OFFICE OF THE PRIME MINISTER'S CHIEF SCIENCE ADVISOR

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State of the Nation's Environment

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Sir Peter Gluckman

Thank you for the kind introduction

What I want to do tonight is look forward but in a somewhat reflective manner rather than looking backwards, even if this sounds a little paradoxical.

I think we all have an understanding of environmental challenges that we now face and I do not intend to rehearse what we all know: what we need to have is a frank, honest and inclusive conversation about how we move ahead. It is very easy to fall into simple rhetoric and advocacy, particularly at this time in the political cycle, and present narrow and somewhat silo-ed and dogmatic views about what needs to be done. But the reality is much more nuanced - we face some very complex decisions. And in my view these need to be informed on an on-going basis by high-quality environmental and social sciences. We need to understand the role of how science in helping us choose between the options ahead of us.

Having said that I want to focus on looking ahead, I'm going to start by being somewhat of an amateur cultural historian. If we think back to the beginning of the 19th century, at least in Western European societies, we saw with the Enlightenment the start of what was to become a dramatic shift in the way human beings respected and treated other human beings. We saw the progressive end of slavery, we saw the gradual development of social support services, the start

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of a commitment to public health, the development of public schooling, the development of democracy, and eventually of women's rights, in most countries the eradication of inhumane punishments, and the rise of social welfare. Since then we've seen progressive and rapid shifts in the position of human rights in most countries that, while still evolving, are now enshrined in the universal declaration of human rights and in many countries in the eradication of a number of prejudice-based stigmatisations. And while there is more to do, if we look back over the past 200 years there would be little doubt that there has been a fundamental and irreversible change in the way we treat each other.

Why do I start here? I think it is useful to reflect on that shift in attitude and see the parallels with what is now happening in the changing attitudes many of us have to the environment. What we are now seeing a relatively rapid shift in our understanding of the relationship between human existence and the environment. And here I emphasize I can only talk about Western culture – many indigenous peoples have very different and deep and spiritual relationships with their environment. But having said that the shift is largely global albeit with some worrying exceptions.

Arguably this attitudinal shift first started with Rachel Carson, with the Love Canal, with the Minamata disaster and so on. But while these largely singular events created some momentum, it has really been the broad impact of humans on the planet that is now feeding our attention and the IPCC must take a lot of credit for that shift in attitude: climate change, ocean acidification, contamination of the oceans by microplastics, widespread loss of biodiversity, urbanisation and the pollution that surrounds it are now the very issues that many people and governments now focus on. We even have a scientific term for the impact of our species on the planet – the Anthropocene - although geologists seem to get rather excited in debating when it started!

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But associated with this are concerns about what Sir John Beddington, the previous UK chief science advisor, termed the perfect storm – concerns about food, water and energy security and what once I termed the demographic storm, because ultimately these changes reflect the exponential rise in the human population – in turn driven by advances in science, public health and engineering.

The growth in the planetary population has been exponential. Ten thousand years ago there may have been 10 million humans, and 2000 years ago about 300 million humans, but we only hit 1 billion humans in about 1800. We entered the 19th century with about 1.6 billion humans and left it with 6.1 billion humans. But 12 years later we had added another billion and we will have added another billion in another 10 years or so. By 2050 we will have reached at least 9.5 billion and some estimates after that are most concerning – depending on what happens to life expectancy and reproductive behaviours especially in the developing world. And this growth brings with it increase demand for food, energy, water and pressures and justifiable expectations for better standards of living. All of this puts more and more pressure on our environment: the demands for food, for water, for space.

These pressures are creating the grand challenges that are reflected in the 17 Sustainable Development Goals which every country has agreed to try and achieve through the UN system. And unlike its predecessors the MDGs, these goals apply to us as much as they do to developing countries. And these goals highlight the complexity and the intertwined nature of the challenges we face – it is increasingly hard to sequester environmental considerations from economic and human dimensions. Indeed it is a manifest reality that in conditions of poverty or deprivation the focus on humans will be on survival and economics rather than on the environment; environmentalism in that sense, while a necessity in our minds, requires some assurance of economic conditions to be engaged in by society.

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We need to think imaginatively and laterally and think about how science, both current knowledge and that which is still to be done, and science-based technologies and innovation might help solve the dilemmas that flow from this equation.

These challenges are global in nature and we are all affected by them: science has an important role to play in addressing them at the global level. Science and technology can help find solutions but it can also help move the international agenda forward. We have seen this to great effect with the Montreal protocol and while the process has been awkward, the IPCC process has been pivotal to getting nations to work together in dealing with the policy challenges they face both domestically and internationally. The SDGs highlight many other areas where science can play a role in resolving impasses at the global level; for example, ocean pollution. However there are problems in global science governance and in the global-science-policy nexus that need to be addressed which I spoke about recently at the SDG forum at the UN[1].

But let me now focus on New Zealand more directly.

It is unrealistic to imagine that we can return NZ to a condition that existed at the time of the arrival of the first of Māori with the dog and the rat and with fire and rudimentary agriculture: the first local extinctions of mega-fauna that when humans arrived, soon followed. This is no different to what happened elsewhere when humans first arrived. But after the arrival of the European 250 years ago we started to see many very rapid changes in our land use, waterscape and our biodiversity. And as our biological economy grew, and as our population grew, and urbanised, even bigger changes occurred and this has been particularly so in recent decades.

[1] http://www.pmcsa.org.nz/wp-content/uploads/Sir-Peter-Gluckman-Speech-to-UN-STI-Forum-of-SDGs-16-May.pdf

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These environmental consequences reflect the reality now that we have 4 ½ million people living in New Zealand and largely living off the back of an agricultural and increasingly touristic economy.

Land was cleared either accidentally or intentionally by fire and bushwhacking, waterways were dammed for agricultural, industrial and domestic use and our agricultural land was turned into giant exotic monocultures of ryegrass and clover and more recently *Pinus radiata.* Multiple exotic species of plant, bird, mammal, fish and insect were intentionally or accidentally imported and the consequences to our indigenous flora and fauna are well understood.

Certainly we preserved important areas in national parks and conservation land and collectively were proud to do so. But outside these areas there was not much consideration what happens to our land and waters. We thought that we could exploit those openly without consideration of the deeper issues because we had put conservation land aside. My recent report on fresh water values [2]highlights that almost complete separation of mind-sets which is only now changing.

And on top of that we now have the challenge of anthropogenic climate change; we have made commitments to address our greenhouse gas emissions, we have a growing concern over the balance of land use reflected particularly in discussions around freshwater, indeed we have many conflicting and complex interests in freshwater as highlighted in the Canterbury region, there are many challenges in the management of our marine estate which we poorly understand and we have ongoing threats to our remaining biodiversity as a result of exotic predators such as stoats, possums and rats, not to mention feral cats. We have problems of imported wasps destroying our native bees, we have to confront biosecurity incursions repeatedly, we have myrtle rust, kauri die back and *Bonamia* to name but a few.

[2] http://www.pmcsa.org.nz/wp-content/uploads/PMCSA-Freshwater-Report.pdf

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In the short time I have to you tonight it's not possible to address all these issues looking ahead but I will try to integrate these in my view of the future and illustrate that with a focus on three areas: fresh water, land use and biodiversity.

Let me start with a simplified version of the core dilemma we face. New Zealand has the problem that can at the same time be an advantage, of being geographically isolated. That means that our position in global value chains, (that is the value add we make to our exports taking into account any imports we have to make to support those exports and which is a more informative measure than crude trade figures), is challenging. For countries such as ours, primary production and its derivatives are likely to remain mainstays of our economy well into the future. The challenge we have long recognised will be how to get added value before that product leaves our shores, and that must include on-farm as well as off-farm considerations. If changed practice can bring greater on-farm returns per hectare, then farmers will shift their behaviours.

And of course primary production has led to a very major environmental footprint. This has been our collective blind spot. As farming was integral to both our economy and sense of our nationhood, we have tended not to notice the environmental consequences; particularly of a laissez-faire view of enabling land utilisation with a minimum of regulatory constraint. The consequences has been that given the high returns for dairy farming we have seen both productive and more marginal land shifted to dairy at the expense of other products and that has led to more rapid environmental degradation, deforestation, erosion, increased methane production and freshwater contamination by phosphate, nitrogen and faecal material. But that sociological problem is now turned on its head; our increasingly urbanised society is vilifying farmers for doing what, in some cases, is what they have always done and from which the rest of New Zealand has benefitted.

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The simple reality is we rely on agriculture and we have relied on the life sciences that for 60 years have sustained our agricultural economy to keep us wealthy and to give New Zealanders the quality of life they want. We now need to use science to help take us forward and solve the dilemma. Diversification away from a primary sector focused economy will be slow and in many ways limited by the realities of global value chains and by the challenge of the retention of growing companies in NZ – a problem all small advanced economies face and not unique to us. While the technology sector grows outside the food and agriculture sector and will bring a growing return, in the foreseeable future agriculture and tourism will be at the heart of our externally facing economy.

Indeed the other industry of roughly equal size is tourism. This can be sometimes seen to be in conflict with agriculture because while agriculture degrades the environment, New Zealand's tourism is largely built around our environmental heritage. But is more complicated than that and the equation is not simple. Mass tourism has a large environmental footprint in multiple ways and we need to increasingly reflect upon that too. The simple answer is that we can neither rely on tourism nor our returns on agriculture without thinking much more clearly about environmental management.

So the question is a pragmatic one – how can research, science and technology help us through this dilemma so as to provide everyone with a high quality of life that requires sustaining a high-quality environment.

I have spent most of the last eight years being a broker between the science community and the policy community. And these are very different cultures. Policy-making is largely about making choices between different options and those options affect different stakeholders in very many different ways. All governments have the challenge of choosing between the impact on different stakeholders

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for good or bad when they make policy choices. And they are torn between managing short-term electoral risk and promoting longer-term strategy. Along-side this we have been slow to use long-term planning and horizon scanning. For example the environmental and sociological consequences of unrestrained dairy expansion should have been obvious and it is only now we are confronting them. These are techniques that need to be better employed in assisting science in providing the evidence that can help policy makers choose in a more informed manner between different options.

Importantly science does not make the policy, it can only inform policy. Democracy works off decision-making informed by many other values-laden considerations: public opinion, political ideology, electoral contract, fiscal considerations, diplomatic considerations etc. Policy making is not the neat cycle it is sometimes suggested to be, rather it is a messy process involving formal and informal actors and politicians tend only to act when a feasible solution presents itself. They cannot be expected to be scientific referees.

Scientists often think that just because they have made one observation, policymakers must act on it. But frankly that is not the way it works. The science that policy makers need is generally incomplete and often ambiguous. They often do not have the luxury of time and of waiting until the ambiguities and uncertainties are addressed.

Scientists are generally very good at problem definition, for example defining an issue such as climate change, but the diagnostician may not be the best placed to find the therapy (although this often does not stop them preaching their preferred solution). Take the example of climate change, here climate scientists could relatively easily identify the issue, but the solutions do not primarily lie in climate science - they lie in economics, in political science, in social science, in energy and other technologies of multiple kinds.

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Environmental and other natural sciences often see social science as an add-on. I have come increasingly to dislike this distinction between social and natural sciences – it is counterproductive – indeed the ICSU and ISSC are currently merging and in the future this increasing fusion will have major impact on how science is funded. Indeed we have seen the elements of this in the way our national science challenges have been constructed.

But we also cannot talk about the interaction between science and policy unless we also think about the interaction between science and society, politics and society, and policy and society. As technologies of many types will play a greater part in our future, we will need the policy community and society via the democratic process to be continually engaged with the scientific discussion. And this will not happen if complex discussions are reduced to political point scoring, 140 character tweets or 10 second sound bites on television. Much more mature and multidimensional discussion will be needed but this is increasingly difficult with the echo chamber of social media, the decline in trust in institutions, in the media and experts. The post-truth world will make many important decisions that much harder and could threaten the nature of democracy itself. Science has an important role in being a bastion against that threat but science in turn must look to itself and identify how to act as an institution of brokerage. While individual scientists may act as advocates, scientific institutions must engage as brokers.

To get there we will have to look again how we better engage between science and the rest of society. It is not as in 1942 Robert Merton, the sociologist of science, described scientists as priests standing on an altar revealing truths to an ignorant society, rather science is deeply embedded within society; a society that still is generally supportive of the scientific effort and which is increasingly empowered in its decision making. We make a big mistake if we approach the rest of society with the deficit model in mind; yet that is still how much scientific communication occurs.

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People have very different and deeply held worldviews reflecting their culture, tradition, past experience, persona and context. We need to understand that science alone will not resolve different worldviews; rather it can actually make them more divergent as we have seen in the case of climate change. People interpret data and evidence through lenses shaped by their cognitive biases. To get beyond this we need to think very differently. This is where enhancing the understanding of the scientific processes themselves are critical. The participatory science programme, funded though the *Nations of Curious Minds* initiative and led with passion by Victoria Metcalf who is in the audience and who reports to me, is an attempt to do just that. It is now piloted in Otago, Taranaki and South Auckland and is designed to bring children, their adult family and whanau, teachers and scientists together to work on problems that the community decides upon. Not surprisingly many of the projects they choose are environmentally focused.

But citizen science in whatever form is not enough. We need to take lessons from the language and scholarship of post-normal science. This is defined as science that is about a complex issue, one in which no matter how much science is done there will always be unknowns, where the science interacts with public values and those public values are in dispute. But despite this decisions are urgent. The very issues we are considering, climate change, biodiversity, future of agriculture, water quality etc., all have these qualities. The post-normal scholars would argue, and I agree with them, that the answer must lie in concepts like extended peer review, co-design and co-production. These are critical but complex and controversial concepts but they will be a large part of the future of science. It will require major changes in how science is managed, funded and how our research institutions act and how researchers are incentivised. The scientific enterprise is inherently conservative and this will not be an easy road for many.

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The last general comment I want to make relates to technologies. And one cannot think about technologies without thinking about the perceptions of risk and precaution. Risk has very different meanings to scientists who think in actuarial terms, to most people, who think in perceptional terms primarily influenced by their cognitive biases, and to policy makers and politicians who think in terms of the electoral cycle. Perceptions of risk for most are largely defined by sense of cost and benefit, gains and losses. I will have a very different view of the risk of any endeavour if I think I will directly benefit and that any negative spill-overs affect you and not me, to how I consider the same innovation in the reverse situation. Imagine a world in which the first use of the internet had been to advance terrorism and the first use of genetic technologies had been through the a public good agency like the WHO to eradicate malaria. Would we have ended up regulating the internet more strictly and have more widespread acceptance of GM? Indeed we see these issues of interest and perception of advantage and gain and loss in every debate over technology and have done for many decades. Look back at the margarine-butter debates that went on for over 100 years.

By definition science disproves rather than proves phenomena and the concept of absolute proof is meaningless. So when we come to words like precaution we need to recognise that this too is a relative term. Yet in its extreme version precaution has been used as an absolute argument against novelty. We have seen this in how the precautionary principle has been interpreted in multiple ways often to support prior positions. It was never meant to be an absolute and definitive and a one-off assessment – it could not be – rather it was meant to be a learning and adaptive tool to allow new technologies to be introduced, evaluated, and either increasingly or decreasingly regulated. But in some areas it has been misused and manipulated to be a recipe for stasis. Without the acceptance of some level of uncertainty, no innovation and no progress is ever possible.

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So now let us try and get specific about some areas of our environmental challenge. Let us look at a short list of issues:

- Predator free NZ 2050
- Water quality
- The future of pastoral farming.
- Land-use
- The future of tourism
- Climate change
- Marine estate management
- Biodiversity
- Biosecurity

There are many others I could add but this is a fairly formidable list.

Firstly progress on many of these requires monitoring and data. And with the new statutory requirement for Tier 1 environmental monitoring a lot of effort is going into developing the environmental database. But data without science is meaningless. Data needs to be interpreted. Monitoring needs to be logical and informative. My freshwater report highlighted the need for a clear logic to specific monitoring in every catchment and clearly common definitions and standards are needed so that we can all understand the level of progress in each specific catchment. And the debate over water quality measurements highlighted other issues. Monitoring in a cross-sectional way is very arbitrary and not very informative. The real progress in those standards, which was largely missed in the subsequent polemic, has been the emphasis on longitudinal monitoring, monitoring that demonstrates that whatever the state is now, it progressively will improve or stay of high quality.

The other problem that the water report highlights is that there is a large list of measures of water quality and they all inform on some particular aspect of quality. We need to be clear why we are monitoring what parameter and what actions that can lead to.

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And as our environmental database grows we can start to better look how systems interact. Not only environmental systems but human and agricultural systems. We are fortunate to have now with the Integrated Data Infrastructure arguably the most complete research data system in the world for data on individuals – marrying this with environmental data could be a very rich scientific and policy data-mine.

Sensors and data will help us with every domain of environmental management but again the data plan needs to be scientifically driven and interpreted. It is easy to get carried away with environmental sensing – the catch cry of the moment is smart cities, sensor based cities but as we pass through the first wave of enthusiasm, it is being replaced with a growing understanding that such databases, modelling and sensing must serve a utilitarian and meaningful function that supports decision making. There will be many new kinds of sensors including biotic sensors – but keystone species and biotic indices themselves are effectively sensors. There is absolutely no doubt that sensing technologies will in the future play a major role in biosecurity protection and in precision agriculture to reduce the burden of herbicides, fertiliser and reduce water demands. Indeed in intensive systems now this is the norm in many countries. In pastoral systems the linkage with microsatellite and drone surveillance is obvious and already developing, indeed here in Lincoln there is a very active programme of research.

But beyond the data and sensor domains there are many other technologies emerging especially in the life sciences.

Let's take the challenge of Predator Free 2050. This is far more complex than simply fencing and trapping – we must recognise the reality that all these predators are also present in our urban domains. One of the intermediate goals set for Predator Free 2050 is to have a strategy to eradicate one species of predator by 2025 – that is to have

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the strategy and technology clear, not to have actually eradicated the pest by then.

The first issue is which species – rats, stoats or possums. And can we eradicate one species without opening the ecological niche for another pest to occupy? There are arguments in favour and against each of these species being the first target. And why focus only on mammalian species. Because they are very obvious – what about the exotic wasps that posing a threat to native birds and insects in honeydew beech forests.

Here you see the interface between scientific considerations and public sense of priorities – they are not always the same. This latter argument reminds me of the challenges we face over a focus on headline species in biodiversity conservation – the public and sponsors tend to focus on the headline species or even the subspecies rather than the ecosystem. Conservation science has moved a long way and now sees conservation areas as not being lines on a map but rather mapping areas to preserve diverse physical environments, the ecosystem and genetic diversity. In thinking about the physical geography of protection it is not just a matter of thinking about the current distribution of the organisms of interest – rather it is about allowing for the diversity of niches that may be needed as species move with on-going climate change. In thinking about genetic diversity we are getting beyond thinking about subspecies protection to thinking about the species and gene pool as whole. Indeed there is an increasing school of thought that it is not every taxon but rather the range of genetic diversity in the taxa that must be protected. These thoughts challenge many aspects of public conservation that is built around headline species although a focus on headline species certainly helps drive public interest and commitment. In NZ it challenges common practices, especially in bird protection, but may also have implications for other species as well. The issue of balance between ecosystem preservation and headline species preservation particularly when species are almost functionally extinct is a huge

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issue in conservation biology where scientific logic is often overridden by emotion.

So back to predator free 2050, if we can resolve the issue of what species to target how are we going to eradicate it?

Trapping can only go so far and for these species is unlikely to succeed. Fencing and sanctuaries do not achieve the vision although they may protect vulnerable species. We already use poisons – think of 1080 – but there is a broader range of possibilities – what about chemicals that induce sterility? What about using biological warfare such as bacteria that infect and cause sterility in the target species? What about using bacteria or plants to produce inhibitory RNAs that are very precisely targeted? What about meiotic gene drive, etc? All of these are conceptually possible but each one of them cannot be developed and applied without social licence – public acceptance can never be taken for granted. National conversations of a very different and mature nature will be needed to use any of these approaches.

So let's take that conversation a little further. The raft of new plant breeding technologies that are emerging offers enormous potential. Some countries have ruled that those that do not introduce foreign DNA are not genetic modifications, provided that they reflect edits that could occur naturally. Others are less certain but the extent to which these are deep philosophical objections or reflect non-tariff trade-barrier positioning or other political considerations is not clear. But the technology is developing fast and newer and more pervasive methods will be developed.

For example could we increase the rate of tree growth, reduce risk of wilding conifers and change the economics of natural carbon capture and thus marginal land-use? Could we produce different forages that change the productivity and the value of our pastoral farming and reducing nitrogen release, greenhouse gas emissions etc? Could we enhance our cropping industry and see land shift back from animals to

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much lower environmental footprint cropping – say for the production of artificial meat and milk? Some calculations suggest we can reduce our pastoral GHG emissions by about 15-20% by such approaches – in particular because we could sustain productivity while reducing stocking rates dramatically, but we really do not know without testing them is the real world.

We face a challenge of decline in phosphate supplies, and most phosphate applied to the land is not taken up by plants but ultimately ends up in our waterways with consequences of eutrophication. Experimental plants have been developed which have 4 to 5 times the uptake capacity and thus reduce the need for phosphate fertiliser by about 75%. This would have multiple benefits.

And what about the potential of bioremediation; the use of modified plants and micro-organisms to extract toxins from our environment?

All these are possibilities and the world is changing fast. The logic of regulation by process rather than by trait is increasingly questioned around the world, especially with these newer techniques that mimic nature as opposed to traditional genetic technology. But even traditional genetic modification cannot be ignored. South Africa would have faced a major food crisis last year as a result of serial droughts associated with major terrestrial warming had it not been for the availability of non-commercially sourced drought resistant GM maize. We are seeing a raft of new gene edited strategies emerge with other desirable outcomes – for example sheep have been developed in China which do not need their tails docked because they are naturally shorter.

We have societal choices ahead of us that are hard – environment, economics, agriculture, and industry interests all intersect. These are decisions which science alone must not make. Nor are decisions we make today necessarily those we will make tomorrow when newer technologies emerge. We will use some technologies and likely choose

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not to use others, but what is certain is that the technological weaponry we will be using in a decade's time will be different to that we now use. The challenge is how to have the conversations and what should be the regulatory regimes that allow for rapid technological change.

The NZ science advisory system has developed over the last 8 years. Its core role is to bridge between the worlds of science and policy. A major step forward was taken in 2013 when we started to appoint science advisors to specific ministries: Ian Ferguson in MPI, Ken Hughey in DOC, David Wratt in Environment, now to be followed by Alison Collins: Lincoln is indeed well represented in this mix. In early 2016 I proposed to the Prime Minister that a major task for the science advisors would be to develop two interrelated research roadmaps – one on the conservation and environment research that the country would need over the next 20 years to inform policy making in these domains and one focused on the future of primary production and the research that the State would likely need to support it, directly or indirectly. Both these roadmaps were major efforts involving partnerships with academia, policy makers, other stakeholders and they traverse an enormously broad scope of research need. They are not prescriptive but they have already become the template by which government departments including MBIE are viewing science priorities and needs in this area. They also provide a justification for the continued to need to present to the politician and the public why taxpayer money should be invested in research. Now is not the time for me to go through each of these roadmaps. Those who are interested need to digest them for themselves. They will need to be regularly updated into the future as we learn more.

And if we look at the national science challenges, four of them are very focused on these issues - Our Land and Water, Biological Heritage, Deep South and Sustainable Seas. These challenges represent a significant shift in the way we do science – from being institutionally competition and siloed into a more collaborative and nationally

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focused approach. Again this is a trend towards mission–led and multi-site, multi-disciplinary research that is being seen in other small countries as they look to maximise their research effort for national benefit.

These roadmaps and the challenges are strong illustration that on-going research will be needed if we are to work our way through the complex range of differing demands and interests and ensure that the decades of environmental pressures we have created are ameliorated and that our biological and environmental heritage is protected into the future.

And I cannot finish without pointing out that the benefits of environmental and biological research have many other spill-over benefit. Beyond the clear benefits of an improved environment, there are benefits of a more diversified economy, the potential for enormous value added in our food sector and real possibilities in clean-tech, environmental technology and agritech. The Lincoln hub with its university and CRI partners and the private sector engaged reflects the commitment and opportunities to seeking these opportunities.

Ultimately science is essential to enhancing our environment but that science will mean nothing without much better national conversation, getting beyond political or interest group point scoring and ensuring conversations that engage the public, NGOs, the private sector, academia and the policy community. Science can make a difference.

Thank you.

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