Transitioning to New Technologies: Challenges and Choices in a Changing World

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Abstract

In a time of ever more rapid and extensive technological change, the task of transitioning to new technologies presents each nation with a set of critical challenges and choices. What will be the most effective response will depend both on the particular capabilities, legal frameworks, and political realities in each national setting, and the ways in which global shifts which shape and sharpen those challenges are expressed. Nevertheless, whilst responses may differ, it is possible to identify a set of key challenges which each national community will need to face as a matter of urgency.

Keywords: challenges of innovation, biotechnology, nanotechnology, ICT, patents, eco-innovation

Introduction

The pace of scientific and technical change is relentless. Every aspect of modern life – production, consumption, the wastes we create, and what we do with them – is constantly being reshaped. So too are the communication processes by which we picture, understand and organise ourselves and our world.

That reshaping includes our understanding of community. It is by now well understood that the emphasis on the national community that was so prevalent in the 20th century, is now being increasingly complicated by the importance of interlinked global, regional and local communities on the one hand, and transnational challenges on the other (Camilleri & Falk, 1992). Nevertheless, the national community is still the site of much social organization and decision making, and the ways those decisions are cast, within a rapidly changing global context, may greatly effect a national community's future.

Australia provides an instructive example. Like every other national community, its politics are intertwined deeply with its economic future in a highly competitive world. And, like every other national community, it is faced with profound choices about its future. It is not so difficult to make out some generic areas of choice that apply to most if not all nations. But within those areas, the answers may be highly specific to national circumstance. For this reason, it is helpful to consider some of these key choices in the context of a case study.

In recent years, Australia, through an organization known as "the Australian Davos Connection" has held an annual "Futures Summit" which is attended by a mixture of government and business leaders, intellectuals and researchers, and representatives of civil society organizations. It is an opportunity to think about the future and to shape attitudes.

In 2005 the summit identified a triad of three technologies, which are well understood to be important pieces of the puzzle of how our futures may evolve. They are: information, bio and nano technologies. The summit asked four questions in relation to the above triad of emerging technologies. Paraphrased they were: How will these technologies affect the way that we work, do business and understand our place in the region and the world? How can they be used to assist in addressing national and global challenges? What can we do to harness them? And what are the social, political and business implications of doing so?

Whilst the answers to these will in some ways be specific to opportunities and challenges faced by Australia, the manner in which they may be approached, and the issues to be taken into account, may be much more generalisable. This paper is informed by a response to the above questions, presented as a lead report to the conference by the author in 2006 (Falk & Taylor, 2006). It considers some general categories of answers which will be applicable to many communities, but in the context of Australia as a case study.

Australia as a Case Study

In some ways Australia is an anomaly – a continent vast in space and richly endowed with mineral wealth, but sparsely populated with only an estimated 20.7 million inhabitants as of January 2007 (Department of the Prime Minister and Cabinet, 2007). It is home to a multitude of cultures drawn from waves of immigrants and refugees, but still primarily English speaking and educated. It is situated remote from its colonial roots to the UK, but most closely embedded in the now vigorously growing regions of South East Asia. In its modern form it developed from 1788, first as a prison colony, then as a colonial supplier of resources to 'mother England'. By now it is a relatively wealthy country, rapidly developing ever more strongly flowing interchanges of materials and goods with the economic dynamo of China, and the rest of Asia.

Like every other country, Australia is confronted with the rapid pace of global change. One driver of this change is the enormous competitive pressure for commercial innovation. In the three years ended December 2003, some 34% of Australian businesses with more than 3 employees introduced some kind of innovation that involved new goods, services or processes. For larger firms the pressure to change was even higher: 61% of businesses with more than 100 employees were innovating businesses (Australian Bureau of Statistics, 2003).

Another driver is research and development. In Australia, between 1991 and 2002 the country's gross domestic expenditure of R&D increased from 1.5% to 1.6%. In 2003–04, Australian businesses spent AUD$7.2 billion on R&D (Australian Bureau of Statistics, 2005). In 2002, reflecting increased government investment in basic R&D, the higher education sector spent some $3.4 billion on R&D, up 22.9% from 2000.

The drive for innovation is worldwide and is propelled by the relentless force of pressures and opportunities from the global economy. In 2004, globally, the 1000 biggest corporate research and development spenders spent a total of US$384 billion on R&D, a 6.5% annual growth since 1999 (Jaruzelski, Dehoff & Bordia, 2005). Here, the rapid growth of China's economy is increasingly understood to be a crucial factor. With economic growth having varied between 8% and 14% per annum over 1993-2005, standing at 10% per annum over the last three years, and projected at more than 7% per annum to 2020, China's future will be a factor in shaping the world's future (Wang, 2007). This has many implications, but one is that it emphasises the pressing need for countries like Australia to be very successful innovators. China will seek from the world what it does not have or cannot make itself. And China, far from being simply a low-wage and low-tech economy, is increasingly a low-wage high-tech economy.

Emerging technologies both are generated by, and contribute to, these drivers of innovation. But whether they emerge to meet new demands, or society changes to use them, or they are used to transform society, it is largely uncontested that they will have a crucial formative impact on the future of nations, and of individuals, and of their children.

A Triad of Key Technologies

As already noted, three technologies – information and communication technology (ICT), biotechnology, and nanotechnology – are by now widely believed to have an important role to play in shaping our future. Whilst often considered separately, this 'triad' of technologies is the outcome of a single broad process of discovery based upon manipulation of materials at very small scale. Although preceded by more than a century of scientific development (from quantum mechanics to numerical computation) the last 25 years has seen this capacity to manipulate the components of materials play an important role in transforming the world.

(i) Information and communication technology (ICT) is the most mature and familiar of these. The capacity to construct circuitry at micro scale (one millionth of a meter) has made it possible to pack ever higher densities of information processing devices together. Together with rapid development in transmission of information and in software, ICT has played a key transforming role in our world over the last few decades. The statistics speak clearly to the current strength of this sector. According to the World Information Technology and Information Services Alliance (a consortium of IT industry associations), ICT accounted for 6.8 percent of global GDP over the period

2001-2005, while worldwide spending on ICT in 2006 totaled over US$3 trillion (World Information Technology and Services Alliance, 2006).

In Australia, over 2002-3, ICT accounted for AUD$36.2 billion representing 4.6% of total GDP (Australian Bureau of Statistics, 2006b). The gross value added of ICT (4.6%) exceeded that of agriculture, forestry and fishing combined. In the same year, business and government invested AUD$26.7 billion in ICT products. The two largest areas of investment were computer hardware (AUD$10.7 billion) and software (AUD$8.2 billion).

Imposing as these levels of investment are, they do not begin to describe the extent to which computer based processes have been utilised to transform our world. Central to that has been the capacity of ICT to allow commercial, government and civil society organizations to organise all the way to global scale. The potential, for social and economic evolution, of the global communication and information systems which now connect individuals and organizations across the world, is still only beginning to be explored.

(ii) Biotechnology utilises biological processes (including those of micro-organisms) to produce commercial products. A wide and expanding range of techniques are now available, some of which intervene, right down at the molecular scale of the gene. These are being used to produce diverse outputs ranging across medicine, agriculture, environmental protection, food processing, chemical production and treatments, and more.

In some countries the industry has taken off. According to a study by consultants Ernst and Young, in 2004 the biotech sector raised US$16.9 billion in the US and US$3.4 billion in Europe, whilst global revenues increased 17 percent. The sector remains dominated by the US, whose biotech companies raised 80% of the venture capital and which was the base for more than 50% of the biotech corporations. Nevertheless, "the Asia-Pacific region, with rapid growth, increasing governmental focus, and improving regulatory regimes and infrastructure, is not far behind" (Ernst & Young, 2005).

Australia punches above its weight in biotechnology research. In 2001 Australia had 1.6% of the 5,834 biotechnology patents filed at the European Patent Office. That was more than Denmark (1.5%), Belgium (1.4%), and Korea (1.2%). Above Australia, the US has 41.2%, Japan 12.3% and Canada 2.8% (Organisation for Economic Cooperation and Development, 2005). By that measure Australia ranks as the country with the fourth greatest number of biotechnology patents. A recent survey shows that the market value of the country's life sciences sector (including biotechnology) increased 58% between 2001 and 2005. In 2001 there were less than 40 life science companies listed on the ASX. By 2006 this had increased to 134 (PriceWaterhouse Coopers, 2006).

The country is thus good at invention in this area. Unfortunately its high technology companies, typically, are less good at transferring to market, not the least because they are usually too small and often focussed on a single product. Beyond CSL, which has a market capitalisation of AUD$7.7 billion, the next largest biotechnology company, Novogen, has a market capitalisation of only AUD$484 million, with all other companies smaller and usually single product (PriceWaterhouseCoopers, 2006, p. 26).

The total market capitalisation of the life sciences in Australia (including two sub-sectors; medical devices and pharmaceutical/biotechnology) was AUD$17.3 billion in 2005. This compares to the massively greater US investment of over US$3.5 trillion in investments in this sector in the same year.

(iii) Nanotechnology, the least mature and well defined of these technologies, refers to a diverse set of techniques for manipulating physical and biological materials at scales of one to one hundred billionths of a meter. Whilst many areas of research operate at this scale, 'nanotechnology' is usually used to suggest actual or imminent practical application of these techniques. Examples include the synthesis of 'nanoparticles'. This can be done through a range of methods (e.g. hydrogen plasma metal reactions, colloidal precipitation, chemical vapour deposition, chloride reduction, and roasting of deposited alkali).

Nano-science is providing an ever better window into the properties of materials at tiny scale. For example, off-the-shelf nanotechnology equipment can now measure diverse properties of materials including surface area, pore size, density, catalytic activities, and water absorption behaviour, to name but a few.

Existing products of nanotechnology include: particles tailored to have specific properties (used, for example, in sun screen preparations); an Australian biosensor (Cornell, Braach-Maksvytis, King, Osman, Raguse, Wieczorek & Pace, 1997); a scanning tunnelling microscope (STM) that can 'see' atoms and electrons; and nano-crystalography capable of depicting the structure of proteins in three dimensions. An important discovery, carbon nanotubes, was made in 1991 (Iijima, 1991). These display a wide range of commercially important physical, electrical and other properties (see for example http://www.pa.msu.edu/cmp/csc/nanotube.html).

Importantly, it is possible to capture and manipulate the wide spectrum of special quantum mechanical properties which can be utilised when engineering at this scale. In principle this allows materials with novel chemical, optical or electrical properties, as well as quantum computers, and microscopic engines and other devices, to be constructed.

As with the other emerging technology areas, the potential for nanotechnology is clearly vast. It may be expected to move beyond the first stage of passive nanostructures (e.g. coatings and particles), to more active ones, followed by nanodevices, and eventually molecular nanodevices and processing systems (Roco, 2005). These should have applications in medicine, sensing and information storing and processing, and manufacture. It is not beyond the potential of the technology to play a major role in facilitating the development of technologies which produce hydrogen by photosynthesis, transform pollutants, and track disease within the body.

It has been predicted in the US that nanotechnology will be the basis for new products and services worth more than US$1 trillion in global products and services by 2013 (Eva, 2004). Certainly the potential has not been lost on governments. They "have led the wave of investment to date, with global government spending jumping from below US$1 billion in 2000 to more than $4 billion in 2004" (Rathjen, Read, Binks, Cornell, Harvey, Innes, Jagadish, Lu & Turney, 2005, p.17).

Claims for the future of nanotechnology need to be assessed in context. When large funds are sought by the industry for investment into research and development in nanotechnology, we are frequently told that nanotechnology 'has the potential to transform the way we live' (Rathjen et al., 2005). When the risks that nanotechnology may present, such as Eric Drexler's prediction of self replicating nanomachines or 'nanobots', or the intrusions into privacy that networks of nano-sensors might create, are raised by others, the tendency is to present nanotechnology as just another name for an evolutionary process of research and development with which we are already familiar.

Challenging Times

What choices does the well known importance of this rapidly developing technology triad present? This is a big question - too big to be addressed comprehensively in a short paper even for a single country. It is important to understand why it is so big. As just one example of the challenge it poses consider what is implied in the subquestion "How will these technologies affect what we do?"

Key to the above question is an assumption that we know how these technologies will emerge. But of course, the way they emerge will depend on the ways that those consumers across the world – individually and in organizations – innovate in the way that these technologies can be used.

ICT as the most mature technology of the triad provides a good example. At the end of the 1970s few understood that a computer on the desk would be of much use to anyone other than a scientist. Then came the applications: word processors evolved into authoring tools; spreadsheets made accessible numerical modelling, simulation, and charting; scanners, digital cameras and photo software opened up the tools of a movie director; music software and digital synthesisers turned our computers into recording studios; and the internet connected our computers as entry points to a global library and mail system. In 35 years this technology has helped reshape the way business and governments operate and the way that we think of ourselves. Much more than in the past, we now are able to see ourselves, not just as members of a local and national community, but also in various senses, members of communities that span the world.

To have predicted this in advance we would not only have had to foresee the developments in the technologies and how they would be used together, but also the way organizations – commercial, governmental and citizen – might expand, to make use of them. Of course, had we been able to predict all this, we could have made our fortune patenting the many applications.

It is foolish to think that we could have confidently predicted how all this has actually turned out. Even 30 years ahead, it turns out, is a long time in the current dynamic state of technological and social change. But this does not mean that we cannot usefully think about the issues raised by emerging technologies. Even though the choices available in the future may be different (perhaps radically so) to the way we currently envisage them, this does not excuse us from making choices which present themselves now.

The Challenge of Competition

A key choice is the priority a national community is to place on being economically competitive in relation to these technologies as they become available. The proposition that we need to be competitive is a 'no brainer'. But put this way it is oversimplified. We have to decide where and how we are to be competitive. This will depend on what we are good at, and what we want to achieve.

Australia has all the advantages of its high standard education system (now a large export industry) and history of research achievement. Research fields in which it is notably prolific and effective are medical, health and biological sciences, engineering and technology, and agriculture, veterinary and environmental sciences (Australian Bureau of Statistics, 2004) as well as the creative industries (creative arts, film, writing, design, etc.).

Another strength is that Australians are known for their readiness to accept and utilise new technologies. Their acceptance of ICT provides a good example. According to a 2005 survey, in Australia 89% of businesses with more than four employees use a computer and 77% have internet use, 90.2% of businesses with 10 or more employees use the internet, and 27% have web presence (Australian Bureau of Statistics, 2006a). Between 2004 and 2005 there was an increase from 41% to 63% of businesses using broadband to connect to the internet.

However, despite this helpful boldness in utilising new technology, it is well understood that the country's response is neither fast enough nor sufficiently well directed to assure its long-term economic sustainability as a nation.

First, as a whole, the Australian community does not place as high a priority on expenditure in research and development as do some others. For example, even though Australian businesses (in 2003-4) spent AUD$7.2 billion on R&D, and between 1991 and 2002 Australia's gross domestic expenditure on R&D increased from 1.52% to 1.62%, its expenditure did not even meet the OECD average (in 2002) of 2.25% (Organisation for Economic Co-operation and Development, 2005).

Second, and more importantly, the balance of trade in relation to high technology remains heavily tilted against Australian innovation. For example, Australia is a high user of information and communication technology. In 2002-3 ICT firms in Australia generated incomes of AUD$47.9 billion, whilst production in ICT goods and services netted some AUD$49.1 billion. But much of this depended on imports. In the crucial balance of exports against imports in ICT goods and services in 2004-5 our exports amounted to some AUD$4.3 billion. In contrast, our imports of these amounted to AUD$18 billion (Department of Communications, Information Technology and the Arts, 2006).

The concern that Australia is not yet well placed to hold its own in relation to emerging technology thus remains real. Right now it is doing very nicely by "selling the farm" – with a seemingly unending outward transfer of raw minerals, metals, coal and gas, feeding in particular the burgeoning economy of China. But this is not a long-term recipe for success. Nauru (which became ruinously dependent on its rapidly depleting stocks of guano – bird droppings – which it exported as fertiliser) can testify to that. A country needs to invest some of the returns of these exports into becoming sustainable economically and environmentally in the long term. Sustainability is delivered through resilience in the face of change. And resilience is best delivered by a diversity of strengths. Included in these is the capacity to use, produce and sell new technologies.

It is important to keep in perspective the relative roles of invention and use. As researchers Smith and West have clearly spelt out, high technology manufacturing industries play only a small part *directly* in every OECD economy (less than 3% of GDP) (Smith & West, 2005). In relation to direct production of high technology manufacturing, Australia under-invests a little in R&D by European standards.

Smith and West also note that the biggest deficiency is not in R&D, nor in Australians' capacity to create many small high technology startup companies. The biggest deficiency is in the capacity of those companies to carry the fruits of their activities to a global market through home grown multinational innovating companies which can utilise and produce and globally market these local inventions (Smith & West, 2005). There is a raft of policy proposals and government investment funding strategies which could assist the development of such companies (Smith & West, 2005), but these have yet to be dealt with adequately as a nation.

But in any case, whether or not Australians are good at driving the development of new technology is not the whole question. For each country the rest of the picture is filled in not by the *direct* production of emerging technologies, but by the capacity to use new technologies in innovative and productive ways. Becoming clever at using new technology will be central to a successful future. This too requires building capacities to do it well.

The Challenge of Ownership

Being good at using emerging technologies and being good at developing them are interdependent strengths. Being close to the development of technologies is a good way to get the literacy to use them creatively. Being good at developing them requires the use of frontier technologies and techniques.

If a community is to be good at these things it needs legal, cultural and economic institutions that encourage and support them. One challenge to doing so is the changing way in which it approaches the issue of ownership.

One important example, is the changing role of patents. Patents are a longstanding institution by which an inventor is granted, for a fixed period of time, a monopoly on the use of an invention in exchange for making its mode of construction and operation public.

Strong patent laws are seen as an incentive for innovation because they protect the investment in the research and experimentation that create emerging technologies. However, they may also act to inhibit the use of new inventions which may be important in further development. This balance is a vital one, and the point at which it is currently set may be becoming increasingly inappropriate in the face of technological and social change.

In Australia, as in many countries, a key factor in this is a more general shift in the attitude towards ownership. Whilst in the first half of the twentieth century it was thought perfectly proper to develop through government a wide range of public services available for public good, this attitude has been undermined by concepts of lean government, privatisation and 'user pays' within the broad philosophy of economic rationalism which has prevailed in Western public policy during the last several decades. One consequence of this is that public research institutions, such as universities, have increasingly been encouraged to raise their own funds by commercially deploying the outcomes of their research. The net effect is that these institutions are locking up their research in patents at an unprecedented rate (Lemley, 2005).

There is now the real prospect of basic building blocks of new fields (including genes) and classes of materials (with all currently envisaged applications of them) being locked up for 20 years through restrictions based on patents. The result could be to seriously restrict their use in further research and development (Lawson, 2004).

Because nanotechnology is the least mature of the triad to emerge, it presents the clearest example yet of the impact of this transformation of public good research to private property through the agency of patent law. Here the number of basic patents is so large that there is concern that those wishing to innovate in this area will increasingly encounter a 'patenting thicket', in which numerous patents on basic materials like carbon nanotubes and semiconducting nanocrystals and methods of research like atomic force microscopes and chemical vapour deposition, along with a restrictive licensing culture, will seriously slow further research and development (Lemley, 2005).

Ironically, the place where this has the potential to impact most seriously is the public research institutions themselves. As universities and other public research institutions have pursued commercialisation the right to experiment or tinker with patented materials or processes has become harder to defend. The Australian Law Reform Commission has identified the current lack of explicit protection for experimental use of patented materials in public universities as an area where legislation is needed (Australian Law Reform Commission, 2004).

In the commercial arena, patenting is an increasingly important way in which companies can create a positive impression in the share market, or simply lock out competitors from pursuing similar areas of investigation. A particular danger is that this pattern of activity will critically impede either research into or production of a nationally needed technology.

Biotechnology is replete with examples. Consider for example the licensing of zanamivar, an Australian invention and one of two antiviral inhibitors for bird flu (avian influenza). Whilst bird flu presents a threat of a lethal pandemic to the entire world, Australia – being closely linked to Asia – may be particularly vulnerable. As of 2006 the Australian Government estimates were that such a pandemic could kill 13,000 Australians. Such had been the concern that demand outstripped supply for the antiviral inhibitors for bird flu and there was a global shortage. The Australian biotechnology company Biota Holdings Limited, owner of the inhaled zanamivar (Relenza®) antiviral has been dissatisfied with the efforts of GlaxoSmithKline, whom it licences to produce the drug, to meet demand, and has sued for what Biota alleges is the failure of GSK to maintain "adequate inventory to meet demand" (Biota Holdings Ltd, 2005).

The Australian Government has the power to manufacture these antivirals itself with or without paying compensation to the patent holder (Lokuge, Drahos & Neville, 2006). Given that Australian taxpayers have made a contribution to the research that led to identification of viral targets, this might well be considered reasonable. But they have not taken that step and if and when a bird flu pandemic is in progress, it may well be far too late.

Australia presents to other countries a problem that it may face itself in relation to the patented technologies from other countries. For its neighbours in Asia the 2006 price of $US17.30 for a full course of antivirals could frequently represent a prohibitive cost. Indonesia, for example, would need to spend 67% of its per capita health expenditure to make these drugs available to its population, based on 2006 UK prices (Lokuge, Drahos & Neville, 2006). Yet if a bird flu variety evolves which is transmissible directly from human to human and breaks out, say in Indonesia, it might easily spread quickly to Australia.

Without intervention through the political process, patenting law extends through processes of testing of the limits of existing law. Through this process the ambit of patent laws has been extended to cover living organisms, including parts of the human genome. Myriad Genetics Inc. has the patent for a human gene whose mutations indicate an increased likelihood of breast cancer in women. In the US and the UK Myriad Genetics has been able to shut down, through the threat of legal action or exclusive licensing agreements, several public and private laboratories offering genetic testing for mutations on the BRCA1 and BRCA2 genes that indicate an increased likelihood of breast cancer in women. Along with exclusive control of testing, Myriad retains the right to collect and own all of the BRCA gene from each customer, for use in its exclusive research into genetic cures for breast cancer.

According to one report, some 20 percent of almost 24,000 human genes have been patented in the US primarily by private firms (63%) and universities (28%). As co-author Fiona Murray said, "While this does not quite boil down to [the patent holders] owning our genes ... these rights exclude us from using our genes for those purposes that are covered in the patent" (Lovgren, 2005).

Although patenting law is largely a national matter, there is a developing fabric of international treaties, agreements and services designed to facilitate an ever more global commerce between different jurisdictions. Internationally there are differences emerging between the United States and the European Union and the United Kingdom over what exactly is patentable. There are choices to be made between bi-lateral free-trade agreements based on restrictive patent standards of the US or international agreements that allow the right to experiment through forums such as the World Trade Organisation (Rimmer, 2005).

The issue is certainly understood internationally. As Judge LeBel (2005, para. 37) noted recently in a judgement in a case before the Supreme Court of Canada:

> *The vast and expanding domain of the law of intellectual property is going through a period of major and rapid changes. The pressures of globalization and technological change challenge its institutions, its classifications and sometimes settled doctrines. Jurisprudence attempts to address – sometimes with difficulty – the consequences of these broad social and economic trends. The state of patent*

law is evidence enough of the stresses on the process of jurisprudential development in a world where statute law itself struggles to catch up with the life of laboratories and markets. The economic value of intellectual property rights arouses the imagination and litigiousness of rights holders in their search for continuing protection of what they view as their rightful property. Such a search carries with it the risk of discarding basic and necessary distinctions between different forms of intellectual property and their legal and economic functions.

The maze of patents and rights negotiations creates the prospect of an increasingly costly barrier to the free development of each country's research and development. The complex commercial arms of universities, with their increasing requirements for skilled staff able to deal with the complex issues of intellectual property, create costs and delays that frequently are not justified by the returns on the individual patents which they gather.

As in many other matters related to innovation, if a nation such as Australia wishes to lead in creating an environment for successful development and use of emerging technologies, it must lead not only nationally but internationally. The best way to do so is to be recognised as being at the forefront of international best practice.

One opportunity this suggests is to review Australia's *Patent Act* 1990 to ensure that it continues to support commercial innovation while not forgoing public, or even wider commercial benefit. Another is to create new institutions and a national approach to the rights created under patent and allied law. A third may be to revise its funding strategies which place ever increasing pressure on its research institutions to chase the legal protection of their contributions to research, but at the cost of the research capacity of the sector as a whole. In each case the aim should be to create the optimal balance between public and private rights, creators and users of innovation, and between people world wide as investors and consumers on the one hand, and on the other as citizens deserving of protection of their right to life and well being under evolving structures and agencies of international law.

The Challenge of Risk

Using new technologies takes us into new areas of risk. The risks cover a wide spectrum, and grow to the extent that the use of the technology takes us into untested and unfamiliar territory. If a community is to be an effective user of new technologies, it needs to be able to confront and deal with these risks.

The history of ICT provides some examples: On 3 June 1980 a misbehaving computer chip gave the message that the US was under nuclear attack, almost precipitating a nuclear war (NORAD, 2006; Philips, 2006). Computers with pre-programmed sell orders profoundly amplified the 1987 Stock Market Crash – the biggest in history. The 'arms race' between legitimate users of computer systems and spammers, fraudsters, those who would steal our identity, virus creators, and hackers is a constant presence. And we all face the extraordinary prospect that in a large war the world's commerce might be brought to a halt by nuclear weapons creating an Electro Magnetic Pulse. Less dramatic, but perhaps equally important, is the steady reshaping of the world through ICT, with the possibility that civil liberties may be undermined and inequalities enhanced. Against these risks must be placed the fact that the world has survived, and the obvious benefits that ICT has brought. But the need to effectively assess and manage future risks remains.

Less mature in its development, biotechnology provides a different series of benefits and risks. Current examples of benefits include new diagnostic tests (for example for hereditary breast and ovarian cancer) (Bourret, 2005), organisms genetically modified to produce desired properties (for example, crops that are resistant to a specific herbicide or which express a particular medically useful property), tools for medical research, treatments of waste, production of animals with desired properties, etc.

The potential for good is enormous – of genetically engineered approaches to dramatically increase the capacity to produce cheap nutritious food, to invent cures for terrible diseases, and to develop many other new valuable products. But a potential for bad also exists – for releasing newly modified species with unpredicted environmental consequences, engineering new biological weapons, inadvertently releasing new diseases, and handing economic control of the world's seed supply into the hands of a small group of powerful corporations.

Over time biotechnology promises the power to transform materials, animals, humans and whole ecosystems, in ways that we are only beginning to understand and whose long term outcomes can only be guessed. Modifying living creatures at all scales, over their capacities to repair, reproduce, think, and interact with their environment, are all potentially within reach. In the long term, the power for transformation of our world through biotechnology is vast, whether for good or bad.

Perhaps inevitably, even apparently straightforward applications of biotechnology may carry significant risks. One current example relates to the quality and safety of genetically modified foods. Of course we already have elaborate systems in place for testing the quality of foods irrespective of their mode of manufacture. Yet it is here where the greatest public nervousness and resistance to the technology seems most evident. That there are some grounds for this is illustrated by the recent decision by the Australian Government's research organization, CSIRO, to abandon a promising development of a genetically engineered weevil resistant pea, after testing on mice showed serious disease problems. On the positive side this shows that careful testing can pick up problems in advance. On the negative side it illustrates the possibility that a genetically engineered food can produce serious unexpected health risks. Whether that is interpreted as a good or bad news story may depend on where one stands.

The range of issues associated with Genetic Engineering goes well beyond the *safety of foods* produced. A second is *environmental* – concern about the impacts of novel (perhaps herbicide tolerant or otherwise altered) organisms being released. A third is ethical (the appropriateness of humans altering or experimenting with living beings, especially with building blocks of humans themselves (such as stem cells or embryos). And a fourth is the *social impact* of new capacities such as the patenting and ownership of living organisms or building blocks such as genes, resultant increasing vulnerabilities (such as those subsistence farmers in developing countries to powerful agribusiness corporations), and beyond that, the capacity to transform ourselves (such as the potential capacity to clone humans, or design humans (genetically or otherwise) for specific characteristics.

Even the apparently simple issue of food safety in the end resolves down to a question of not just what tests have been done to demonstrate safety, but are they sufficient to convince consumers. In other countries where genetically modified foods have been allowed onto the shelves, consumers have forced their presence to be identified, and consumer resistance has then forced large chain stores to declare themselves GMO (genetically modified organism) free. Those judgements which are accepted as social have the potential to become intensely political. In Australia, as a consequence of expressed concerns, all state governments, except Queensland, in 2007 still had a moratorium on the commercial growing (as opposed to trials[1]) of genetically modified crops including Bayer CropScience's InVigor® GM canola and Monsanto Australia's Roundup Ready® GM canola. This was despite the Federal Office of Gene Technology Regulator approving these crops for commercial use in 2003[2].

Irrespective of our views on whether genetically modified crops are ready to be released into the environment or used for agricultural purposes, the above stalemate suggests that Australians have not been very good, *as a whole community*, at managing the risks. A country that was leading in the use of new technologies would have the processes in place to enable decisions to be made which did not end up in political stand-off.

The extent to which this is possible will depend not simply on the properties of the technologies themselves, but the extent to which the community feels satisfied that the risks that accompany them are being adequately managed. To achieve that it is crucial to have in place the very best practices, to build that confidence. A national audit of risk management in relation to emerging technologies, with proper provision for on-going community input and challenge, progressively updated, might help build that confidence.

This is not just a matter of educating the community. It is a collective activity between the various groups which make up a society – government, advocacy groups, business, researchers – to shape the structures for regulating new risks, the processes for identifying those risks, the values which are to have priority in technological choices, and the choices which are to be made between risks and benefits. In short, beyond actually believing that technically a community is at the front in risk management, it shares the challenge of establishing a form of constructive community engagement with emerging technologies. The aim of it will be to shape a path using emerging technologies which sufficiently convinces active sectors of the community that it will maximise the likelihood of achieving what is widely understood as a good future for that country.

The Challenge of Community Engagement

It is ironic that the very success of science and technology in developing powerful new products creates in the community a questioning of the traditional reliance on scientific advice to decide what emerging technical possibilities should be utilised.

New technologies and techniques have now become so central to all aspects of modern life that communities have had to evolve organizations that can enable them to play some role in influencing how technologies are used and for what ends. Examples include: farmer groups, biotechnology corporations, public regulatory agencies, and NGOs (Non Government Organisations). These actively intervene in political debate over the boundaries of what will be acceptable. They play into the important processes by which "public opinion" as sampled by pollsters, or expressed through the political parties, electoral processes, and "consumer demand", all develop.

It is pointless for companies or governments to regret the presence of intervention by these organisations in the process of developing powerful new technologies. It is merely a sign that the issues associated with emerging technologies have become so central to modern life that they are becoming the subject of daily democratic life of the community. The key challenge is to understand this process and assist it to give rise to informed and effective conclusions.

The public resistance to use of genetically modified organisms is an example. This resistance can be very real. But it may still be either transient or long term. And even if long term, does it apply to all or just some GMOs? For example, a difference may exist between attitudes to GMOs (for example, herbicide resistant canola) in foods and GMOs grown for other uses. If so, this could suggest that the environmental concerns about GMOs are less dominant than food safety concerns. Systematic studies of this sort of proposition, whilst admittedly not resolving all the issues associated with GMOs, would at least give some indication of where the most straightforward opportunities exist for innovation. Caution, of course, would need to be exercised since public sensibilities and priorities are not fixed in time. But much of the work in systematically analysing and facilitating the interchange between emerging technologies and different public groups remains to be done.

A recent paper by Macnaghton, Kearnes and Wynne (2005), who focus on the social studies of science and technology, has an important observation in relation to this. It is that it is better for the community to become engaged earlier ('upstream') in the innovation process, than in a reactive way at the point where major projects are proposed for deployment at commercial scale. This conclusion echoes earlier work, notably in the UK, which is also reflected in the outcomes of various public inquiries.

From the point of view of investors in this technology, including governments, this sounds sensible enough. It is foolish to invest vast amounts of money in, say, developing genetically modified crops, only to find that the public won't accept them being grown. It is better to understand any potential obstacles, and either seek to change the views of the public or shape the proposals to meet their concerns.

So engaging the public early sounds like a good idea, but there is much to be worked through on how to do it. What themes should be chosen and how? Who should create the process? What groupings from the community should be involved? And what lessons does the considerable experience here and overseas suggest as to what best practice might be? It should be stressed this is not just a matter of educating the public because they fail to understand experts (the so called 'deficit model'). Rather it is a matter of working together to shape outcomes which will be widely understood to be in the public good.

An example is provided by nanotechnology, still in its infancy. Already some NGOs have taken as part of their work the task of critically examining innovation in this area, whilst other NGOs are being set up for this purpose. The opportunity is to learn from the experience of biotechnology and intervene as a community to create a more effective and constructive process of public engagement.

A community may be able to open up public involvement in developing a national innovation strategy for nanotechnology. This could allow this big word to be unpacked into a spectrum of different developments, some near-term with limited issues, and others longer term across a much wider range of possibilities and with some much bigger potential impacts. The task then would be to seek to gain some consensus on which outcomes seem most attractive, where our strengths as a society to lie in creating and using the different forms of nanotechnology, which risks we are best equipped to manage, and which areas may be most deserving of public support.

A process of public engagement that focuses upstream has more capacity also to unravel, some of the "meta" issues. These include questions like: how can the community constructively engage with scientific certainty and uncertainty? What relative importance should be given to the application of the precautionary principle in these sorts of developments? What different forms of expertise need to be brought to bear? What risks are or could be managed? What processes might be provided to assist in gaining social 'closure' on whether these risks are acceptable? And how should the relative importance of commercial, public, and environmental benefit can be discussed and balanced?

These are big questions. But a national community which engages effectively with emerging technologies will need to develop answers to them. With appropriate research and development it should be possible to put public engagement with emerging technologies on a more systematic and constructive basis. This is an important challenge to accept if we are to create the greater and broader sense of agreed purpose necessary to facilitate the effective development and use of emerging technologies.

The Challenge of Imagination

Enough has been said to suggest that, at the scale of national community, emerging technologies pose big choices not only as to how it may use them, but for what purposes. These choices are strategic in the full sense of the word – requiring us to decide between the options for the sort of world we wish to live in, and the priorities we choose in reaching that goal. It is impossible to do this without exercising their imagination.

The issue of imagination – whether at local, national, regional or global scale - is often neglected. Yet in many senses it overarches all we have discussed. The issue of environmental degradation is one of many examples. Right now, in most countries (including Australia), the problem is understood to be acute and worsening. But in Australia, as in many other places, the imagination which would allow the community to resolve it seems underdeveloped.

Much of the degradation of the environment is initiated and amplified through our use of technology. Thus our reliance on fossil fuels has created the threat of global warming. Our rapacious consumption of the natural world, and transformation of it into novel chemicals and wastes, is leading to a devastatingly rapid acceleration in the extinction of species.

If we are to imagine how we might get from here to a more sustainable country in a sustainable world, one thing seems clear. Whilst technological innovation has been a central part of the problem, it is hard to imagine a credible path forward where innovation is not a central part of the solution.

The example of the destruction of the ozone layer caused by CFCs demonstrates just how important it is to be able to imagine technical alternatives. It is highly doubtful that sufficient international consensus could have been created to sign the Montreal Treaty, rapidly phasing out the use of CFCs, if alternatives could not have been imagined. The French Situationists used to urge the community to "Transform your dreams into reality". For the destruction of the ozone layer, this transformation from imagined desirable possibilities to reality is precisely what has taken place. The UNEP concludes, that if current trends continue, the problem of ozone depletion will be resolved within half a century (UNEP, 2000).

Similar to the above, the challenge for global warming provides a paradigmatic example of the decisions we must face. Regrettably, solving the problem caused by greenhouse gas emissions is monumentally more difficult than that of CFCs. Some imagine a future for Australia where the country battles to retain a privileged role as one of the highest greenhouse gas emitters per head of population in the world ("Australia tops GHG league tables", 2004). This is likely to be seen internationally as increasingly unconstructive.

An alternative is to imagine a very different and more inventive future – one where the nation can be seen to play a leading role in "eco-innovation", demonstrating new directions in the development and use of existing and emerging technologies to create both niche economic and political strengths for ourselves in the world context.

The convergence of ICT with other areas of technological production and consumption presents critical opportunities for this. As described elsewhere, massive opportunities exist in the strategic principles of eco-innovation: focussing on prevention of impacts, preserving and restoring natural capital, thinking in terms of life cycles, increasing eco-efficiency (by "factor X"), decarbonising and dematerialising the economy, and eco-innovation by design. As an example, consider the implications of Australia choosing to increase eco-efficiency by "factor X" (Falk & Ryan, 2007).

Eco-efficiency refers to doing more with less. As used by international bodies, such as UNEP and the OECD, it describes a form of innovation aimed at increasing the efficiency with which resources, energy and labour are used in commercial processes. Factor X is the efficiency improvement required to operate within the biosphere's carrying capacity (Kerr & Ryan, 2001). The size of factor X clearly depends on the nature of the economy and its impacts, and the ways in which that might change. The greater the growth in the consumption of goods and services, the higher factor X has to be to maintain sustainable conditions. Depending on assumptions and methodologies, a range of values has been suggested: factor four (as a transitional goal – 'halving resource use and doubling wealth') (von Weizsäcker, Lovins & Lovins, 1997), factor 10 (Factor 10 Club, 1994), and factor 20 (Jansen & Vergragt, 1992).

Some have had the courage to imagine a future where efficiency is sufficient for sustainability. In Carnoules,France, in 1994, an international gathering of scientists, and national and international government agencies concluded that factor 10 was a necessary and realisable target for industrialised countries and created the 'Factor 10 Club'. This was reinforced by other bodies. Austria wrote a factor 10 goal into its national environment plan in 1995. The same factor was proposed by a meeting of 30 senior business leaders in Japan in 2000, and the Ecocycle Commission in Sweden set an overall policy goal for factor 10 change within 25-50 years. The Dutch government program on Sustainable Technological Development (1992-7) adopted a 50 year horizon and corresponding increase in eco-efficiency of factor 20 (Weaver, Jansen, Van Grootveld & Van Spiegel, 1999).

New policy approaches in Europe and Japan have already been designed to support the strategic principles of eco-innovation in the support of goals such as those above. The trend is to spearhead environment policy first with industry policy and then with innovation policy, all directed towards eco-efficiency and environmental sustainability. These policies capitalise on the dramatic changes which have already been achieved in increasing the eco-efficiency of production. For example, a 2001 study of data for five countries (Austria, Germany, Netherlands, Japan and the USA) shows that Domestic Material Output per unit of GDP had fallen 30% since 1975 (Dept of Trade and Industry & Dept of Environment, Food and Rural Affairs, 2003; Matthews et al, 2003). Central to this has been the utilisation of developments in ICT, including the use of the internet (Laitner, 2003).

Some countries have taken up this sort of realisation into their national imagination. Examples of results of this include the UK Government's Framework for Sustainable Consumption and Production which seeks to decouple economic growth from growth in resource consumption through facilitating life-cycle thinking, improving regulation and stimulating relevant innovation (Dept of Trade and Industry & Dept of Environment, Food and Rural Affairs, 2003).

Ideas like Factor X provide national goals around which we can imagine a different future. Whether applied to the sub-question of efficiencies required to stabilise atmospheric greenhouse gases, or the broader question of what is required to reach sustainable production and consumption, they provide a target around which a complex debate can focus, and progress in eco-innovation can be shaped and assessed.

For countries like Australia the challenge is: should we establish such a target? If we did it, should this be the beginning of the process in which we as a nation invest in the innovation required to establish these goals? Setting a target would not only provide a national sense of a better future. It would also provide a framework in which our competitiveness could be strengthened in a direction which achieves for ourselves both a national economy and a global role, which is satisfying and worth striving for.

As with many other countries, Australia faces the challenge and opportunity of investing in development and use to make itself a showcase of utilising emerging technologies in support of eco-innovation. If this challenge is to be accepted we will need national investment in eco-innovation, through research, education, training and infrastructure, clustering of skills around the sustainable, the digital, and design, and a culture developed in which the community imagination extends to embrace the concept and practice of eco-innovation as a social goal.

Conclusion

Enough has been said to indicate that in relation to the problematic of transitioning to new technologies, a series of very broad but critical choices confront national communities. In this paper we have brought these together as a set of challenges to be confronted by each community, admittedly set within the particular national context of actual capabilities, legal frameworks, and political realities, but set also within a set of global shifts which shape and sharpen those challenges.

At this moment of history, every community and every country stands at a moment of great challenges and choices. The question is not so much how to transition to emerging technologies but what sort of future they wish to strive for. And this involves not just that choice but the question of how to approach it as a community, at all scales, but most certainly included amongst those, at that of the nation. Certainly one of conclusion ought to be to become good as a nation at utilising emerging technologies to meet national goals. In doing so, a community will be faced with some big challenges: to retain and build our competitiveness; to create an appropriate balance between private investment and public good; to manage risk creatively; to engage the community strategically, and early through innovative processes, in our use of technology and shaping of society; and to foster a sufficiently creative and expansive national imagination, so that we can see the options that will reward us with a strong, satisfying and sustainable future. Every country needs to be aware of these challenges, and there is no point in waiting to begin the task.

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Notes

1. In May 2004, the Victoria the Minister for Agriculture introduced a moratorium on commercial planting of these crops until February 2008, under the Control of Genetically Modified Crops Act 2004, as recommended by the Prof Peter Lloyd in his *Report of the Independent Reviewer to the Victorian Government.* Most Australian states are to review their moratoria in 2008.

2. Only Bayer CropScience is trying to have their InVigor® GM canola approved by for commercial sale by states, after Monsanto gave up trying to introduce its product to the Australian market.

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