English title of 'Astronomer Royal.' He asked, "do you do the Queen's horoscopes?" I responded, with a straight face: "If she wanted one, I'm the person she'd ask." He seemed eager to hear my predictions. I told him that stocks would fluctuate, there would be new tensions in the Middle East, and so forth. He paid rapt attention to these 'insights'. But then I came clean. I said I was just an astronomer—not an astrologer. He abruptly lost all interest in my predictions. And rightly so—scientists are rotten forecasters—almost as bad as economists.

Nor do politicians and lawyers have a sure touch. One rather surprising futurologist was F. E. Smith, Earl of Birkenhead, crony of Churchill and Lord Chancellor in the 1920s. In 1930 he wrote a book titled *The World in 2030*.[i] He'd read futurologists of his era like Wells and JBS Haldane'; he envisaged babies incubated in flasks, flying cars, and such fantasies.

In contrast, he foresaw social stagnation. Here's a quote:
'*In 2030 women will still, by their wit and charms, inspire the most able men towards heights that they could never themselves achieve'.*

Enough said!

I'll make a few predictions, but very tentatively. They will draw on my recently-published book "On the Future: Prospects for Humanity" where I try offer a balance between scientific optimism and political pessimism

The theme is this:
Our Earth has existed for 45 million centuries. But this century is special: it's the first when one species, ours, has the planet's future in its hands. We're deep in the anthropocene. We could irreversibly degrade the biosphere -- or misdirected technology could cause a catastrophic setback to civilization. But there would be the capability to provide a bright and sustainable future.

Bio, cyber, robotics and space all offer huge potential benefits but also expose us to novel vulnerabilities. I'll address these in my second part of my talk – though they're hard to predict even twenty years ahead.

But before that let's focus on two things we can predict even with a cloudy crystal ball: the world in 2050 will be more crowded -- and it will be warmer.

Fifty years ago, world population was about 3.5 billion. It's now about 7.7 billion. The growth's been mainly in Asia and Africa. The number of births per year, worldwide, peaked a few years ago and is going down, nonetheless world population is forecast to rise to around 9 billion by 2050. That's partly because most people in the developing world are young. They are yet to have children, and they will live longer. The age histogram in the developing world will become more like it is in Europe.

Population growth seems underdiscussed. That's partly, perhaps, because doom-laden forecasts by for instance, the Club of Rome— proved off the mark. Also, some deem population growth to be a taboo subject—tainted by association with eugenics in the 1920s and '30s, with Indian policies under Indira Gandhi, and more recently with China's hard-line one-child policy. As it's turned out, food production and resource extraction have kept pace with rising population; famines still occur, but they're due to conflict or maldistribution, not overall scarcity.

To feed 9 billion in 2050 will require further-improved agriculture – low-till, water-conserving, and GM crops – and maybe dietary innovations: converting insects—highly nutritious and rich in proteins—into palatable food; and making artificial meat.

To quote Gandhi – enough for everyone's need but not for everyone's greed.

By mid-century, Africa will have 5 times Europe's population – Lagos and other megacities could have populations

around 40 million. Moreover, if families in Africa remain large, then according to the UN that continent's population could double again by 2100, to 4 billion, thereby raising the global population to 11 billion. Nigeria alone would by then have as big a population as Europe and North America combined. .

Optimists say that each extra mouth brings two hands and a brain. But it's the geopolitical stresses that are most worrying. As compared to the fatalism of earlier generations, those in poor countries now know, via internet, etc, what they're missing. And migration is easier. However, the advent of robots, and 'reshoring' of manufacturing, mean that still-poor countries won't be able to grow their economies by offering cheap skilled labour, as the Asian Tiger states did. It's a portent for disaffection and instability – multiple mega versions of the tragic boat-people crossing the Mediterranean today.

Wealthy nations, especially those in Europe, should urgently promote growing prosperity in Africa, and not just for altruistic reasons.

And another thing: if humanity's collective impact on land use and climate pushes too hard, the resultant 'ecological shock' could cause mass extinctions– we'd be destroying the book of life before we've read it.

Already, there's more biomass in chickens and turkeys than in all the world's wild birds. And the biomass in humans, cows and domestic animals is 20 times that in wild mammals.

Biodiversity is a crucial component of human wellbeing. We're clearly harmed if fish stocks dwindle to extinction; there are plants in the rain forest whose gene pool might be useful to us. And insects are crucial for the food chain and fertilization. But for many environmentalists, preserving the richness of our biosphere has value, over and above what it means to us humans to quote the great ecologist E O Wilson 'mass extinction is the sin that future generations will least forgive us for'.

So the world's getting more crowded. And there's a second firm prediction: it will gradually get warmer. In contrast to population issues, climate change is certainly not under-discussed, though it is under-responded-to

The fifth IPCC report presents a spread of projections, for different assumptions about future rates of fossil fuel use. Moreover, it's still unclear how much the climatic effects of CO2 are amplified by associated changes in water vapour and clouds – that's a further uncertainty. And the need for urgent action was highlighted in the update published last October.

However, despite the uncertainties there are two messages that most would agree on:

1. Even within the next 20 years, shifts in weather patterns, and more extreme weather, will aggravate pressures on food and water, and enhance migration pressure.

2. Under 'business as usual' scenarios we can't rule out, later in the century, catastrophic warming, and tipping points triggering long-term trends like the melting of Greenland's icecap.

But even those who accept both these statements have diverse views on the policy response. These divergences stem from differences in economics and ethics -- in particular, in how much obligation we should feel towards future generations.

The Danish campaigner Bjorn Lomberg has bogyman status among environmentalists – somewhat unfairly, as he doesn't contest the science. But his 'Copenhagen Consensus' of economists downplays the priority of addressing climate change in comparison with shorter-term efforts to help the world's poor. That's because he applies a 'standard' discount rate – and in effect writes off what happens beyond 2050. But if you care about those who'll live into the 22nd century and beyond, then, as economists like Stern and Weitzman argue, you deem it worth paying an insurance premium now, to protect those generations against the worst-case scenarios.

So, even those who agree that there's a significant risk of climate catastrophe a century hence, will differ in how urgently they advocate action today. Their assessment will depend on expectations of future growth, and optimism about technological fixes. But, above all, it depends on an ethical issue – in optimizing people's life-chances, should we discriminate on grounds of date of birth?

(As a parenthesis, I'd note that there's one policy context when an essentially zero discount rate is applied – radioactive waste disposal, where the depositories are required to prevent leakage for 10000 years – somewhat ironic when we can't plan the rest of energy policy even 30 years ahead)

What will happen on the climate-policy front? The pledges made at the Paris conference are a positive step.

But politicians and won't gain much resonance by advocating unwelcome lifestyle changes now or a high carbon tax – when the benefits accrue mainly to distant parts of the world and are decades into the future.

Jean-Claude Juncker famously said in a different context "we know what to do, but we don't know how to get re-elected if we do it"

`But there's one 'win win' roadmap to a low-carbon future. Nations should accelerate R and D into all forms of low-carbon energy generation. And into other technologies where parallel progress is crucial – especially storage (batteries, compressed air, pumped storage, flywheels, etc.) and smart grids.

The faster these 'clean' technologies advance, the sooner will their prices fall so they become affordable to, for instance, India, where more generating capacity will be needed, where the health of the poor is jeopardized by smoky stoves burning wood or dung, and where there would otherwise be pressure to build coal-fired power stations.

Sun and wind are of course front-runners, but other methods have geographical niches. Geothermal power for instance, is readily available in Iceland; Harnessing tidal energy seems attractive where the topography induces especially large-amplitude tides. Britain's West Coast is one such place and there are proposals for tidal barrages or lagoons

Because of local intermittency we'll need continental-scale DC grids – carrying solar energy from Morocco and Spain to the less sunny Northern Europe, and east-west to smooth peak demand over different time-zones in North America and Eurasia – perhaps all the way along the Belt and Road to China.

.

And despite ambivalence about nuclear energy, it's surely worthwhile to boost R and D into a variety of 'Fourth Generation' concepts, which could prove to be more flexible in size, and safer. And the potential pay-off from fusion is so great that it is surely worth continuing experiments and prototypes.

It would be hard to think of a more inspiring challenge for young scientists than devising clean and economical energy systems for the world.

And, incidentally, in talking about 'science' I include technology and engineering. Indeed the latter are more challenging. My engineering friends like a cartoon that shows two beavers looking up at a vast hydroelectric dam. One says to the other 'I didn't actually build it but it's based on my idea'. Armchair theorists like me should be very modest compared to those who build things that work and meet public demand.

Let me turn now to other technologies.

We should be evangelists for new technology, not luddites – without it the world can't provide food, and sustainable energy, for an expanding .and more demanding population. But we need wisely-directed technology. Indeed, many of are anxious that it's advancing so fast that we may not properly cope with it. – and that we'll have a bumpy ride through this century.

We're ever more dependent on elaborate networks: electric-power grids, air traffic control, international finance, just-in-time delivery, globally-dispersed manufacturing, and so forth. Unless these networks are highly resilient, their manifest benefits could be outweighed by catastrophic (albeit rare) breakdowns that cascade globally -- real-world analogues of what happened in 2008 to the financial system.

Our cities would be paralysed without electricity. Supermarket shelves would be empty within days if supply chains were disrupted. Air travel can spread a pandemic worldwide within days. And social media can spread panic and rumour, and psychic and economic contagion, literally at the speed of light.

And, by the way, pandemics cause far more societal breakdown than in earlier centuries. English villages in the 14th century continued to function even when the black death halved their populations. In contrast, our societies would be vulnerable to serious unrest as soon as hospitals were overwhelmed– which would occur before the fatality rate was even one percent. (And there's likewise huge societal risk from cyber attacks on infrastructure, etc.)

Advances in microbiology -- diagnostics, vaccines and antibiotics -- offer prospects of containing pandemics. But the same research has controversial aspects.

For instance, in 2012 groups in Wisconsin and in Holland showed that it was surprisingly easy to make the influenza virus both more virulent and more transmissible – to some, this was a scary portent of things to come. In 2014 the US federal government decided to cease funding these so-called 'gain of function' experiments.

The new CRISPR-cas 9 technique for gene-editing is hugely promising, but there are already ethical concerns --- for instance, about Chinese experiments modifying embryos-- and anxiety about possible runaway consequences of 'gene drive' programmes to wipe out species – as diverse as mosquitos or grey squirrels.

Governments well surely adopt a stringent and precautionary attitude to biotech. But I'd worry that whatever regulations are imposed, on prudential or ethical grounds, can't be enforced worldwide – any more than the drug laws can --- or the tax laws. Whatever can be done will be done by someone, somewhere.

And that's a nightmare. Whereas an atomic bomb can't be built without large scale special-purpose facilities, Biotech involves small-scale dual-use equipment. Indeed, biohacking is burgeoning even as a hobby and competitive game.

We know all too well that technical expertise doesn't guarantee balanced rationality. The global village will have its village idiots and they'll have global range. The rising empowerment of tech-savvy groups (or even individuals), by bio as well as cyber technology will pose an intractable challenge to governments and aggravate the tension between freedom, privacy and security.

These concerns are relatively near-term – within 10 or 15 years. What about 2050 and beyond?
The smartphone, the web and their ancillaries – ubiquitous today -- would have seemed magic even just 25 years ago. So, looking several decades ahead we must keep our minds open, or at least ajar, to transformative advances that may now seem science fiction.

On the bio front we might expect two things. A better understanding of the combination of genes that determine key human characteristics --- and the ability to synthesis genomes that match these features. If it becomes possible to 'play God on a kitchen table' (as it were), our ecology (and even our species) may not long survive unscathed.

And what about another transformative technology: robotics and artificial intelligence (AI)?

Already AI can cope with complex fast changing networks -- traffic flow, or electric grids. It could enable the Chinese to gather and process all the information needed run an efficient planned economy that Marx could only dream of. And in science, its capacity to explore zillions of options could allow it to discover recipes for better drugs, or a material that conducts electricity with zero resistance at room temperature.

And Deep Mind's 'Alpha Go Zero' computer achieved world-championship level in the games of Go and Chess in just a few hours – it was given just the rules and learnt by playing against itself repeatedly. But it could complete several games every second.

And it's of course the speed of computers that allows them to succeed by 'brute force' methods. They learn to identify dogs, cats and human faces by 'crunching' through millions of images – not the way babies learn. They

learn to translate by reading millions of pages of multilingual text – EU documents for instance (their boredom threshold is infinite!).

The implications for our society are already ambivalent. If there is a 'bug' in the software of an AI system, it is currently not always possible to track it down; this is likely to create public concern if the system's 'decisions' have potentially grave consequences for individuals. If we are sentenced to a term in prison, recommended for surgery, or even given a poor credit rating, we would expect the reasons to be accessible to us—and contestable by us. If such decisions were delegated to an algorithm, we would be entitled to feel uneasy, even if presented with compelling evidence that, on average, the machines make better decisions than the humans they have usurped.

AI systems will become more intrusive and pervasive. Records of all our movements, our health, and our financial transactions, will be in the 'cloud', managed by a multinational quasi-monopoly. The data may be used for benign reasons (for instance, for medical research, or to warn us of incipient health risks), but its availability to internet companies is already shifting the balance of power from governments to globe-spanning conglomerates.

There will be other privacy concerns. Are you happy if a random stranger sitting near you in a restaurant or on public transportation can, via facial recognition, identify you, and invade your privacy? Or if 'fake' videos of you become so convincing that visual evidence can no longer be trusted? Or if a machine knows enough about you to compose e-mails that seem to come from you?

The 'arms race' between cybercriminals and those trying to defend against them will become still more expensive and vexatious when drones, driverless cars etc proliferate.

Many experts think that AI, like synthetic biotech, already needs guidelines for 'responsible innovation'. [Moreover, the fact that AlphaGo Zero achieved a goal that its creators thought would have taken several more years to reach has rendered DeepMind's staff even more bullish about the speed of advancement.] But others, like the roboticist Rodney Brooks (creator of the Baxter robot and the Roomba vacuum cleaner) think that for many decades we'll be less concerned about artificial intelligence than about real stupidity.

And machines are still clumsy compared to children in sensing and interacting with the real world.

Be that as it may, it's crucial to be aware of the burgeoning potential of artificial intelligence, even though we may worry more about the impacts of real stupidity.

The incipient shifts work has been addressed in several excellent books by economists and social scientists.

Clearly, machines will take over much of the work of manufacturing and retail distribution. They can replace many white-collar jobs: routine legal work, accountancy, computer coding, medical diagnostics, and even surgery. Many 'professionals' will find their hard-earned skills in less demand.

In contrast, some skilled service-sector jobs—plumbing and gardening, for instance—require non-routine interactions with the external world and will be among the hardest jobs to automate.

The digital revolution generates enormous wealth for an elite group of innovators and global companies but preserving a healthy society will surely require redistribution of that wealth. There is talk of using it to provide a universal income. It is better when all who are capable of so doing can perform socially useful work rather than receive a handout.

Indeed, to create a humane society, governments will need to vastly enhance the number and status of those who care for the old, the young and the sick. There are currently far too few, and they're poorly paid, inadequately esteemed, and insecure in their positions. Far more fulfilling than work in call centres or Amazon warehouses.

I can see this happening in Scandinavia, though there might be ideological barriers here.

Be that as it may, it's likely that society will be transformed by autonomous robots, even though the jury's out on whether they'll be 'idiot savants' or display superhuman capabilities.

Leading the gung-ho enthusiasts is the futurologist Ray Kurzweil. He wrote a book called 'The age of spiritual machines' where he predicted that humans would transcend biology by merging with computers. In old-style spiritualist parlance, they would 'go over to the other side'.

But Kurzweil is worried that his nirvana may not happen in his lifetime. So, he signed up with a company in Arizona that will freeze and store your body, so that when immortality's on offer you can be resurrected, or your brain downloaded.

I was surprised to find that three academics in England had gone in for these cryonics. Two have paid the full whack; the third has taken the cut-price option of wanting just his head frozen. I was glad they're from Oxford, not from my university.

I told them I'd rather end my days in an English churchyard than an American refrigerator.

But some think ageing is a 'disease that can be cured. More generally, it's surely credible that human mentality and physique may become malleable via genetic and cyborg technologies.

This is a game changer. When we admire the literature and artefacts that have survived from antiquity, we feel an affinity, across a time gulf of thousands of years, with those ancient artists and their civilizations. But we can have zero confidence that the dominant intelligences a few centuries hence will have any emotional resonance with us—even though they may have an algorithmic understanding of how we behaved.

And now I turn briefly to another technology – space. This is where robots surely have a future, and where I'll argue that these changes will happen fastest and should worry us less.

We depend every day on space for satnav, environmental monitoring, communication and so forth. Europe has a strong aerospace industry. ESA is fully a match for NASA in space science

During this century the whole solar system will be explored by swarms of miniaturized probes – far more advanced than the probes that have beamed back pictures of Saturn's moons, Pluto and beyond -- 20,000 times further away than the Moon)

Think back to the computers and phones of the 1990s, when these probes were designed, and realize how much better we can do today.

The next step will be the deployment in space of robotic fabricators, which can build large structures under zero gravity, – for instance, solar-energy collectors or giant telescopes with huge gossamer-thin mirrors.
What about manned spaceflight? The practical case gets ever-weaker with each advance in robots and miniaturization.

Were I an American I would only support NASA's un-manned programme. And I certainly wouldn't support a manned programme done by ESA. – I would argue that private-enterprise ventures -- bringing a Silicon Valley culture into a domain long-dominated by NASA and a few aerospace conglomerates -- should 'front' all manned missions. They can take higher risks than a western country can impose on publicly-funded civilian astronauts. There would still be many volunteers --- some perhaps even accepting 'one-way tickets' -- driven by the same motives as early explorers, mountaineers, and the like.

By 2100 courageous thrill-seekers may have established 'bases' independent from the Earth – on Mars, or maybe on asteroids. Elon Musk (aged 47) says he wants to die on Mars – but not on impact.

But don't ever expect mass emigration from Earth. Nowhere in our Solar system offers an environment even as clement as the Antarctic or the top of Everest. Here I disagree with Musk and my late colleague Stephen Hawking. It's a dangerous delusion to think that space offers an escape from Earth's problems. Dealing with climate change on Earth is a doddle compared to terraforming Mars. There's no 'Planet B' for ordinary risk-averse people.

But those pioneer adventurers who escape the Earth could be cosmically important. This is why. They'll be ill-adapted to their new environment; they'll be beyond the clutches of our terrestrial regulators. They will use all

the resources of genetics and cyborg technology to adapt – they will change faster and could within a few generations become a new species.

Let me conclude by focusing back closer to the here and now. My book emphasizes how our society is brittle, interconnected and vulnerable.

We fret unduly about small risks – air crashes. carcinogens in food, low radiation doses, etc. But we're in denial about some newly emergent threats that could be globally devastating. Some of these are environmental – the pressures of a growing and more demanding population. Others are the potential downsides of novel technologies.

A wise mantra is that 'the unfamiliar is not the same as the improbable'.

And of course, most of the challenges are global. Coping with potential shortage of food, water, resources -- and transitioning to low carbon energy --- can't be solved by each nation separately. Nor can threat reduction. Indeed a key issue is whether nations need to give up more sovereignty to new organizations along the lines of the IAEA, WHO, etc

Science is a universal culture, spanning all nations and faiths. So, scientists confront fewer impediments on straddling political divides. They owe it to their fellow citizens to maximize the societal benefits of their discoveries and minimize the downsides.

Universities have a special role as opinion-formers -- partly because they're full of young people who will live to the end of the century. And partly because they can use their staff's expertise, and their convening power, to assess which scary scenarios -- Eco threats, or risks from misapplied technology -- can be dismissed as science fiction and how best to avoid the serious ones.

Scientists have an obligation to offer their expertise directly to government, though they can often have more leverage indirectly -- by involvement with NGOs, via blogging and journalism, so that the public and the media amplify their voice.
Of course, no political decision is purely scientific – it involves economics and ethics and politics where scientists have no special expertise but are just engaged citizens.

Two recent instances:

Scientists in the Pontifical Academy provided input to the Papal encyclical Laudato Si – which had a world-wide influence in the lead-up to the Paris climate conference in 2015. There's no gainsaying the church's global reach, long-term vision and concern for the world's poor.

And in UK, I doubt that Michael Gove, would have become exercised about non-degradable plastic waste had it not been for the public impact of BBC's Blue Planet 2 programmes fronted by David Attenborough – especially the images of albatrosses returning to their nests and regurgitating plastic debris.

But though we may be political pessimists, we must remain techno-optimists. Advances in AI, biotech, nanotech and space can boost the developing as well as the developed world. Undiluted application of the 'precautionary principle' has a manifest downside.

"Space-ship Earth" is hurtling through the void. Its passengers are anxious and fractious. Their life-support system is vulnerable to disruption and break-downs. But there is too little planning -- too little horizon-scanning,

We need to think globally, we need to think rationally, we need to think long-term—empowered by twenty-first-century technology but guided by values that science alone can't provide.

I give the last word to one of my scientific heroes -- the eloquent biologist Peter Medawar:

"The bells that toll for mankind are like the bells of Alpine cattle. They are attached to our own necks, and it must

be our fault if they do not make a tuneful and melodious sound."

---

i The Earl of Birkenhead, *The World in 2030 AD* (London: Hodder and Stoughton, 1930).