9 Innovation nation

DR ZHENGRONG SHI, chief executive officer of Suntech, the world's largest solar photovoltaic company, recently wrote an article titled 'Can Australia save the world?'. Dr Shi observed that the United Kingdom had shown the world the way to use coal for energy and that the United States had shown the world how to harness atomic power. He asked whether it would be Australia and China that would show the world how to best use solar power.

The answer to Dr Shi's question is a resounding 'yes'.

Dr Shi is an Australian citizen and former researcher at the University of New South Wales' School of Photovoltaic and Renewable Energy Engineering. The school has had a quite extraordinary impact on the global photovoltaic industry. Four of the top six global manufacturers in solar photovoltaic technology are linked with the University of New South Wales. Beyond Suntech, there is the world's second largest manufacturer, JA Solar, also founded by former researchers at the school. Trina Solar, the fourth largest, was founded by one of its PhD graduates. The technology of the sixth largest, Yingli Green Energy Holding, was piloted by another graduate of the school.

In fact, the influence is so great that the school refers to these graduates and former researchers as its 'gigawatt club'—the group of former staff and students whose global firms now produce more than a gigawatt of solar products a year.

The story of the School of Photovoltaic and Renewable Energy Engineering has a moral: it shows how the economic benefits of 'spillover' in innovation can accrue to all nations—when one country creates a breakthrough in technology all others stand to benefit.

The transition to a low-carbon economy will be a story of innovation. The costs of the transition will depend on how effective we are in discovering and applying new technologies for producing goods and services with fewer emissions; or in satisfying demand in ways that produce fewer emissions, or which sequester carbon dioxide and store it safely.

There are multiple motives for innovation in some of these areas. Increased efficiency in the use of energy, the development of new energy sources for electricity and the accumulation of carbon in soils may all lead to lower costs independently of the need to reduce emissions. The rising costs of oil—with depletion of the limited stock of natural resources that are readily and cheaply accessible—strengthen this motive for energy saving and alternative energy. This motive has been further strengthened recently by the large increases in current expectations of future oil prices.

Some firms and countries will undertake or encourage innovation in these areas because they see themselves—firm or country—as producers of goods embodying the technology, like Suntech. For some countries and firms, there may be anxiety that others will gain earlier access to superior new technology and receive competitive advantages in the marketplace.

Countries that are large importers of fossil fuels and face future price increases may see development of emissions-saving technologies as a way of reducing prices. When the imports are especially important to domestic economic stability, as they are with oil, and are drawn from places that carry political risks, the motives for innovation that reduces reliance on imports may include national security.

And now for governments, and for firms as well if the costs of carbon emissions are subject to a price, there is the motive of reducing greenhouse gas emissions.

All of these motives were woven into the main theme of President Barack Obama's State of the Union address in January 2011:

> Meanwhile nations like India and China ... are investing in research and new technologies. Just recently, China became the home to the world's largest private solar research facility and the world's fastest computer ...
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> This is our generation's Sputnik moment. Two years ago, I said that we needed to reach a level of research and development we haven't seen since the height of the Space Age ... We'll invest in, especially, clean energy technology—an investment that will strengthen our security, protect our planet, and create countless new jobs for our people ...
>
> Already we're seeing the promise of renewable energy ... We're telling America's scientists and engineers that if they assemble teams of the best minds in their fields, and focus on the hardest problems in clean energy, we'll fund the Apollo projects of our time ...
>
> So tonight, I challenge you to join me in setting a new goal: By 2035, 80 percent of America's electricity will come from clean energy sources ...
>
> So instead of subsidising yesterday's energy, let's invest in tomorrow's.

It is unlikely that the other motives alone will go anywhere near reducing greenhouse gas emissions enough, and in a short enough timeframe, to avoid great damage from climate change. Moreover, there would be no reason for any investment at all in technologies to store carbon dioxide wastes in geological structures if we provided no incentives for emissions reductions and relied on other motives.

Placing a price on emissions of greenhouse gases that reflects the damage that they do to other human activities is the economically efficient way to increase incentives for innovation in technologies that reduce greenhouse gas emissions. It will increase the expected profitability of all such activities, increase the levels of innovation, and speed it up. No useful area of innovation to reduce emissions will miss out on the encouragement. It will add to other motives for investing in innovation, and lead to higher levels of investment in innovation than the other motives alone are encouraging.

President Obama was not reacting to shadows in referring to international competition for low-emissions technologies in his State of the Union address. There is heightened awareness that the leading industrial countries are engaged in a great race to find the technologies that will carry the world to a low-carbon economy. There is awareness that future generations will be using energy from different sources and in different ways than we do. Firms and countries will need to produce goods and services that make sense when those different ways have become business as usual.

I have conducted recent correspondence with a senior researcher at the Development Research Centre of China's State Council (Cabinet), Yongsheng Zhang, on China's interest in innovation in low-emissions energy. The Development Research Centre and the World Bank are jointly conducting a research project on green energy in future Chinese development. There is acute awareness in China that the long-term development path of China will be greatly affected by its success in innovation to reduce the costs of low-emissions energy. In addition to facilitating implementation and then extension of China's own international commitments on emissions, it will determine the role that China can play as a supplier of capital goods to a low-carbon global economy.

In the remainder of this chapter, I look at how Australia fits into the global innovation story, and discuss policies for innovation in Australia.

Pinpointing market failures

The carbon price will make it more profitable for firms and industries to invest in research, development, demonstration and commercialisation of low-emissions technologies. It guides and provides incentives for investments in low-emissions technologies.

It is impossible to know in advance where investment in innovation will occur or whether it will be successful. Entrepreneurs will form their own views and back them with investment in the full awareness that they are taking risks. The leaders of public entities that provide fiscal support for innovation will also be making decisions under great uncertainty. The advantage of a broad-based market instrument like a carbon price is that it will draw out the most prospective low-emissions innovation across the Australian economy. In much the same way that such a mechanism identifies least-cost abatement, a carbon price is the most efficient stimulus for innovation.

But these positive effects alone will not be enough to generate economically desirable levels of investment in innovation.

When a private firm invests in research, development, demonstration or commercialisation of new technologies, it takes large risks and spends money on discovering knowledge. If it is successful, it reduces risks and discovers knowledge from which it will receive some benefits in future, but which other firms will share. Patents can keep a proportion of the benefits within the innovating firm, but sometimes only a small proportion, and only for a while. The benefits that one firm's innovation confers on others justifies public subsidy—without public support, there will be much less innovation than is desirable from the point of view of the community as a whole.

Innovation is especially valuable at a time of large and rapid changes in relative prices and in economic structure. In these circumstances, private expenditure on innovation falls short of socially valuable levels by an especially large amount, so the case for public subsidy is especially strong.

To take advantage of the new opportunities provided by a carbon price and to reduce emissions at low cost, substantial public support for innovation is required. Economically valuable innovation has national and international dimensions. This is clear from the Suntech case. The benefits of investment in research, development, demonstration and commercialisation of new technologies are not generally confined within national boundaries. Australian firms will eventually benefit from successful innovation in, say, new biofuels technology that is developed elsewhere. But other Australian firms are likely to benefit more quickly and perhaps more comprehensively from innovation that is undertaken successfully in Australia.

What follows from this international character of the external benefits from innovation?

One consequence is that there may be too little public support for innovation if it is left to the isolated decisions of individual countries—just as there is likely to be too little investment in innovation if it is left to private entities alone without public fiscal support. Sovereign governments will provide support for innovation on the grounds that there will be substantial 'spillover' benefits within their own territories. Indeed, the national advantage from one country establishing itself as a major global centre for production of goods and services embodying a new technology may be large enough to encourage a high level of activity. But we are more likely to obtain a globally optimal level of investment in innovation if each national government is confident that others are making large contributions.

Since the Great Crash of 2008, just such a shift has taken place, with many countries turning to substantial ‘green’ stimulus spending. This has reversed the 35-year decline in real terms in low-emissions energy research, development and demonstration. Stimulus spending saw such investment by governments of developed countries grow from US$15 billion in 2008 (in 2009 prices) to US$23 billion in 2009. The major contributors were the United States, at around US$12 billion, and the European Union, at around US$6 billion.

But, just as in other dimensions of the mitigation project, overall research and development spending in the major developing countries is growing more rapidly still. Chapter 4 discussed China’s use of stimulus spending in response to the Great Crash to accelerate development of low-emissions technologies. The growth in the general level of China’s official research and development spending has continued more or less in line with its high economic growth rate. This growth in investment easily outstrips rates in all other countries, and is expected to continue. The Indian Government has recently established a National Clean Energy Fund for research and innovation, which is financed from production and imports and is expected to provide at least US$550 million per year.

While the increase in government financial support should drive innovation, the International Energy Agency has cautioned that the global impetus for investment in this area through the 2008 and 2009 stimulus packages may not be sustained as governments of the developed countries seek to restore order to national budgets, citing a lack of major announcements in the first half of 2010. Indications for 2010 show that spending levels have dropped and were closer to 2008 levels, marking the end of stimulus spending.

There are good reasons for high-income countries to play their proportionate part in a global innovation effort. That part will be most productive if each country contributes in areas in which it has a comparative advantage in research.

Developed countries have superior endowments of relevant human and physical capital for successful research and development. They are also in a better position than developing countries to invest in long-term and risky projects that hold out the possibility of high returns.

As leading American economist Jagdish Bhagwati has argued influentially in the Indian discussion, developing countries could see a commitment by developed countries to low-emissions innovation and dissemination as a way of discharging their historical responsibility for exhausting the planet's capacity to absorb greenhouse gases. This adds to the case for developed countries to accept commitments to provide fiscal support for research, development and commercialisation of new technologies, whether at home or in developing countries.

In the 2008 Review I noted the requirement for investment in low-emissions technologies of around $US100 billion per year to reduce the costs of transition to a low-carbon economy. I proposed a Low-Emissions Technology Commitment, within which developed countries would undertake to provide their share of a global effort on this scale, calibrated according to national income. Australia's share was calculated at $2.8 billion, which comes down to about $2.5 billion with the exchange rates and other parameters of 2011. Each country would be free to allocate these funds according to its own priorities for work to be undertaken at home or in developing countries.

Australia should commit to its share of the Low-Emissions Technology Commitment, building up to $2.5 billion per year over several years. This funding would be allocated to a number of measures to support increased investment in the research, development, demonstration and commercialisation of low-emissions technologies. Measures to lower the cost to Australia of the transformation to a low-emissions economy should include increasing support for public and private basic research, market-led support for private demonstration and commercialisation, and strong and independent governance arrangements.

There are already a number of government expenditures in these areas, which are harder than might be imagined to separate out in the budget allocations. My recommendations on innovation are based on the expectation that current commitments to expenditure on low-emissions technology innovation during the forward estimates period should be maintained, and that the presumption be made that such expenditures—to the extent of three-quarters of a billion dollars per year—would have been continued beyond the forward estimates throughout the ten-year carbon revenue budget period, without drawing on carbon revenues.

Existing arrangements include the Australian Government's $5.1 billion Clean Energy Initiative. The capacity to make good use of innovation expenditure would rise over time so budgetary provision is phased up towards $2.5 billion per year. Carbon revenues would be used to fund the gap between expenditure required under the Low-Emissions Technology Commmitment and expenditure within the established budgetary arrangements—the gap above three-quarters of a billion dollars in the later years.

Over the first five years of the carbon pricing arrangements, funding committed under these programs would meet a substantial part of the fiscal support for innovation. The funding from the general revenue would be gradually brought within the governance arrangements for innovation support from the carbon revenue. Funding from general revenue could be redeployed in the light of experience, subject to contractual and other indelible commitments. In later years the majority of the innovation support would be funded from carbon price revenue.

New or modified governance arrangements are required to ensure that funds for innovation in low-emissions technologies are used effectively. While a number of steps have been taken towards stronger and more independent governance arrangements, the recommendation from the 2008 Review to establish a new low-emissions innovation council remains relevant today. The council would have oversight of programs across all areas of innovation relevant to mitigation. Ultimately, it would be preferable to have a single overarching body to administer programs for all technologies that will play a role in lowering Australia's emissions.

After a time, the case for accelerated investment in innovation in this particular area would decline, as the market caught up with the sudden expansion of opportunities created by the introduction of the carbon price. Australian fiscal support for innovation in low-emissions technologies could then ease back towards general levels of innovation support, a decade or so after the introduction of carbon pricing.

After a period of adjustment to the carbon price—a transitional period of perhaps ten years—the special case for higher funding for innovation in low-emissions technologies will probably have run its course. However, this should be assessed closer to the time. Beyond this transitional period, funding for innovation in low-emissions technologies can be made through the economy-wide measures available generally to support research and development.

For the rationale for exceptionally large fiscal support for firms that invest in new low-emissions technologies to be sound, government must be able to assure the Australian community that its approach to innovation support is efficient, effective and likely to yield a net benefit to society.

At the basic research end of innovation, there is no alternative to governments, and independent experts on behalf of governments, making decisions on the projects to which public funds will be allocated. Market forces cannot drive Australia's public organisations towards the most beneficial projects in basic research. Government will obtain the best results if it entrusts the task of selecting projects to receive government research funds to a well-equipped independent body. The goal of the body will be to allocate finite resources towards areas of research that will generate large national benefits if they are successful and where Australia already has a strong capability. Comparative advantage in research and national interest in deployment should be the main criteria for allocating funding for basic research.

At the demonstration and commercialisation stage, government can rely on market processes to pick those projects that have the best chance of success and are likely to generate large gains if successful, and are therefore most worthy of taxpayer support. Good governance and sound criteria are of central importance to this approach.

There are three strong reasons for supporting basic research and development. First and foremost, basic knowledge is a public good: once new basic knowledge is created, it is impossible for the person or firm that created it to contain the value or capture all the benefits.

Second, a range of other benefits arise from basic research, principally in the ongoing development of the labour force through concurrent education and training. Third, basic research often entails collaboration, which in turn generates benefits that exceed the sum of the individual research parts. Sometimes this collaboration extends across disciplines and institutions and the parts are only combined in the most productive ways through institutional change. Also, building basic research capacity enables faster resolution of intractable problems that typically arise when developing complex first-of-a-kind technology systems; solving these problems often requires a basic research breakthrough.

The economic case for investment in basic research and development is uncontroversial and widely accepted. The Productivity Commission opposes research and development support purely for the sake of fostering infant industries for good reasons. But it accepts that where underinvestment is a bigger problem in an emerging industry than an established one, more government support could potentially lead to better outcomes for society.

At the demonstration and commercialisation stage, the primary market failure is spillovers—the costs faced by early movers who make the initial investment to demonstrate or apply new technologies that benefit the industry more widely. They can include the costs associated with training in new skills; working through new regulatory frameworks; development of supporting industries and a reliable supply chain; demonstrating and communicating the safety and effectiveness of new technologies to the community; and educating providers of debt and equity about the technical and commercial dimensions of a new technology.

Public funding of education and training can help overcome these barriers, while regulatory and legal barriers to innovation can be reduced with foresight and active policy.

Learning by doing

As a new industry or sector develops and expands, it uncovers cost reductions and more efficient approaches to technology deployment. For example, on-the-ground learning in Spanish solar thermal manufacturing and deployment has led to a fourfold increase in the speed of parabolic mirror assembly, significantly lowering the cost of the product overall.

Costs can also be expected to fall because of economies of scale. As global demand for new technologies increases, production will also shift from batch engineering to more efficient mass-production processes. The cost reductions from mass manufacture of solar photovoltaic panels is a well-documented example of this phenomenon—it is estimated that there has been a twentyfold increase in manufacturing capacity in China in just four years. Unit costs have been falling rapidly with the increase in scale. The cost of nuclear power plants in China has fallen well beyond earlier expectations as multiple orders have allowed production of components and construction to be placed on a continuous basis rather than being produced to order.

Cost reductions can also accrue when multiple identical projects occur in the same geographic area—also known as the local convoy effect—potentially delivering a 5 to 15 per cent reduction in capital costs. Discussion with industry suggests that this is a significant driver of higher costs for wind generation in Australia, where wind farms tend to be dispersed across rural areas, according to the availability of spare transmission capacity.

Learning by research can create a step change in technology cost curves. Significant cost reductions are possible in the shift from the use of parabolic mirrors to concentrating solar thermal towers to produce solar thermal energy more efficiently by achieving higher operating temperatures. Some analysts suggest that the rate of technological advance in concentrating solar thermal could make it competitive with conventional generation sources in the next five to ten years.

Technology costs

The resources boom has lifted Australian costs in general, which has affected the cost of new as well as established technologies. The prices of labour, goods and capital that go into generating new technologies are all higher than expected in the 2008 Review. This contrasts with generally falling capital costs for low-emissions technologies in most of the world.

The rapid growth in new energy technologies has placed a strain on supply and raised the costs of a number of raw materials. For instance, the rising price of polysilicon raised the cost of photovoltaic modules. The requirement for rare earth materials for the production of batteries is another example. This will generally be a short-term effect, as higher prices will provide incentives for large increases in supply and subsequently for lower prices.

The cost pressures have been offset in this country to a degree by the strong Australian dollar, which has reduced the costs of many of the imported components of low-emissions technologies.

Nonetheless, the general market constraints in Australia for materials, skills and finance have created a temporarily high level of price inflation on top of the 'real' technology cost curves. Within this context, however, several low-emissions technologies in the electricity and transport sectors have the potential for surprising rates of cost reduction as a result of innovation.

The remainder of this chapter contains four examples of areas of technological innovation that have particular interest to Australia, given the nature of our economy and natural endowments. The first two, carbon capture and storage and biofuels and biosequestration, are areas in which Australia has a strong comparative advantage in research as well as a strong national interest in application. The third, solar energy, is an area where Australia has some strengths in research capacity through which it has made, and will continue to make, globally significant discoveries, but in which it will generally be a user of the successful outcomes of overseas research, development and commercialisation. Finally, there is a brief update on developments in technology in the transport sector. Here Australia will generally be applying technologies developed elsewhere, although again, we will make contributions to technological innovation in niche areas.

The application of technologies that have been developed elsewhere in a new setting always requires innovation. The maintenance of some world-class research capacity in a field is generally helpful to early adoption of technological innovation from abroad.

Carbon capture and storage

In 2008, it seemed that carbon capture and storage technologies would be a viable and substantial part of the suite of future low-emissions technologies. Its eventual emergence on a large scale was built into the Garnaut–Treasury modelling of the costs of mitigation. Studies and trials to date indicate that there are no insurmountable technological challenges.

Carbon capture and storage has been applied in commercial contexts for several decades and carbon dioxide has been injected in geological reservoirs to enhance oil recovery; several large-scale sequestration projects are building on this experience.

The Gorgon Carbon Dioxide Injection Project, currently under construction in Western Australia, is an important example of capture and sequestration in the process of gas liquefaction. On completion, it will be the world's largest geosequestration project. The project will cost approximately $2 billion and is an integral component of the $43 billion Gorgon Liquefied Natural Gas Project. It will inject between 3.4 and 4 million tonnes per year of carbon dioxide equivalent into a geological formation which is more than two kilometres underground. This would account for nearly 1 per cent of Australia's annual emissions. This is about one-quarter of the emissions of a large brown coal-fired power station (for example, Hazelwood in Victoria), so carbon capture and storage is already important in Australia.

The successful expansion of carbon capture and storage in gas would be of considerable significance. Fugitive emissions from gas and coal currently account for around 7 per cent of Australia's emissions and are expected to account for around 25 per cent of total emissions growth to 2020 under current policies. The contribution would be expanded considerably if geosequestration of emissions from gas combustion were added. Even if carbon capture and storage were applied to emissions associated with gas liquefaction alone, it could make a substantial contribution to Australia's mitigation effort.

The deployment of carbon capture and storage in the electricity generation sector, especially where coal is the energy source, is more technically challenging and expensive. There are large differences in capture costs depending on underlying costs of energy and the distance from and quality of storage sites. The cost of energy matters because capture and storage require large amounts of energy. The Latrobe Valley has significant advantages, with an especially cheap energy source and proximity to an excellent and well-known geological structure, the Gippsland Basin. But other areas with less propitious circumstances face high costs. The effects of high costs have been exacerbated by the economic challenges relating to climate policy uncertainty and first-of-a-kind technology risks.

In recent years, several prominent demonstration projects in the electricity generation sector have failed—including the $4.3 billion, 400 megawatt ZeroGen project in Central Queensland and the US$2.2 billion, 275 megawatt original FutureGen project in the United States. For the ZeroGen project, the primary hurdle was the difficulty of locating an appropriate geological formation. Exploration for bankable storage sites to serve large-scale demonstration projects can be at least as costly and risky as oil and gas exploration. The second large challenge is in accurately estimating the costs of large-scale projects.

Despite initial disappointments in the electricity sector, this is not an unexpected path for the development of such a challenging and complex technology. The G8 goal of broad deployment of carbon capture and storage by 2020 remains achievable, but will be challenging and require political leadership at all levels of government. Governments have made commitments to support around 25 large-scale projects worldwide with a significant increase in allocated funding in 2010. In total, governments have now committed up to US$40 billion to support carbon capture and storage demonstration projects. And the funding allocated to specific large-scale projects is expected to double in the next couple of years.

But we may be close to the point where the risk of disillusionment will accumulate to prohibitive levels in relation to geosequestration from coal-based electricity. This would seriously diminish the prospects for effective action against climate change. It would also seriously diminish the viability of coal as a long-term energy source in Australia's export markets as well as in Australia. It would be unfortunate if a technology with such potential for Australian and global mitigation and such significant implications for the future of the coal industry were abandoned before it had been tried in favourable locations and conditions.

Biofuels and biosequestration

Australia has been at the forefront of research and development in the biological sciences related to the land sector for more than a century. Australian rural industries are built on continuous application of the results of research and development in a country in which soils and climatic conditions are more challenging for agriculture and forestry than in most of the rest of the world.

Australia also has immense opportunities for the absorption of carbon into soils, pastures, woodlands and forests. These are discussed at length in Chapter 10. Here it is enough to observe that research, development, demonstration and commercialisation of new technologies in the land sector should be a major focus of research efforts and public expenditure related to the transition to a low-emissions economy. Australia has a major role to play in the global system in relation to research on measurement of carbon in land environments, biosequestration technologies and practices, and the development of domestic and international rules for incorporating reductions in emissions associated with rural activities into national and international systems of incentives for mitigation.

Australia also has an important role to play in research and development on biofuels.

Biofuels using traditional agricultural land as a source of biological inputs are problematic, largely because they displace food crops. But the new (second-generation) biofuel production systems, which use advanced technologies and non-food plant materials, do not have these problems. They offer the potential for significant emissions reductions compared to fossil fuels and some existing (first-generation) biofuel production systems. The feedstocks for these new systems include algae, crop and forestry residues, and purpose-grown non-food agricultural products. Biofuel products include ethanol, butanol and biodiesel.

These new sources of biomass can be produced on less productive land, allowing relatively low production costs, avoidance of competition with food production, and new commercial opportunities for landholders.

Algae is particularly promising, because of its high efficiency in converting the sun's energy and carbon dioxide into hydrocarbons. It requires much less land or sea area than plants to convert a specified amount of carbon dioxide. Biofuel production technologies that use algae as feedstocks will allow Australia to use resources that it has in abundance—sunlight and saline water and land. There is significant research being undertaken on algae as a feedstock within public research organisations, and commercialisation efforts within several private firms. These warrant strong support.

The new biofuel production systems are at varying stages of development, with numerous pilot projects in operation around the world. Good progress is being made internationally on research, development and commercialisation for some technologies—large-scale production of ethanol from lignocellulosic material is predicted to become cost-competitive (without subsidies) with fossil fuels by 2015.

Australia's relatively modest investment in biofuel research, development and commercialisation deals with new production technologies and transport infrastructure suited to Australia's environment, land management systems and transport fuel needs. Further investment in innovation is needed across the production chain, from biomass availability and harvesting through to processing and fuel production technologies, vehicle performance and distribution infrastructure.

Solar energy

There are two well-established solar energy technologies: solar thermal (including concentrating solar power) for large-scale power generation; and solar photovoltaic. In Australia, solar thermal water heating has been the predominant form of solar energy use to date, with solar photovoltaic representing only 5.8 per cent of total solar energy consumption.

The global photovoltaic market has exploded in the last decade, with an average annual growth rate of 40 per cent. Significant cost reductions have been associated with the increase in installed capacity, linked to both technological improvements and economies of scale. A considerable proportion of the total cost of installing a solar photovoltaic system is represented by the array of photovoltaic cells known as the 'module'. Photovoltaic modules have displayed a well-documented historic learning rate of 22 per cent almost consistently from 1976 to 2010, while capital costs have fallen by 22 per cent for each doubling of capacity. No other energy technology has shown such a high rate of cost reduction over such a long period. Costs are continuing to fall at a rapid rate with expansion of large-scale production in China.

Reflecting the global trend, Australia's total photovoltaic peak generation capacity has increased fivefold over the last decade, driven partly by support through the Solar Homes and Communities and Remote Renewable Power Generation programs. Domestic prices of photovoltaic systems have dropped as a result of an increase in international competition among a larger number of suppliers (influenced by rapid growth of solar energy in China), increased scale of production and a strong Australian dollar. There are still considerable cost-reduction opportunities for photovoltaic systems in both technology improvements and efficiencies of scale, with capital costs expected to fall by 40 per cent by 2015 and 70 per cent by 2030.

The form of solar thermal known as 'concentrating solar power'—a less mature technology than photovoltaic—has also made considerable progress in recent years. A range of sources agree that it has significant cost reduction potential, based on known technical improvements, economies of scale and the increase in industry knowledge from continued deployment of the technology, similar to the observed learning rates of solar photovoltaic. Forecasts of capital costs in the short term are similar to the expectations set out in the 2008 Review, but the longer-term projected cost reductions are significant.

While the vast majority (96 per cent) of concentrating solar power plants built to date have been parabolic troughs, analysis by the CSIRO and others shows that power towers (with a central receiver) have the potential to achieve the lower cost.

Concentrating solar power has been deployed globally since the 1980s and is now undergoing a resurgence, particularly in Spain and California. Its inherent advantages include high efficiency of energy conversion; easy integration with low-cost thermal storage to provide renewable power well into the evening demand peak; and use in conjunction with fossil fuels (notably gas) using the same boilers and generators. Such hybrid generation increases the steadiness of output and reduces the cost of power, and provides more uniform output compared to other intermittent renewable technologies.

The advantages of concentrating solar power and the prospects for rapid cost reductions in both solar photovoltaic and concentrating solar power hold promise for the global mitigation challenge.

Fast trains and electric cars

The 2008 Review discussed the many ways in which emissions would be reduced in the transport sector in the transition to a low-carbon economy. Innovation would be important, but Australia would be mainly absorbing technologies from abroad. (The main exception is probably the role that Australia could play in the development of new feedstocks for biofuels, discussed above.)

The continuation of high oil prices and increasing road congestion in our large cities have helped to sustain the growth in demand for public transport that was evident three years ago. The use of public transport in all states is constrained by capacity. The shift to more emissions-efficient smaller cars with a leavening of hybrids has continued.

The most important overseas developments in the cost of new transport technologies relate to mass production of fast trains in China, and the development of electric vehicles and reduction in their costs everywhere at a much faster rate than had been anticipated in 2008.

China used its stimulus package in response to the Great Crash of 2008 to bring forward from 2020 to 2012 its plans for constructing 13,000 kilometres of fast train track. This has brought into existence a formidable supply capacity that will in due course reduce the costs of deploying fast trains outside China, including in Australia.

There have been major developments relating to electric cars. Zero-emissions road vehicles now seem set to be the most promising source of abatement in the transport sector, through the interaction of electrification of vehicles with the decarbonisation of electricity. The 2008 Review projected that electric vehicles would account for 14 per cent of the transport task in Australia in 2050. Since then there have been many signs that the penetration of electric vehicles will proceed much more rapidly than was built into the Garnaut–Treasury models.

There are a number of reasons for this accelerated transition.

First, stimulation of demand for electric vehicles in the European Union, United States and China has turned out to be stronger than expected. A range of subsidies, tax credits and other incentives have created this effect.

More importantly, after a period of intense debate between the automakers and governments, stricter vehicle emissions regulations are becoming the norm. China's fuel economy standards rank third globally behind Japanese and European standards. President Barack Obama, in his 2011 State of the Union address, announced an objective of having one million electric vehicles on American roads by 2015. Targets announced by major economies would see the sale of more than 20 million electric vehicles by 2020.

Third, direct multibillion-dollar government investments in battery and electric vehicle research and development are leading to a faster rate of technological development and associated cost reductions. Supply-side factors are also playing a role in accelerating electric vehicle penetration. Economies of scale, design improvements and technological improvements are driving battery production costs down. Some analysts have noted that battery costs have been declining more rapidly than expected. Through its multibillion-dollar investment in batteries and electric vehicles, the Obama administration is projecting cost reductions of more than 80 per cent by 2020 along with significant concurrent improvements in battery performance and durability. For a number of years before the global financial crisis, Toyota made batteries the main focus of its large research and development effort in anticipation of pressures for reduction in emissions, and its early lead still puts it in a strong position for hybrid vehicles.

After several years of progress by private Chinese investors seeking to jump ahead of rivals in a new automotive technology where they have no disadvantage from being a latecomer, they have recently been the recipients of major venture capital investment from the United States. In May 2011, Volkswagen announced that it was building a plant for electric vehicles in Shanghai.

The economics of petrol versus electricity as a source of fuel have changed with higher oil prices. In the 2008 Review, forward oil prices in the US$60–70 per barrel range were built into the modelling, but global forecasts now tend to be in the range of US$120–130 per barrel. Strong growth in developing country demand and limited opportunities for expanding supply raise the possibility of prices going much higher at times, pending the development of alternative sources of energy for transport.

One central determinant of future rates of adoption of electric vehicles will be the ability to finance and roll out extensive charging networks. The many hundreds of millions of dollars already committed by private investors suggest that finance will not be a barrier. Australian investors in this area emphasise the potential for the storage capacity of batteries in electric vehicles to transform management of power demand costs and so to lower the costs of generation and distribution of power.

Transport emissions are likely to be reduced earlier and at a lower carbon price than had been anticipated, as long as there is early decarbonisation of the electricity sector.

Conclusion

Past experience with market-based approaches to pollution control in Australia and overseas suggests that government forecasts tend to underestimate the rate of commercial innovation and thereby overestimate the costs of such schemes to society once adequate incentives for innovation are in place. Recently, the Chinese authorities have been surprised by the rate at which the costs of some low-emissions technologies—wind, solar and nuclear—have fallen. Industry projections from overseas suggest that there is the potential for these costs to fall substantially in the short to medium term.

The falling costs of new low-emissions technologies generally bode well for the global and Australian transitions to low-emissions economies.

Technological change can substantially reduce the costs of these transitions to a low-emissions economy. We cannot anticipate the shape or the extent of that change before it unfolds, as firms and individuals find new ways to respond to incentives to economise on emissions. We can, however, put in place the policies that will encourage individual investment in emissions-reducing innovation.

The central policy instrument to encourage the use of established low-emissions technologies and to discover and to apply new technologies is carbon pricing. Putting a price on carbon increases the profitability of investment in innovation.

But the carbon price alone will not lead to adequate investment in research, development and commercialisation of new technologies, because the private investor can capture only part of the benefits. Fiscal incentives can bridge the gap between benefits to the whole of society and benefits to the individual investor in innovation. Part of the carbon pricing revenues—on the plateau of expenditure between about five and ten years from the commencement of carbon pricing, about $2.5 billion per year of the Australian revenue—can be used productively for this purpose.

Support for innovation should extend from basic research and development to the demonstration and commercialisation of new technologies. The basic research will be conducted mainly but not only through public institutions. It requires decisions on allocations of expenditure according to assessments of Australia's comparative advantage in research capabilities, and national interest in successful outcomes. At the commercialisation end of innovation, allocations are best guided by private priorities backed by private commitments of funds, in the form of matching grants or other benefits from government.