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CLIMATE CHANGE
REVIEW UPDATE 2011

Low emissions technology and the innovation challenge

Update Paper 7

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Update Paper seven:

Low-emissions technology and the innovation challenge

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LOW-EMISSIONS TECHNOLOGY AND THE INNOVATION CHALLENGE

Key points

- The cost of effective global and Australian mitigation will be materially lower if opportunities for innovation in low-emissions technologies are fully utilised.
  - There is too little private investment in innovation generally in the absence of public fiscal support.
  - The urgency of the adjustment task and the large change in incentives derived from carbon pricing justify a large transitional increase in public support for innovation related to low-emissions technology.
- Global public expenditure on research, development, demonstration and commercialisation of low-emissions technologies increased in the aftermath of the Great Crash of 2008, reversing several decades of decline in investment in innovation in alternative energy and energy saving technologies.
  - The increased global effort has accelerated progress in cost reductions in low-emissions energy across several technologies.
  - Substantial increases in investment in innovation are still warranted.
  - A new feature of the global innovation effort is a substantial contribution from China and then India.
- Australia should do its proportionate part as a developed country in the global innovation effort:
  - in basic research focusing on areas where we have comparative advantage in research capacity and strong national interest in application;
  - in commercialisation, following business priorities backed by investment commitments; and
  - reducing other costs of innovation by expanding relevant high-level education and removing regulatory and legal barriers to new activities.
- Australian policy on research, development, demonstration and commercialisation has evolved in productive ways since the Review.
  - New general mechanisms for supporting commercial research and development can play a productive role in delivering additional support for low-emissions innovation at the commercialisation end of the chain.
- To ensure the optimal level of innovation in Australia in the transition to a low-emissions economy, I propose a package of measures including:
  - increasing support for public and private basic research;
  - market-led support for private demonstration and commercialisation;
  - the Low-Emissions Technology Commitment on total funding, leading to roughly a doubling of research, development and commercialisation expenditure to $2-3 billion per annum; and
  - strong and independent governance arrangements.

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1. Introduction

1.1 Innovation as a result of a carbon price

New technologies will significantly affect the cost of a global effort to mitigate climate change. As discussed in Update Paper six (*Carbon pricing and reducing Australia's emissions*), putting a price on carbon will provide an incentive to reduce emissions. Innovation will make the transition faster and less costly.

The introduction of a carbon price will deliver a structural shift in the economy as producers and consumers make and use goods, services and processes that generate lower emissions.

A technological response will lower the cost of the structural shift. There will be opportunities for cost-reducing innovation across all sectors of the economy: energy and electricity generation; energy efficiency; transport; urban planning and design; agriculture, forestry and biosequestration more generally; manufacturing; and mining. The policy recommendations in this paper apply to all parts of the economy.

A successful Australian innovation effort will encourage the effective and early use of technologies developed in other countries, as well as the discovery and application in Australia of globally new technologies. Australian policy should support both dimensions of innovation: the early application of technologies developed abroad; and early-stage research and development of technologies in areas in which Australia has comparative advantage in research and strong national interest in successful application.

Australian policy and institutional developments since the Review mean that we can increase our effort in innovation through incremental development of established frameworks. Funding will come from greater use of established arrangements and from carbon pricing revenue.

The carbon price will make it more profitable for firms and industries to invest in research, development, demonstration and commercialisation of low-emissions technologies. Firms will be seeking new goods and services that release fewer emissions and ways of producing them that embody lower emissions. Firms will be encouraged to innovate to reduce emissions because they will make more money by doing so.

It is impossible to know in advance where innovation will occur and be successful. 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.

The design of innovation policy must therefore recognise that the primary role for government is to provide a clear and credible carbon price signal to the world's researchers, innovators and entrepreneurs. For goods that have long asset lives, such as power plants, these signals have to be enduring. The carbon pricing scheme proposed in Update Paper six (*Carbon pricing and reducing Australia's emissions*), with its clear rules and independent governance arrangements, should provide the necessary signal.

But while the carbon price will lead to an increase in investment in innovation, on its own it will not increase it by enough.

1.2 The economic rationale for additional support for innovation

In the context of significant reform and structural change, market failures such as innovation spillovers[1] that lead to suboptimal levels of investment increase the economic cost of the transition. While an emissions trading scheme will drive the development and uptake of new technologies, market failures that impinge on the efficient and competitive functioning of markets for new ideas and technologies are likely to result in suboptimal levels of investment in innovation. This could lead to unnecessarily expensive substitutes being deployed to reduce emissions and to a carbon price that is higher than it would otherwise be (Garnaut 2008).

There are large ‘external benefits’ from one company’s 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 hold a proportion of the benefits within the innovating firm, but sometimes a small proportion, and only for a while.

Innovation is especially valuable at a time of large and rapid changes in relative prices and in economic structure. Private under-expenditure is especially large and the case for public subsidy especially strong in these circumstances. Moreover, the general and potentially large change in incentives leads to a clearer understanding of the value of innovation in a particular area (in this case, new products and processes that are associated with lower emissions) than is generally the case. These are the circumstances in low-emissions technologies now and in the years immediately ahead. These circumstances warrant a higher rate of subsidy for a transitional period for innovation to reduce emissions than in other activities, during which the exceptionally large gap between actual and optimal rates of investment in innovation is reduced to levels that are typical across the rest of the economy.

There is therefore a general economic case for exceptionally large fiscal support for firms that invest in research, development and commercialisation of new low-emissions technologies in the world as a whole and in Australia, through a transitional period. The Update suggests that the transitional period could be considered to cover a decade with special support being gradually withdrawn after that time.

This rationale provides necessary but not sufficient grounds for special support for innovation in the transition to a low-emissions economy. Government must also 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. This assurance must come through policy design. This is a large challenge, because innovation is inherently risky and unpredictable and traditional indicators of performance—efficiency, effectiveness, value for money—are difficult to specify, and even harder to measure in relation to fiscal support for innovation.

Chapter 18 of the Review and Section 2 of this Update Paper discuss the innovation chain, from pure research to the pioneering applications of new technologies on a commercial scale. At the basic research end of the innovation chain, there is no alternative to governments and independent experts on behalf of governments taking decisions on the projects to which public funds will be allocated. Market forces cannot drive Australia’s public and private research organisations towards the most beneficial projects. 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 that is able to allocate finite

[1] Spillovers are a form of what economists call externalities. They occur when the costs or benefits of an activity are borne, at least to some extent, by others not directly involved in the activity. As a result, too much (negative spillovers) or too little (positive spillovers) of the activity may be performed from the perspective of society as a whole. Much of the knowledge and information inherent in innovation can be seen as a positive spillover, since others not directly involved in an innovative activity may benefit from the knowledge or information gained through it.

resources towards areas of research where Australia has a strong capability and that, if the research is successful, will generate large national benefits.

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 simple criteria are of central importance to this approach.

1.3 Global dimensions of innovation

Economically valuable innovation has national and international dimensions. The external benefits of investment in research, development, demonstration and commercialisation of new technologies are not generally confined within national boundaries, although the local and national spillovers may be proportionately larger than the global spillovers. Australian firms will eventually benefit from successful innovation in, say, new biofuels technology that is developed in Germany, China or the United States. But other Australian firms are likely to benefit more quickly and perhaps more comprehensively from innovation that is undertaken successfully in Australia.

Even where there is successful commercialisation of a new technology in another country—say, a new solar-gas hybrid for power generation in the United States—the first firm to apply the new technology in Australia will carry some costs of innovation.

Two implications follow from the international character of the external benefits from innovation.

One is that just as there is likely to be too little investment in innovation if it is left to private entities alone without public fiscal support, so there may be too little public support for innovation if it is left to the isolated decisions of individual countries. 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 government is confident that others are making large contributions. There are advantages in each country announcing clearly its contribution to innovation, and that it sees itself as making a proportionate contribution to an international effort.

The second implication is that domestic support for innovation could contain two categories. One category, warranting a larger level of support, contains globally significant innovation. The second category, warranting a lower rate of support, represents pioneering applications in a national context of technologies that have already been applied successfully in other countries.

So national support for innovation needs to be calibrated according to judgements about reasonable contributions to a global effort. Within this total support, higher weightings should apply to investments in research, development, demonstration and commercialisation that are globally rather than nationally significant.

So Australia's public support for research, development, demonstration and commercialisation of low-emissions technologies is at one level a means of bringing down the costs of the national mitigation effort. At another level, it is our contribution to a global effort. The global effort needs to reach an adequate total scale if it is to optimally reduce the global costs of mitigation. Each country can make an important contribution to a global innovation effort by concentrating its own expenditures in areas in which it has comparative advantage in generating the technologies, and a strong national interest in their use.

As business in other countries responds to carbon constraints and other governments expand their support for low-emissions technologies, Australia benefits from innovations in other countries. We can already see this in declining costs for solar and wind power. We would be beneficiaries of others' expenditures on innovation if we were to enter nuclear power generation. Good innovation policy in Australia will combine rapid absorption and effective use of overseas technological innovation, alongside domestic innovation and its effective use at home and abroad.

Australia is a small player in global research and development, and we will absorb more innovation than we generate. But both the absorption and generation of new technologies will be important in Australia's low-emissions future.

1.4 Structure of this paper

In Section 2, I re-examine the rationale for government support for innovation that was presented in the 2008 Review, and draw lessons from recent policy experience.

Some high-level trends and underlying drivers of change in low-emissions technologies and their effects on costs are discussed in Section 3. In Section 3 and elsewhere in this paper, I emphasise that innovation is important right through the economy. However, I illustrate the conceptual points that I am making mainly with examples and case studies from the electricity and transport sectors, which account for the majority of Australia's greenhouse gas emissions (DCCEE 2011). I will discuss further the relative costs of various low-emissions technologies in the energy sector in Update Paper eight (*Transforming the electricity sector*). Section 4 provides an overview of recent changes to innovation policy in Australia and outlines some of the lesson learned. Section 5 outlines my recommendations for a package of measures supporting low-emissions innovation in Australia.

2. The rationale for innovation support in the current policy environment

2.1 Returning to the market failures framework

A long-term carbon price that is derived from a long-term cap on emissions will create necessary conditions for an unprecedented technological transformation. A carbon price will encourage a switch towards less emissions-intensive activities and promote the uptake of suitable low-emissions technologies. Mature technologies will be the first to benefit, but a price on carbon will also spur research and development activities by creating the demand for low-emissions products and processes.

Understanding the opportunities to reduce costs of new low-emissions technologies is important for assessing the economics of climate change and to guide policy decisions on the timing and trajectory of emissions reductions and on the policies required to achieve the necessary mitigation outcomes at the lowest possible sacrifice of short-term incomes and purchasing power.

One must exercise some caution about the results of analysis of new technology costs as their reproduction in black and white type can provide a false sense of predictability. Proponents of some new technologies may rely on such predictions to argue for financial assistance for aggressive deployment of policies targeted at specific technologies; this is not a sound basis for the development of innovation policy (see Box 1).

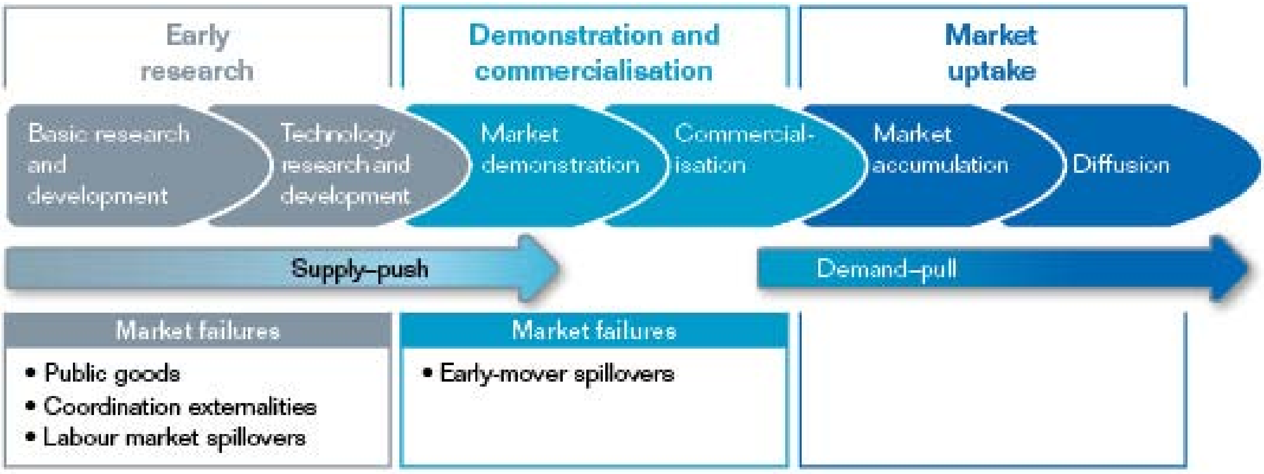
I reiterate two concerns raised in 2008.

First, the exploration of new technologies is inherently highly uncertain. One can be sure that any assessment now of the relative costs of various technologies at some time in the future will be wide of the mark. Policy must allow for uncertainty and, indeed, in many cases, failure.

Second, undisciplined innovation policies will become the focus of strong pressures on the political process for unjustified payments to industries and firms (Banks 2008). The economic case for innovation support must return to the basic arguments for why there may be inefficient underinvestment in research, development, demonstration and commercialisation, and whether the instruments and institutions through which support is available can deliver the intended effects.

In 2008, I argued for innovation policies that address the material market failures along the innovation chain, as illustrated in Figure 1. While for the purposes of illustration this diagram presents innovation in a linear way, it is important to note that innovation is generally an iterative process, with often a need for further basic research in the demonstration and commercialisation process.

Figure 1: Market failures along the innovation chain



Market failures in early research

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 the benefits (Arrow 1962).

Second, a range of positive externalities 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. Also, building basic research capacity enables faster resolution of intractable problems that typically arise when building complex first-of-a-kind technology systems; these problems often require a basic research breakthrough to solve them.

The economic case for investment in basic research and development is uncontroversial and widely appreciated (Productivity Commission 2007b, Garnaut 2008).[2]

Market failures in demonstration and commercialisation

As discussed in 2008, the primary market failure at the demonstration and commercialisation phase is one of spillovers (see also Productivity Commission 2008). There can be strong competition for the economic rents that are captured by innovators but, as Griliches (1992) describes it, the attraction of such rents is dominated by the problem of a firm's imperfect ability to capture the returns from such activities. For instance, while some knowledge spillovers can be internalised through the creation and enforcement of intellectual property rights under the patent system, not all knowledge lends itself to patent protection (Jaffe et al. 2005; Fri 2003).

[2] The Productivity Commission opposes research and development support purely for the sake of fostering infant industries, but accepts that where underinvestment is a bigger problem in an emerging industry than an established one, more government support could potentially lead to better societal outcomes (PC 2010).

The spillovers identified in the Review comprise the following:

- Knowledge externalities — Early movers who make the initial high-cost investment to demonstrate or apply new technologies, which benefits the industry more widely.
- Skills spillovers — Early movers bear the costs of training a new labour force and later movers are able to draw on this pool of skilled labour.
- Regulatory and legal spillovers — Early movers bear the large initial costs of working with government and other industries to develop new regulations and standards, including the costly resolution of legal disputes. Later movers benefit from regulatory clarity and have established avenues for secure agreements and contractual arrangements.
- Support sector externalities — The development of supporting industries and a reliable supply chain requires heavy investment by early movers to identify suppliers with appropriate manufacturing capabilities, develop suitable products and product standards with those suppliers, and test new parts and components.
- Social acceptance spillovers — Later movers can enjoy the fruits of the efforts of early-movers that bear the costs of demonstrating and communicating the safety and effectiveness of new technologies to the community. The difficulties in building community acceptance for an onshore Carbon Capture and Storage demonstration project in the Dutch town of Barendrecht highlights the value of such spillovers for some technologies (see Global CCS Institute [2010]). Communities in countries and regions with nuclear power facilities are usually more supportive of their expansion than are communities in other places of the development of a new nuclear power industry.

One further externality has come to light and can be added to this list: *financial market spillovers.* These are benefits that are created by early movers in educating providers of debt and equity about the technical and commercial dimensions of a new technology. This can make a big difference in capital-intensive industries. Banks do not like to take risks with new technologies. Once a new technology is technically and commercially proven, subsequent projects benefit from a better informed financial sector being willing to lend.

Some of these external benefits of innovation can be partially corrected by other policy interventions.

The skills spillover—the extra costs that an innovator must carry in educating a labour force in new skills—can be reduced by public support for appropriate education and training. This is particularly important when a high level of specialised basic education is required quickly to understand new techniques and to apply new processes. A focused effort to increase the supply of high level skills in engineering and management relevant to innovation is warranted by the innovation challenge that lies ahead, and is the subject of a recommendation of this paper.

Some of the regulatory and legal barriers to innovation can be reduced with foresight and active policy. The efforts that have been made by the Australian and Victorian Governments to remove or reduce regulatory barriers to geo-sequestration provide an important and positive example. The Australian Government's Carbon Farming Initiative in advance of fiscal incentives to innovation in biosequestration is an outstanding example. Development of the physical infrastructure for large-scale use of electric vehicles will require major adjustments to state and local regulatory requirements.

Box 1: Inadequate arguments for deployment policies

Given the urgency and magnitude of technological change required for the transition to a low-emissions economy, there have been many calls to move away from technology neutral approaches towards policies that create demand for certain technologies that appear to be able to provide a single compelling solution. Feed-in tariffs, contracts for difference, supplier obligations, public procurement, mandatory standards or requirements and Apollo/Manhattan style projects[3] are all presented as ways of creating enough demand to pull particular favoured technologies into commercial viability, above and beyond the demand created by a carbon price.

There are economic problems with these policies predicated on prior identification of promising foci of investment.[4] There are no significant market failures that warrant such targeted public support when technologies are relatively mature; such arguments tend to boil down to demand for assistance in industry development. In areas where government has intentionally played an industry development role, these programs appear to have been largely ineffective.[5] This confirms other historical experiences with industry development measures that have proven to be difficult to withdraw and to end up as production subsidies in perpetuity.

Government is never well placed to determine which technology is going to be worthy of such patronage. There needs to be some caution. Once a technology has been identified as one that "must" be part of the solution, there will be a tendency to offer as much public money as is necessary for deployment. Private investors have incentives to push new but mature technologies to the point of being cost-competitive.

Deployment support is expensive. A comparative analysis of policies for promoting low-emissions innovation for the UK Department of Energy and Climate Change concluded that demand-pull deployment support for particular technologies will always be more expensive than supply-push approaches (Frontier 2009). In contemplating policies that create a demand-pull effect, there is an additional risk to consider: the use of some instruments, such as power purchase agreements, contracts for difference and feed-in tariffs go further than merely stimulating demand. These instruments can inappropriately insulate projects from legitimate commercial risks. In addition to encouraging inefficient levels of investment, this also exposes government to potentially unlimited fiscal exposure; the experience of the New South Wales Ggovernment with its premium feed-in tariff is cautionary.

[3] Some commentators have advocated the approach taken in the Apollo and Manhattan projects where government acted as the developer, patron and end-user. However, a number of reports take the opposite view and caution against misusing the analogies of the Manhattan and Apollo projects to justify the approach where governments make a 'big push' in a particular field of research (Mowery, Nelson and Martin 2009, NESTA, Ogden et al 2008).

[4] The exceptional case where demand-pull policies may be warranted is where there are markets with major public good characteristics (OECD 2010a).

[5] For example, the Photovoltaic Rebate Program and the Renewable Remote Power Generation Program subsidised the installation of around 16,000 photovoltaic systems in an 8 year period, but industry has continued to argue for ongoing support (Wilkins 2008).

Modelling of innovation policy

Until relatively recently, the most common approach in climate policy modelling was to omit the effect of innovation policy.[6] As a result, the returns to public investment in innovation were not reflected in the final results. The results therefore tended to overestimate the costs of mitigation and to understate the benefits of innovation policy. Recent modelling which incorporates the effects of innovation policies alongside a carbon price almost always shows a less costly transition when these measures are applied together (see Box 2).

Box 2: Findings from modelling of innovation policy

The additional economic benefits of innovation policies for low-emissions technologies are demonstrated in a number of recent studies which attempt to model technological change in response to such policies. Many studies find that either innovation policy or carbon pricing on its own is unlikely to yield outcomes that are as good as a combined policy package that balances both elements. For example:

> Social gains from innovation increase only if innovation can allow-emissions to be more fully priced. Technology policy is more effective with fuller emissions pricing and is better viewed as a complement to than a substitute for mitigation policy (Fischer 2008).

> ... an optimal portfolio of policies will include an emissions price and subsidies for technology research and development and learning... a policy portfolio of this type can reduce emissions at significantly lower cost than any single policy alone, although the emissions reductions continue to be attributable to primarily the emissions price (Fischer and Newell 2008).

> Policies that include adoption and research and development subsidies in combination with carbon dioxide-trading schemes thus are more cost-effective in achieving the abatement target than trading schemes alone (Otto & Reilly 2008, p 2890).

> ... a global research and development fund to subsidise research and development and/or low-carbon technology deployment could further reduce mitigation costs if it came on top of a carbon price (Bosetti et al. 2009, p6).

> ... optimal policy involves both “carbon taxes” and research subsidies, so that excessive use of carbon taxes can be avoided... (Acemoglu et al. 2010, p 29).

2.2 The contemporary context: an uncertain carbon price

Only global agreement can reduce emissions with the speed and scale necessary to hold risks of climate change to acceptable levels. The world is taking action to reduce emissions, but the approach is uncoordinated, and does not yet support deep international trade in emissions entitlements.

Update Paper six (*Carbon pricing and reducing Australia’s emissions*) noted that the first objective of Australian mitigation policy must be to support the emergence of a strong and effective global agreement. This objective drives the setting of Australia’s domestic carbon price. The setting of the initial price should put Australia on a path towards longer-term outcomes. The carbon price must deliver on multiple objectives. It must be credible in the face of what science tells us is necessary, as well as in response to public and business expectations. It must meet what we have committed to do, domestically and internationally.

[6] Choosing a functional specification that fits within a model, but at the same time is empirically valid, is not an easy task—see Gillingham et al. (2007) for a survey of models with endogenous technological change.

Beginning Australia's emissions trading scheme with a fixed (and rising) price, for three years, can prepare Australia for movement towards a quantity constraint (emissions trading with a target). Such an approach has the added benefit of building industry capacity, and establishing and testing necessary institutions and administrative infrastructure.

This fixed price will stimulate less than optimal levels of innovation and investment. And as Wilkins pointed out, even with a well-designed scheme, the inherent uncertainty around future government regulation could still lead to underinvestment (Wilkins 2008). With uncertainty, the 'demand-pull' effect on new technologies is weaker, and the transition to a low-emissions economy more costly than it would otherwise be. The Organisation for Economic Cooperation and Development recently highlighted that policy stability is the most significant contributor to innovation benefiting the environment (OECD 2010). Our current circumstances, where a carbon price remains the subject of fierce dispute and threats to repeal, will make investment and innovation more expensive and diminish its extent.

Recent analyses have highlighted the possibility that this uncertainty may lead to delays in investment, and decisions to invest in a suboptimal mix of future electricity generation technologies (Blyth 2010, Frontier Economics 2010, Nelson et al 2010). With an initial fixed price period and forward price uncertainty, there is an additional case for government support to ensure that more than the minimal level of innovation and associated structural adjustment takes place.

3. Understanding the likely future costs of low-emissions technologies

''Technological change is at once the most important and least understood feature driving the future cost of climate change mitigation'' (Pizer and Popp, 2008). In general, the costs of novel technologies are expected to fall with time and experience. The phenomenon of learning by doing was articulated by the Wright Brothers in 1936, analysed by Kenneth Arrow in 1962, and popularised by the Boston Consulting Group through the 1960s. Since then many studies have sought to quantify the 'learning-by-doing' effect.[7] There is now ample evidence that the costs of new technologies fall with cumulative global experience.

Real rates of cost reductions are inherently difficult to forecast because the headline rate is the result of a range of cumulative (or even multiplicative) factors, which are in turn driven by technological progress or market dynamics (see CSIRO [2011a and 2011b]). In addition, these market dynamics are played out at both the global and local levels, according to the source of the various input components.

For many low-emissions technologies with components manufactured overseas, Australia is a price and technology taker. The fast rate of technological development and cost reductions at the global level and the strengthening Australian dollar reduce the cost of our adjustment to a carbon price. More abatement is possible at a lower price. However, local cost pressures flowing from the resources boom and higher commodity prices due to increased global demand for energy and metals will offset the technological gains for Australian but not global costs in the short to medium term. In addition, the cost of finance for small and medium firms has risen as a result of a reassessment of risk following the Great Crash of 2008.

The following sections describe how the combination of these global and local factors has resulted in marked increases in electricity generation costs in Australia (see ATSE 2011 and Worley Parsons 2011). I explore the likelihood of these inflated costs being a temporary phenomenon, as there are further breakthroughs from accumulated experience and research—for example, the 'learning-by-doing' effect, as well as technological change resulting from research and development—and as the prospects

[7] A progress ratio of 0.8 is accepted to be the norm i.e., costs are generally expected to decline by 20 per cent with the doubling of cumulative production.

for large falls in generation costs in the medium to long term improve as domestic capacity constraints related to the resources boom start to ease.

3.1 Learning by doing and scale economies: temporarily restricted by the expansion of production capacity

Learning by doing emerges from the economics of repetition and specialisation. As a new industry or sector develops and increases in its experience, 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 four-fold increase in the speed of parabolic mirror assembly, significantly lowering the cost of the product overall (Hearps and McConnell 2011).

Looking across a number of relevant recent studies, the projected reductions in costs of energy can also be attributed to learning by doing in different and interacting components of the technology. For example, photovoltaic installations consist of photovoltaic modules and various other components that make up the ‘balance of system’, each of which has different learning rates (Shum and Watanabe 2008). Similarly wind turbines consist of many discrete capital components, each of which has opportunities for cost reductions (Blanco 2009 and Hearps and McConnell 2011).

Costs can also be expected to fall because of economies of scale. As low-emissions technologies graduate from niche markets to commercial markets, the scale of components and activities can lead to falls in per-unit costs. An example of economies from physical scale is the increasing span of wind turbine blades which have increased approximately six-fold over the last twenty years without the same scale of increases in cost (see Hearps and McConnell 2011).

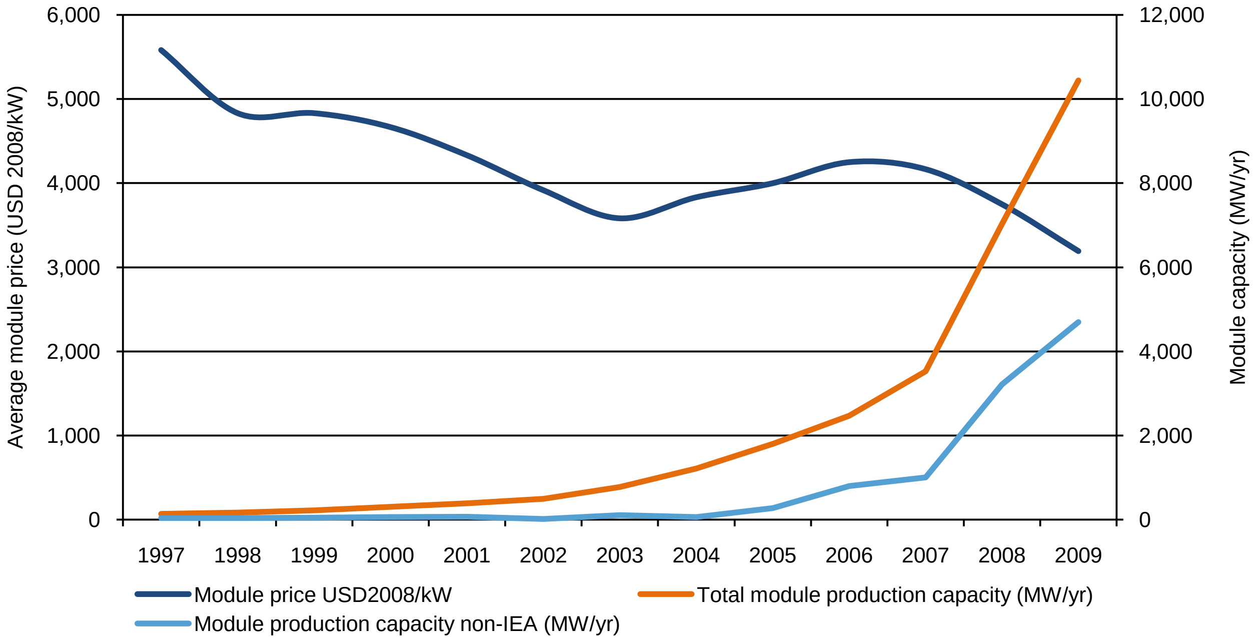
As global demand for new technologies increases, production will also shift from batch engineering to more efficient mass production processes. The cost reductions from mass manufacture of solar photovoltaic panels is a well documented example of this phenomenon—it is estimated that there has been a twenty-fold increase in manufacturing capacity in China in just four years (Hearps and McConnell 2011) and Chinese officials have been pleasantly surprised by the steady year-on-year cost reductions in the costs of panels and expect the recent average annual reductions of 6 to 7 per cent to continue through the foreseeable future (National Development and Reform Commission, personal communication, January 2011). Figure 2 shows the price of modules and the industry’s production capacity. Most of the planned capacity expansions are in China (CSIRO 2011a).

Finally, cost reductions can also accrue when multiple identical projects occur in the same area—also known as the local convoy effect—potentially delivering a 5 to 15 per cent reduction in capital costs (Balagopal et al. 2010). 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.

3.1 Technological breakthroughs: the returns from investments in innovation

Learning by research can create a step change in technology cost curves. Examples of recent technological breakthroughs which have led to dramatic cost reductions include the shift from the use of parabolic mirrors to concentrated solar thermal towers (see IEA [2000] and CSIRO [2011a]). Some analysts suggest that the rate of technological advances in concentrated solar thermal could make it competitive with conventional generation sources in the next five to ten years (Balagopal et al. 2010).

Figure 2: Photovoltaic module price and capacity trends



Source: CSIRO 2011a

One potential driver of accelerated technological development in low-emissions technology is the recent increase in public investment in innovation following the Great Crash of 2008. The injection of substantial 'green' stimulus spending by governments within stimulus packages following the Great Crash reversed the 35-year decline in real terms in low-emissions energy research, development and demonstration (IEA 2010) and raises the prospect of significant breakthroughs. This may extend beyond breakthroughs in learning by doing to shifts in technological processes or shifts in the production function.

Stimulus spending saw low-emissions energy research, development and demonstration investment by governments of developed countries grow from US$15 billion in 2008 (in 2009 prices) to US$23 billion in 2009 (IEA 2010). The major contributors were the United States, at around US$12 billion, and the European Union, at around US$6 billion. The Obama Government has sought to maintain high levels of expenditure on alternatives to fossil fuels, and this was a major feature of President Obama's January 2011 State of the Union address.

Overall research and development spending across all sectors in the major developing countries is growing at higher rates than those of the United States, Japan and Germany. For example, China's rate of growth in total research and development investment has in recent years been similar to its economic growth rate of 9 to 10 per cent; this growth in investment easily outstrips rates in all other countries, and is expected to continue (R&D Magazine 2010). Another indication of the growing contribution from the major developing economies is the Indian Government's new 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 (Robins et al. 2010).

While the increase in government financial support should drive innovation in both developed and major developing countries, 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, citing a lack of major announcements in the first half of 2010 (IEA 2010).

In addition to the increase in public spending on innovation, private sector investment in low-emissions technology has also increased since 2008. For example, early stage venture capital investments into clean technology companies since 2000 have been US$21.6 billion and these investments grew from 2000 to 2008 at a compound average annual growth rate of 36 per cent.

The Australian Stock Exchange listed clean technology sector grew from approximately A$5 billion in market capitalisation in 2005 to approximately A$18 billion before the Great Crash of 2008 (ASX 2010). However, the current level of market capitalisation (approximately A$11 billion) gives only a partial picture—almost 80 per cent of the companies in this sector are small and unlisted (Australian Cleantech 2010).

Clean technology is a growing segment of the global financial universe and private funding of the entire clean technology value chain—from venture capital to commercial project finance—is expected to increase (SAM 2010).

3.2 The Australian constraints: the resources boom and the cost of finance

There are several drivers of higher electricity generation costs that are not specific to the development and deployment of low-emissions technologies, but are a result of the added pressure on the economy's capacity due to the resources boom, and the re-assessment of risk since 2008.

First, labour markets have been returning to the tight conditions experienced prior to the Great Crash, with the re-emergence of skills shortages. The unemployment rate has declined from its mid-2009 peak of 5.8 per cent to its current level of 5.1 per cent. While this is still higher than 2008 levels, it is around the levels of early 2005 when growth in the Labour Price Index picked up to around 4 per cent per annum.

The resources boom has lifted Australian costs in general and resources sector costs in particular. It is leading to particularly strong employment and wages growth in the mining sector (Lowe 2011). The resources boom is also leading to increased demand for a whole range of ancillary professional services. These include engineers, project managers, lawyers, accountants, recruiters and IT specialists. Since 2004, hourly wages in the mining industry have grown substantially more rapidly than across all industries (ABS 2011). To date, reports of skills shortages have been largely confined to mining-related occupations and some specialised professions—the skills in the mining sector are also required in the deployment of new low-emissions technologies. The main story is the lift in construction and related investment costs—all costs that compete for inputs with the resources sector.

The Review noted the large increases in costs of capital construction in the years leading up to its completion in 2008. High rates of increase in capital costs have persisted throughout the last three years despite the pause in growth during the Great Crash and its immediate aftermath. Prices for mineral and metal commodities, such as steel, cast iron, copper and carbon fibre have risen since about 2003, with a brief pause during the Great Crash, and the increases have persisted since 2008 (ABARES 2011). In addition, technology-specific raw materials and novel components required in low-emissions technologies have also sustained high prices as supply shortages have emerged as demand for these new technologies has grown. The CSIRO (2011a) discusses the observed impact of the price of polysilicon on the cost of photovoltaic modules. The requirement for rare earth materials for the production of batteries is another example.

Third, the lingering effects of the Great Crash of 2008 on capital markets is adding to the cost of finance, including for electricity generation projects, both globally and domestically. Prior to the Great Crash, the costs of credit had fallen to historically low levels, and firms had relatively easy access to finance. Since 2008, however, there has been a significant re-assessment of risk and the cost of bank funding has increased, reflecting both regulatory and market pressures. While conditions in global financial markets are markedly improved from their position in late 2008 and early 2009, conditions remain fragile and volatile. "...markets have not returned to their pre-2007 state, but that is generally a good thing as those conditions were not sustainable" (Debelle, 2010). Going forward, global regulatory changes will ensure that the recent trend toward more expensive sources of funding will remain, with borrowers generally paying more for banks' services.

The Great Crash affected the cost and composition of Australian banks' funding, with flow-on effects to their lending rates. Business lending rates rose by around 1.2 percentage points throughout 2009 and 2010. In addition to the increase in the cost of finance, Australian lenders have adjusted their risk profile, making it more difficult for riskier investments to source finance. The difficult conditions in financial markets are likely to have had—and are likely to continue to have—an impact on firms undertaking research and development in low-emissions technology.

These pressures have been offset to a degree by the strong Australian dollar, which has reduced the costs of many of the imported components of low-emissions technologies. Over 2010, the Australian dollar has appreciated by around 23 per cent against the US dollar. As the Australian dollar has appreciated, the decline in the price of imported manufactured goods and the price of machinery and equipment has been particularly pronounced. Indeed, over 2010, the difference in the inflation rate for manufactured goods and the inflation rate for other goods and services was larger than it has been at any time over the past two decades (Lowe 2011).The increased buying power of the Australian dollar magnifies the reductions in component costs that is being achieved overseas (discussed below).

3.3 Technology cost projections for select low-emissions technologies

Since the 2008 Review, a number of studies have updated technology cost predictions for Australia in both the energy and transport sectors—see EPRI (2010), ACIL Tasman (2010) and Worley Parsons (2011). There has been a clear shift from the costs that were assumed in 2008. On behalf of the Update, the Academy of Technological Sciences and Engineering has compared the cost curve assumptions from the 2008 Treasury/Garnaut modelling with the more current technology assumptions.[8]

The analysis by the Academy of Technological Sciences and Engineering shows that—contrary to the global trend of falling costs—there has been a general increase in capital costs for technologies across the board in Australia. However, the costs for some technologies, in particular solar thermal and solar photovoltaic, are expected to fall at a faster rate than previously expected, reflecting powerful international developments.

It seems that general market constraints for commodities, skills and finance have created a temporarily high level of price inflation on top of the 'real' technology cost curves (CSIRO 2011a, CSIRO 2011b).

The Update also commissioned a number of reports examining more recent cost projections both overseas and in Australia.[9] The report by the Melbourne Energy Institute examines the likely future costs for wind, solar photovoltaic and solar thermal. The CSIRO produced five reports examining the technology cost trends for wind and solar photovoltaic, solar thermal, Carbon Capture and Storage, geothermal and wave technologies.

Drawing on these reports and interactions with industry and officials in Australia and overseas, this section considers four case studies of low-emissions technologies in the electricity and transport sectors, which are of particular interest to Australia given the nature of our economy and natural

[8] The Academy of Technological Sciences and Engineering report uses the cost data used in the recent Australian Energy Market Operator modelling for the National Transmission Network Development Plan (AEMO 2010). Available from www.garnautreview.org.

[9] Available from www.garnautreview.org.

endowments. These case studies provide an indication of the nature of the technological challenges in the transition to a low-emissions world, as well as the potential for surprising rates of innovation.

Case study 1: 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 have been applied in commercial contexts for several decades (Interagency Task Force on CCS 2010, Global CCS Institute 2011) and carbon dioxide has been injected in geological reservoirs for the purposes of enhanced oil recovery, and several large-scale sequestration projects are building on this experience. The substantial progress on commercial-scale Carbon Capture and Storage technologies to date has come through in niche markets like enhanced oil recovery and the sequestration of emissions in the process of gas liquefaction.

Given the regulatory requirements to reduce carbon dioxide emissions, and in some cases in response to a carbon price, some gas projects have been injecting the carbon dioxide collected in this manner back into an underground reservoir for permanent storage. An example is the Sleipner project in Norway, which has been injecting a million tonnes of carbon dioxide into underground storage every year since the mid 1990s.

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 may be the world's largest geosequestration project. The Gorgon Carbon Dioxide Injection Project will cost approximately $2 billion and is an integral component of the $43 billion Gorgon Liquefied Natural Gas (LNG) Project. It will inject 3.4-4 million tonnes per annum of carbon dioxide equivalent into the Dupuy formation, which is more than two kilometres underground. This would account for nearly 1 per cent of Australia's annual emissions. By comparison a large brown coal fired power station, Hazelwood, emits 16 million tonnes of carbon dioxide equivalent per annum. The successful demonstration of Carbon Capture and Storage in this sector would raise the prospect for significant emissions reductions—fugitive emissions currently account for around 7 per cent of Australia's emissions and are expected to account for around a quarter of total emissions growth to 2020 under current policies (DCCEE 2011). 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. If geosequestration of emissions from gas combustion were added, it would make a decisive contribution—especially when the possibilities for conversion of coal to gas prior to combustion are taken into account.

That said, there is no reason yet in the development of knowledge for abandoning the prospects for capture and storage directly from coal combustion in locations where coal is cheap and good geological sites are nearby.

The deployment of Carbon Capture and Storage in the electricity generation sector and especially where coal is the energy source is more technically challenging and expensive. The high costs make its deployment anywhere in the world difficult—the more so with the economic challenges related to climate policy uncertainty, first-of-a-kind technology risks, and the current high cost of Carbon Capture and Storage relative to other technologies (Interagency Task Force on CCS 2010). However, recent analysis undertaken for the Government suggests that the anticipated cost for Carbon Capture and Storage is competitive with most low-emissions technologies. Incorporating Carbon Capture and Storage into a power plant is likely to increase costs by between 40 and 75 per cent depending on the technology and fuel source. The capital investment costs represent the source of most uncertainty

(Global CCS Institute 2011) but these are now expected to improve more quickly than previously assumed (ATSE 2011, Worley Parsons 2011).

There are large differentials in capture costs depending on underlying costs of energy and the distance from and quality of storage sites. On both of these issues, the Latrobe Valley has large advantages, with its ample supply of cheap brown coal and proximity to the excellent and well known geological structures of the Gippsland Basin,[10] where there is an estimated 50 GT of storage (Carbon Storage Taskforce 2009).

It is essential that modelling of Carbon Capture and Storage as an element of energy futures in Australia should differentiate Carbon Capture and Storage costs by location. The most likely location of a large-scale, commercially viable capture hub is the Latrobe Valley, due to its relatively low energy, carbon transport and storage costs.

Analysts seem more reserved than they were in 2008 about the near-term prospects for Carbon Capture and Storage in the electricity sector (for example IEA 2010, Balagopal et al. 2010, CCS Taskforce 2009). In 2007-08, a commercial-scale electricity generation project with Carbon Capture and Storage seemed imminent but since the Great Crash of 2008, there has been slow progress. Several prominent demonstration projects in the electricity generation sector—including the A$4.3 billion 400 MW ZeroGen project in Central Queensland and US$2.2 billion 275MW original FutureGen project in the United States—have failed to come to fruition. These two projects highlight the challenges for the future of Carbon Capture and Storage.

The first is the identification of viable storage sites. The exploration for bankable storage sites to serve large-scale demonstration projects can be as costly and risky as oil and gas exploration, especially in regions where there are limited opportunities to exploit depleted oil and gas fields (and the wealth of prior exploration and production data associated with such fields) (Global CCS Institute 2011). The experience of ZeroGen highlights the importance of geological risk: there were several years of exploration (at a cost of approximately AU$90 million) of an initially preferred target area before it was determined in 2010 to be unsuitable for large-scale storage (Garnett 2010). There are large advantages in the use of suitable sites which have been drilled extensively for oil and gas production—in Australia, including in Bass Strait, the Cooper Basin and off the northwest coast.

The second large challenge is in accurately estimating the costs of large-scale projects. FutureGen continues to receive substantial support from the United States Government, but has been scaled back following a series of significant cost increases on original estimates.

Capturing the carbon produced through the burning of coal for electricity generation is a complex process, involving large chemical engineering facilities and significant additional energy use. Capital and operating costs can therefore be high (Carbon Storage Taskforce 2009). However, a range of new technologies continue to be developed to improve the viability of Carbon Capture and Storage in electricity generation. One such technology, known as Integrated Gasification Combined Cycle (or Integrated Drying and Gasification Combined Cycle for brown coal), involves converting solid coal into monoxide and hydrogen or other fuels prior to combustion. The carbon monoxide can be converted into carbon dioxide and then sequestered. The gasification process can be expensive but results in greater thermal efficiency and precludes the need for dedicated capture technology as in post-combustion carbon capture and storage methods. A joint venture pilot carbon capture and storage project, based on coal gasification technology, is currently operational in Victoria (CO_2 CRC 2010).

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[10] Preliminary cost indications for transport of large quantities of carbon dioxide from the electricity generation sources in the Latrobe Valley to Gippsland Basin storage sites range from $1–10/MWh in additional electricity generation costs. This does not include the costs for the new upstream generating and capture capacity (Carbon Storage Taskforce 2009).

Notwithstanding 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 (IEA/CSLF 2010). Governments have made commitments to support around 25 large-scale projects worldwide with a significant increase in allocated funding in 2010; in total, governments committed up to US$40 billion to support Carbon Capture and Storage demonstration projects. Furthermore, the funding allocated to specific large-scale projects is expected to double in the next couple of years (Global CCS Institute 2011).

So while the failures in geosequestration projects are not related to underlying technological and economic realities, there is much less optimism than four years ago about the prospects for Carbon Capture and Storage from the exhausts of coal combustion for electricity generation and industrial production. The increased availability and lower prices of gas in the United States have taken the focus from coal to gas in any case. The continued shortage and high cost of energy in China has discouraged focus on an energy-intensive sequestration technology. The high profile failures of particular projects have affected enthusiasm, despite not being associated with developments in knowledge that seriously diminish realistic expectations about the technology's place in a future low-emissions economy.

We may have reached a stage at which there is a risk that disillusionment will accumulate to prohibitive levels in relation to geosequestration from coal-based electricity in the absence of early success with a commercial-scale project. For reasons set out by Stern (2007) and in the Review, this would seriously diminish the prospects for effective action against climate change. It would also seriously diminish the prospects 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 the potential to improve significantly the prospects for Australian and global mitigation and to offer long-term future prospects for parts of the Australian coal industry were abandoned before it had been tried in favourable locations and conditions.

Case study 2: Solar energy

There are two main types of 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 (Geoscience Australia and ABARE 2010).

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, referred to as the 'module'. Photovoltaic modules have displayed a well documented historic learning rate of 22 per cent[11] almost consistently from 1976 to 2010. No other energy technology has shown such a high rate of cost reduction over such a long period (Hearps and McConnell 2011).

Reflecting the global trend, Australia's total photovoltaic peak capacity has increased five-fold over the last decade driven partly by support through the Solar Homes and Communities program and the Remote Renewable Power Generation Program (Geoscience Australia and ABARE 2010). 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, with the sudden and temporary reduction in demand in the Great Crash contributing downward pressure on prices for a while (Geoscience Australia and ABARE 2010; Hearps and McConnell 2011). There are considerable cost reduction opportunities for

[11] Capital costs have reduced by 22 per cent for each doubling of capacity

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 (Hearps and McConnell 2011).

Concentrating Solar Power is a less mature technology than photovoltaic, but it has also made considerable progress in recent years. A range of sources agree that there is 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 (Hearps and McConnell 2011). Forecasts of capital costs in the short term are no higher than expectations in 2008, but the longer-term projected cost reductions are significant (Hearps and McConnell 2011).

While the vast majority (96 per cent) of Concentrating Solar Power plants built to date have been parabolic troughs, the bottom-up analysis of costs by the CSIRO (2011c) and others show that power towers (with a central receiver) have the potential to achieve the lowest cost in the long term because of their ability to reach higher temperatures and utilise more efficient thermodynamic cycles. An estimate of the costs of different technologies suggests that power towers with storage will have the lowest costs of technology in 2015, compared to fixed and tracking photovoltaics and parabolic troughs (Geoscience Australia and ABARE 2010).

In the future, major opportunities for Concentrating Solar Power include: the mass-manufacture of mirror components which make up the largest proportion of capital cost; implementation of higher temperature steam cycles; increased scale of plant sizes; and convoy/experience effects on engineering and indirect overheads (Hearps and McConnell 2011 and CSIRO 2011c).

The advantages of Concentrating Solar Power (see Box 3) and the prospects for rapid cost reductions in both solar photovoltaic and Concentrating Solar Power technologies bode well for the global mitigation challenge.

Box 3: Advantages of Concentrating Solar Power

Concentrated solar power has been deployed globally since the 1980s and is currently undergoing a resurgence, particularly in Spain and California, due to its inherent advantages, as follows:

- Its potential to become a low-cost technology and reduce its levelised cost of electricity from around $225/MWh currently to $135/MWh by 2020 (assuming the improvements identified in United States roadmaps are achieved). Improvements below $100/MWh are technically feasible by moving to novel high temperature thermodynamic cycles and new low-cost approaches to field design.
- Its unique ability to be integrated with low cost thermal storage to provide renewable power well into the evening demand peak. Storage costs are expected to fall from around $90/MWhth today to $22/MWhth by the end of this decade.
- Its ability to be used in conjunction with fossil fuels (notably gas) using the same boilers and generators, i.e., as a hybrid form of generation, which increases the steadiness of output and reduces the cost of power.
- Its more uniform output compared to other intermittent renewable technologies.
- Its ability to exploit the advances already achieved with conventional thermodynamic cycles and power generation equipment.

Source: CSIRO 2011c

Case study 3: Biofuels

Update Paper four (*Transforming rural land use*) showed how biofuels using traditional agricultural land as a source of biological inputs are problematic, but new (second-generation) biofuel production systems using 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 (Balagopal et al. 2010). The feedstocks for these new systems include algae, crop and forestry residues and purpose-grown non-food plantings. 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. Biofuel production technologies that use these feedstocks will allow Australia to benefit from its natural advantages including abundant sunlight, and areas of less productive land.

These new biofuel production systems are at varying stages of development, with numerous pilot projects in operation around the world (Warden and Haritos 2008). 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 2012 to 2015 (Balagopal et al. 2010). Update Paper four (*Transforming rural land use*) discusses recent Australian developments in production of biofuels from algae and through pyrolysis of plant material.

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 (Warden and Haritos 2008). 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 (Warden and Haritos 2008). I identify additional support via Australia Rural Research and Development Corporations as a suitable platform for providing support in Section 5.

Case study 4: Electric vehicles

As outlined in 2008, zero-emissions road vehicles will be the most important source of abatement in the transport sector, through the interaction of electrification of vehicles with the decarbonisation of electricity. It was projected that electric vehicles would account for 14 per cent of the transport task in Australia in 2050 (Garnaut 2008). Since then other studies have continued to forecast relatively modest levels of uptake (AECOM 2009) but there are many signs that the penetration of electric vehicles will be much quicker than predicted (Jamison Group 2010, Energeia 2010, Deutsche Bank 2009, Becker 2009).

There are a number of reasons that underpin 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 create this effect, but 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 (Oliver et al 2009). The next rounds of vehicle emissions standards in the European Union and United States are likely to be beyond the efficiency improvement potential of the internal combustion engine and therefore necessitate the introduction of hybrid and electric vehicles sooner rather than later (Deutsche Bank 2009).

Secondly, direct multi-billion 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 (Deutsche Bank 2010). Through its multi-billion 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 (US DOE 2010).

The economics of petrol versus electricity as a source of fuel have also changed reflecting higher oil prices. In the 2008 Review, forward oil prices were assumed to remain in the US$60-70 per barrel range, but global forecasts now tend to be in the range of US$120-130 per barrel.

One key determinant of future rates of adoption will be the ability to finance and roll out extensive charging networks for electric vehicles. The many hundreds of millions of dollars already committed by private investors suggest that finance will not be a barrier.

Transport emissions may be reduced earlier and at a lower carbon price, as long as there is decarbonisation of the electricity sector, in conjunction with the accelerated electrification of the vehicle fleet.

3.4 Implications for Australia's transition to a low-emissions economy

Past experience with market-based approaches to pollution control in Australia and overseas suggest that government forecasts tend to underestimate commercial innovation and thereby overestimate the costs of such schemes to society (Grattan 2010). Recently, the Chinese authorities have been surprised by the rate at which the costs of the low-emissions technologies—wind, solar and nuclear—have fallen. Recent industry projections from overseas suggest that there is the potential for these costs to fall substantially in the short to medium term (Hearps and McConnell 2011).

All else being equal, the falling costs of new low-emissions technologies generally bodes well for the global and Australian transition to a low-emissions economy. But conversely, if efforts to develop and deploy new low-emissions technologies are unsuccessful or more expensive, there will be a larger reduction in national incomes.

The problems of Japanese nuclear plants following the March 2011 earthquake and tsunami raise doubts about expansion of nuclear capacity just as it was moving back into the lists of possible new investments in the United States, parts of Europe and Japan, and had become important in plans for electricity generation investments in China and India. The impact of the Japanese experience is uncertain. It will depend on the unfolding of current events. Nuclear is potentially an important part of the story of decarbonisation of the global economy. As will be discussed in Update Paper eight (*Transforming the electricity sector*), it is less likely for the foreseeable future to be economic in Australia given the domestic availability of gas at lower prices than in other developed countries.

Sensitivity analysis of the economic modelling undertaken for the 2008 Review found that the projected impact of global mitigation on Australia's economy could range from 3.6 per cent to as high as 5.7 per cent of GNP[12] in 2050—depending on the level of technological progress (Treasury 2008).[13] While the 2008 modelling assumed that a proportion of tax revenue would be allocated to innovation policy, it did not allow for any increase in the rate of technological improvement as a result of additional government support. This was simply because we did not have a clear basis for making any particular assumptions about increased rates of change as a result of higher levels of investment in research,

[12] Garnaut -10 scenario.

[13] The range in 2100 is even more stark, starting at 2.7 per cent of GNP in the optimistic technology case, rising to 12.2 per cent in the pessimistic case (Treasury 2008).

development, demonstration and commercialisation of new technologies. The assumption in the modelling was conservative—excessively so. Since 2008 other studies that have incorporated technological change support the adoption of complementary low-emissions innovation policies to facilitate a smoother transition and less costly adjustment to a carbon price (see Box 2 above).

Without rerunning the modelling with updated figures on technology cost curves, it is difficult to assess how the updated costs might yield a different story for Australia's low-emissions transformation. However, recent electricity market modelling undertaken by the Australian Energy Market Operator for the National Transmission Network Development Plan shows that for the time being the general trends in the electricity sector are unlikely to be substantively different from those written into the modelling reported in the 2008 Review (see AEMO 2010). The developments with transport electrification suggest that the costs of decarbonisation may turn out to be lower in that sector than had been presumed in 2008.

4. Lessons learnt from Australia's low-emissions innovation effort

4.1 Recent improvements to the Australian innovation system

Innovation policy in Australia has undergone various changes in recent years, many of which have improved the prospects for an efficient technological response to a carbon price.

First, the Review of the National Innovation System (the Cutler Review [2008]) and the subsequent government response, *Powering Ideas: An innovation agenda for the 21st century*, set in train a number of changes to programs and governance arrangements.

The most significant change has been the planned replacement of the Research and Development Tax Concession with a Research and Development Tax Credit. Like other entitlement schemes[14] the Research and Development Tax Credit is broad based and market driven. The core components of the package are a non-refundable 40 per cent research and development tax credit for all eligible entities and a 45 per cent refundable[15] tax credit for small and medium businesses. The differential is based on the idea that smaller businesses will be less inclined to undertake substantial amounts of research and development. The credit has similar value for firms whether or not they currently have taxpaying status. It is intended that the new scheme will also be clearer and better targeted, with a tighter definition of eligible 'research and development activities' to ensure value for money for taxpayers (AusIndustry 2011).

Australia is part of a trend amongst developed economies to increase the use of entitlement based schemes, particularly research and development tax credits, and to increase the assistance rates. This growing preference is in part due to the fact that such approaches are less likely to distort private decisions and market behaviour than more targeted direct support (OECD 2010).

The other major development in Australia since 2008 is that innovation in new sources for low-emissions electricity, derived from both renewable sources and fossil fuels, have received a boost in government support, primarily as part of the Australian Government's $5.1 billion Clean Energy Initiative and various programs listed in Table 1. Low-emissions and renewable-energy innovation has been an important focus of reinvestment in the Australian innovation system, receiving 32 per cent of

[14] See OECD (2010d) for an overview of the variants of research and development credits and the alternative approaches taken in different countries. Thompson and Webster (2011) provide an overview of how such schemes perform relative to other forms of research and development support.

[15] The size of the tax credit is only slightly larger for small businesses but the refundable nature of it ensures that a business receives its credit in cash, even in years when the business's tax liability is a fully private decision.

the grant funding allocated for science and innovation programs in 2009-10. Other Commonwealth programs such as ‘Smart Grid, Smart City’ and a variety of state clean energy innovation programs have added to the funding available to support research and technology demonstration in this area.

Table 1: Direct Australian Government funding for innovation in low-emissions technologies

	Program	Objective	Announced funding
Carbon capture and storage and clean coal	Carbon Capture and Storage Flagships Program	To demonstrate CCS technologies on a commercial scale and accelerate the broader deployment of CCS in Australia from 2020.	$1.85 billion
	National Low Emission Coal Initiative	To support projects and other activities, including the Low Emissions Coal Initiative Council, aimed at the development and deployment of low emissions coal technologies in Australia.	$385 million
Solar	Solar Flagships Program	Round one only - to select up to two projects with an electricity generation capacity from solar energy of up to 400 megawatts across both projects. $1.5 billion is the entirety of the program funding.	$1.5 billion
	Australian Solar Institute	To support solar thermal and solar photovoltaic research and development, and to foster collaboration between researchers in universities, research institutions and industry in Australia and overseas.	$150 million
	Australian Centre for Renewable Energy Solar Projects	To provide the large scale demonstration of the commercial viability of new solar energy technologies, and, therefore, encourage the roll out of these technologies to assist in meeting the RET.	$92 million
Renewables	Emerging Renewables Program	Provide support to technologies that offer significant potential as sources for large scale base load power.	$40 million
	Renewable Energy Venture Capital Program	To make critical, early stage equity investments that augment private funds to help commercialise emerging renewable energy technologies.	$100 million*
	Renewable Energy Demonstration Program	To provide large-scale demonstration projects to test and if possible to prove the commercial viability of new solar energy technologies	$235 million
Biofuels	Australian Biofuels Research Institute	To focus on commercialising research into second generation biofuels	$20 million
	The Second Generation Biofuels Research and Development Program	To provide grants and support the research, development and pre-commercialisation of second generation biofuel technologies.	$12.6 million
Storage	Advanced Electricity Storage Technologies Program	To reduce barriers to the uptake of renewable energy technologies by providing grants and supporting the development and demonstration of electricity storage technologies for use with variable renewable generation sources	$20 million
Wind	Wind Energy Forecasting Capability Initiative	To fund the development and installation of software and systems for the effective forecasting of wind energy generation in Australian power systems.	$14 million
Geo-thermal	Geothermal Drilling Program	To develop geothermal energy by supporting the cost of proof-of-concept projects, including drilling geothermal wells	$50 million

Note: Funding runs to 2016-17

*funded from the Renewable Energy Future Fund. The $652.5 million Renewable Energy Future Fund announced in May 2010 will be delivered through a number of departments and agencies, with the Department of Climate Change and Energy Efficiency coordinating Fund priorities and progress.

Source: Information collated by the Department of Resources, Energy and Tourism

Such support targets the market failures of demonstration and commercialisation discussed in Section 2. The significant quantum of public support goes a long way to addressing the recommendations in the 2008 Review for an increase in available matching funding in this area.

Finally, a large number of institutions and governing bodies have been established in recent years to facilitate investment in low-emissions technologies in Australia, the region and the world. Examples of multilateral, bilateral and project-based partnerships in which Australia is involved are provided in Table 2.

In 2009, the Leaders of the Major Economies Forum on Energy and Climate[16] agreed to dramatically increase and coordinate public sector investments in research, development and demonstration of low-emissions technologies, with a view to doubling such investments by 2015 (MEF 2009). This is a positive step for coordination of international action and promotion of greater financial commitments. A further positive step on international coordination was the agreement at the United Nations climate change talks in Cancun in 2010 to establish a Technology Mechanism to accelerate technology development and transfer to developing countries for adaptation and mitigation.

Table 2: Examples of international low-emissions technology partnerships involving Australia

Partnership title	Description
Asia Pacific Partnership on Clean Development and Climate	Addresses climate change, energy security and air pollution while promoting economic development and poverty reduction. Covers clean coal, renewable energy, distributed generation, and power generation and transmission. An example activity is a joint CSIRO-Thermal Power Research Institute (China) project to capture carbon dioxide from a coal-fired power station in China.
Carbon Sequestration Leadership Forum	Ministerial-level initiative to facilitate improved cost-effective technologies for separation and capture of carbon dioxide for transport and storage.
Climate REDI (Renewables and Efficiency Deployment Initiative)	Program to accelerate deployment of renewable energy and energy efficiency technologies in developing countries.
Global Carbon Capture and Storage Institute	Aims to help deliver the G8 goal of developing at least 20 industrial-scale carbon capture and storage projects by 2020.
Global Research Alliance on Agricultural Greenhouse Gases	Facilitates collaboration and investment in research into estimating and managing emissions and carbon sequestration in agricultural systems.
International Partnership for the Hydrogen Economy	Forum for government cooperation and information sharing in advancing hydrogen and fuel cell technologies.
International Renewable Energy Agency	Promotes widespread and increased adoption and sustainable use of all forms of renewable energy.
Major Economies Forum Technology Action Plans	Plans identify mitigation potential of high-priority technologies, best practice policies, and specific actions countries can take to accelerate low-carbon technology development and deployment.
Methane to Markets Partnership	Government and private sector partnerships to advance methane recovery and use for energy. Focuses on: fugitive emissions from coal mines; agriculture; landfills; and oil and gas systems.
Renewable Energy and Energy Efficiency Partnership	Non-profit organisation aiming to catalyse the market for renewable energy and energy efficiency, with a primary focus on emerging markets and developing countries.
US-Australia Solar Research Collaboration	Supports joint projects to cut the cost of solar energy technologies.

Sources: CSIRO 2010, DRET 2011, Gillard 2010, Global Research Alliance on Agricultural Greenhouse Gases 2011, MEF 2009b, REEEP 2011, Office of the Press Secretary 2009.

[16] The Major Economies Forum on Energy and Climate represents about 80 per cent of global energy emissions.

4.2 Outcomes of Australia's demonstration and commercialisation approach

Assessing the effectiveness of innovation policies is inherently complex due to the highly risky nature of such endeavours, the challenges in measuring innovation (Smith 2005) and the short amount of time during which such programs have been in place.

The Wilkins Review of Climate Change Mitigation Policies was critical of existing programs up to 2008. In particular, it found that existing low-emissions technology development and demonstration programs have not produced benefits that justify the costs involved, do not represent best practice policy design and are unlikely to deliver a sufficient portfolio of technologies that will facilitate Australia's transition to a low-emissions economy (Wilkins 2008). The review warrants careful consideration.

It appears that, to date, government support for innovation in low-emissions technologies is characterised by delays in program implementation and under-expenditure.

In 2003-04, the Australian National Audit Office had identified the timely achievement of program objectives as a substantial risk for programs administered by the then Australian Greenhouse Office; in particular, it drew attention to the timeframes of negotiations over funding agreements for which there were substantial delays (ANAO 2004). This remains a problem for more recent programs. The selection and contracting processes are highly resource and time intensive from the perspectives of both the Government and those bidding for funds. Two or three years often lapse between announcement and the finalisation of successful projects (Grattan forthcoming).

A large proportion of allocated funds have not been spent. While it would be wasteful and thoroughly undesirable to pursue expenditure for its own sake, the high proportion of unused funds in conjunction with apparently robust demand—as indicated by calls and applications for grant funding—suggests that delays indicate a deeper issue. Three grants programs assessed by the Australian National Audit Office in 2010 were characterised by significant under-expenditure. The $500 million Low-Emissions Technology Development Fund spent less than 5 per cent of its budget over a 5 year period. The $93.8 million Solar Cities project spent 26 per cent of its budget allocation over the same period (ANAO 2010). The $400 million Greenhouse Gas Abatement Program spent just 40 per cent of its budget allocation over 10 years. It is said that this phenomena of under-spending is a common occurrence across Commonwealth and State programs (Grattan forthcoming).[17]

Australia's experience in this area is not unique. The UK Department of Energy and Climate Change (and its predecessors) planned to provide support for renewable energy technologies totalling £367 million between 2000 and 2009, but only £186 million was actually spent (Committee of Public Accounts 2010). This under-expenditure is clearly problematic, considering the high level of project attrition. In the UK, many proposals for renewable energy schemes do not proceed; 40 per cent fail to secure planning approval in England while others are unable to obtain finance (Committee of Public Accounts 2010).

4.3 Lessons for future demonstration and commercialisation programs

Project delays and allocated but unused funds come at a cost to the Australian economy and the innovation effort in related fields. These issues may arise for good reason and may in fact be unavoidable; innovation is unpredictable and depends on context and circumstance and project cancellations highlight the risks with such ventures.

[17] Some funds may be initially allocated but undergo a period where the successful applicant is 'grant squatting' before pulling the plug on the approved project. Grant squatting occurs when a substantial proportion of funded projects take several years before a proponent formerly withdraws their project thereby freeing up the allocated funds (Grattan forthcoming).

However, it may also signify that proponents of new technologies are having difficulty making the most of the current suite of programs and available public funds, or that the elements of program design are out of alignment with market conditions. It is important for the Government to absorb the lessons that can be learnt from policies and programs to date.

Drawing on recent studies including the Wilkins Review and Australian National Audit Office (ANAO) audit of the Administration of Climate Change Programs, the Update identifies five areas of the recent policy experience from which we can draw instructive insights. These findings—discussed below—apply the principles for innovation programs proposed by Thomson and Webster 2011 listed in Box 4.

Box 4: Principles for the design of research and development schemes

The best research and development scheme should engender lasting innovation capabilities and embody enough flexibility for support to be re-orientated in response to changing opportunities and needs.

A desirable scheme should:

- be enduring to an extent that allows formation of a stable and predictable source of funding for industry;
- embody clear and unambiguous rules that are easy for industry to discover and interpret;
- explicitly acknowledge that some projects will be unsuccessful;
- recognise that support should match one-to-one with external benefits so that separate research and development schemes are additive;
- consider judicious targeting at a few technology areas in which Australia has a comparative advantage;
- allow little or no scope for bureaucratic discretion and political interference in the selection process; and
- not target additionality or otherwise over-engineer selection criteria with unachievable or unmeasurable goals.

Source: Thomson and Webster 2011

Lesson 1: Policies and programs lack clear objectives

Historically, the impacts of programs that seek to promote innovation in low-emissions technologies have been diluted by having mixed objectives. The Australian National Audit Office audit of the Administration of Climate Change Programs highlighted the need to set clear and measurable objectives as an overriding issue; programs generally have broad, if not multiple overriding objectives (ANAO 2010).

These overlapping objectives may include greenhouse gas abatement, industry support and regional development. In the absence of a carbon price, it is understandable that innovation programs related to climate change tend to include greenhouse gas abatement as a key objective; this is not desirable once we have a carbon price. The introduction of a carbon price should allow such programs to be focussed on innovation market failures. And there is no case for objectives of industry support and regional development to be mixed with and to dilute the correction of innovation market failures. With overlapping objectives, it is not surprising that there is apparently no explicit link between expected spillover effects and the quantum of funding committed (Wilkins 2008).

Lesson 2: Instruments of support are inflexible

To date, grant tendering has been the primary means of providing innovation support in Australia (Cutler 2008; Wilkins 2008). Aldy et al. (2009) and others have said that there is as yet limited evidence on the most effective and efficient measures for supporting innovation (see also Frontier [2009]).

The delays experienced with the Low-Emission Technology Development Fund raise questions about whether more flexible instruments would have been better.

Support for technology demonstration and commercialisation, such as is provided from the Low-Emissions Technology Development Fund, which involves one-off funding decisions, does not fit well with the model used for financing and delivering large technology demonstration projects in the commercial sector (Wilkins 2008). The approach of the Low-Emissions Technology Development Fund appears to have been repeated with more recent large-scale demonstration programs.

Lesson 3: Program criteria are complex

The high level of under-expenditure on recent programs has been attributed to the complexity involved in identifying and developing suitable projects (Grattan forthcoming). This is in turn dependent on the specification of criteria that can be complex and onerous. There is an argument that some complexity in criteria is necessary, even unavoidable, to ensure that taxpayers receive value for money and beneficial project outcomes. However, complex criteria can be partly attributed to a low tolerance for project failure by government. This is problematic, as risk, and therefore a proportion of failures, is an inherent feature of innovation.

It is not clear whether the use of more complex criteria has been effective in reducing failures. In fact, some officials suggest that the highly engineered nature of programs to deliver particular outcomes has made it more likely that projects have to be withdrawn, and that more numerous and more stringent criteria increase the likelihood of non-conforming bids. Thomson and Webster (2011) draw a similar conclusion.

Lesson 4: Support is not technology neutral

Direct support for innovation in low-emissions technologies increasingly tends to be allocated to specific technology areas or sectors (Wilkins 2008). As Table 1 shows, many emergent low-emissions technologies have been furnished with their own set of supporting measures. Most economists accept that a technology neutral approach to research and development is preferred. The free flow of funds to the most meritorious projects, without government deciding that a particular technology is likely to succeed, is likely to yield the greatest returns to society.

Lesson 5: There is a lack of funding continuity

Programs have to exist for an extended period before being well understood by business and industry, particularly smaller entities (Thomson and Webster 2011). Reductions in funding allocations over time have become common. Examples include:

- the reduction on two occasions of funding to the Carbon Capture and Storage Flagships program—$65 million was redirected to the Sustainable Geoscience Australia Initiative in the 2010-11 Budget, and in early 2011 $90 million was cut and $160 million deferred to fund the Queensland flood reconstruction;
- the Renewable Energy Demonstration Program, which was reduced by almost a third in the 2010-11 budget; and

- the National Low-emissions Coal Initiative, from which approximately 20 per cent of the original 2008-09 Budget allocation was redirected to the Global Carbon Capture and Storage Institute.

In many cases, funding is reduced to meet the urgent priorities of the Government. For example, the recent reductions to various programs to fund the flood reconstruction in Queensland highlight the vulnerability of historical allocations to research and development in situations of fiscal constraints. While there are important reasons to retain fiscal flexibility, this has to be balanced against the need to provide funding continuity for research, development, demonstration and commercialisation in low-emissions technologies. Recent assessments in the UK have affirmed that long-term support is critical and support that does not extend beyond a three year period is inadequate (C&AG 2011).

5. A package of measures to promote innovation in low-emissions technologies

Building on the policy progress in recent years and taking into account the lessons from experience, I propose a modified package of measures to ensure the optimal level of innovation in Australia in the transition to a low-emissions economy. The paper builds on the recommendations of the Review and mostly involves extending changes in direction that have been proceeding since 2008. In summary, there are four main elements to this package.

1. Driving public and private basic research in low-emissions technologies (Section 5.1)

- Provide public sector research organisations with additional funds to be directed at areas of national interest where Australia has a comparative advantage in basic research.
- Provide new and established (in this case, rural) industry research and development corporations with a temporarily higher rate of matching Commonwealth funds in areas of low-emissions research.
- Allocate additional funding for basic research by businesses in low-emissions technologies through a premium on the proposed Research and Development Tax Incentive.

2. Market-led support for demonstration and commercialisation (Section 5.2)

- Provide support in the form of up-front grants, matching commitments by private investors and therefore embodying their priorities.
- Implement simple assessment criteria and explore possible proxy indicators that would reduce the informational requirements for funding approval.
- Adopt an ‘open for business’ approach to demonstration and commercialisation support rather than a series of competitive funding rounds.

3. The Low-Emissions Technology Commitment (Section 5.3)

- Adopt a Low-Emissions Technology Commitment with a funding pledge that increases over time to $2-3 billion per year. This pledge is for both public and private basic research and market led support for demonstration and commercialisation. Expenditure by the Australian Government for innovation activities in any sector relevant to lowering emissions in Australia or overseas would count towards the acquittal of this commitment.
- The Low-Emissions Technology Commitment should not allocate specific proportions or quanta to particular technologies. A larger initial allocation towards basic research is warranted on the grounds that established institutions have the capacity to quickly expand the effective research

effort. Demonstration and commercialisation could represent a high proportion of growth in expenditure after the initial period.

4. Strong and independent governance arrangements (Section 5.4)

- Establish a new Low-Emissions Innovation Council to oversee and direct Australia's basic research effort in low-emissions technologies and to administer the government's policies and programs supporting relevant projects at the demonstration and commercialisation phase.

5.1 Driving the basic research and development agenda

Research targeted at areas of national interest where Australia has a comparative advantage

The first element of the new package of innovation measures targets basic research. Public sector research organisations such as universities and the CSIRO should receive additional funds for research and development in low-emissions technological innovation in areas of national interest where Australia has a comparative advantage in research.

As discussed in 2008, three considerations are important when assessing what is in Australia's national interest: Australia's emissions profile; technological solutions that related specifically to local conditions and natural resources; and economic activities that have large roles in the Australian economy at present or prospects for having large roles in future. More generally, basic research is relevant to Australia's national interest if it is in an area or technology that would naturally have a large part in Australia's future in a low-emissions world.

Comparative advantage in research relates to relative strengths in demonstrated Australian capacities, compared with relative strengths of other countries. It would be possible over time to develop quantitative indicators of comparative advantage in research.

Three areas of basic research that potentially meet the dual criteria of national interest and comparative advantage are discussed in Box 5.

Additional support for research and development corporations

For areas where industry-based research and development corporations are the primary vehicle for commissioning such research, as they are for most large Australian rural industries, it would be appropriate for government to rely on the strengths of such arrangements. Government could provide a temporarily higher rate of matched funding for research on emissions-reducing technologies through the research and development corporations. This could be particularly important in relation to utilisation of new opportunities for biosequestration in rural areas that would be opened by the linking of the Australian Government's Carbon Farming Initiative to the carbon pricing scheme.

The strengths of the Research and Development Corporations are well documented (Thomson and Webster 2011, Productivity Commission 2010). The Productivity Commission's Review of Rural Research and Development Corporations (PC 2010) has recommended changes to Australia's framework, in particular, the creation of a new body—Rural Research Australia—to focus on cross-cutting research that is likely to be under-provided by the industry-specific Research and Development Corporations. Climate change mitigation would be one such issue.

On average the Australian Government funds 50 cents in every dollar of research undertaken by the rural Research and Development Corporations (Productivity Commission 2010). Based on the economic rationale for targeted support discussed in Section 2, I recommend a rate of matched funding that is 20 per cent higher for research and development in areas relevant to Australia's transition to a low-emissions economy. This higher rate would apply to all non-Commonwealth funds committed to a project, including within reasonable limits private and state government commitments to projects jointly funded by rural research and development corporations and others.

In the same way, new industry-based research and development corporations that are established to respond to the need for innovation in response to a carbon price could also attract the higher rate of matched funding. The 2008 Review highlighted the potential for voluntary levies to raise significant funds for industry driven research and development, particularly in the coal sector.

Box 5: Examples of areas of national interest and comparative advantage

Carbon Capture and Storage, geothermal energy and biosequestration are three examples of fields of research that meet the national interest and comparative advantage criteria for basic research.

It is clearly in the national interest to reduce the large contribution made by coal-fired electricity generation to Australia's emissions profile, and to preserve a role for coal exports in future through other countries adopting Carbon Capture and Storage. Australia's abundant coal resources have enabled low domestic energy prices while providing substantial export revenue. Carbon Capture and Storage will serve the national interest by maintaining the value of this resource in domestic use and for export. The proximity of carbon dioxide sources to sites for geological storage with enormous potential resources make this technology particularly suited to further exploration and research in Australia (Carbon Storage Taskforce 2009, CSIRO 2011d).

Australia's geology and large land area produce considerable physical potential for geothermal energy (Geoscience Australia & ABARE 2010). Realising a small fraction of this potential could provide reliable, baseload, dispatchable and low-emissions electricity, as well as heat suitable for many applications (CSIRO 2011e). With these characteristics, geothermal energy could provide an alternative to emissions-intensive energy sources in Australia and improve energy security. As Australia's geothermal resources, related to deep hot rocks, are of a different type to most of the resources currently exploited overseas, development of technologies suited to these conditions is required. Innovation in Australia would have global application.

Australia has strong research skills in fields required for innovation in geosequestration and geothermal energy, based on its history of internationally competitive mining and related engineering and construction.

The land sectors are a major source of emissions in Australia. At the same time, they could play a significant role in the national mitigation effort, because of the large scale of rural land use and availability of a range of potential biosequestration options applicable to Australian conditions (see Update Paper four [*Transforming rural land use*]). Positive links between biosequestration and economic gains could enhance the role of the rural sector in Australia's economy. Australia's strength in agricultural and biological research provides a clear comparative advantage for low-emissions innovation in the land sectors.

Additional support for business research and development

As the carbon price increases the appetite for new technologies amongst relevant industries, private businesses will increase their investments in innovation throughout all phases of the innovation chain. Some businesses may undertake projects that span the research and development and demonstration and commercialisation phases. Indeed large scale demonstration and commercialisation projects often entail some level of basic research.

Where businesses engage in basic research and development, they can generate the same kinds of spillovers and public good benefits that were discussed in Section 2. Private businesses can generate public knowledge, provide education and training on the job and collaborate with other businesses and not-for-profit research organisations. There is therefore a case to direct much of the additional funding to stimulate the level of private research and development activity.

Two instruments fare important for funding an expanded private effort.

The case for additional support for commercialisation of low-emissions technologies through a transitional period can be met by drawing on the strengths of the Research and Development Tax Incentive scheme that is soon to be introduced (see Section 4). A premium can be applied for research and developments incentives which qualify as being applied to low-emissions technologies. This is the approach taken in the UK in another area of high priority research and development with the Vaccine Research Relief program—research on vaccinations for Malaria, AIDS and tuberculosis qualify for an additional level of deduction (HM Revenue and Customs 2011).

In the context of mitigation research, the government would apply a premium to the Research and Development Tax Incentive for businesses undertaking research and development in low-emissions technologies. The definitions required to identify low-emissions technologies would be provided by the Low-Emissions Innovation Council, in conjunction with the relevant departmental portfolios. The criteria would need to be carefully defined so as to not complicate implementation of the underlying scheme.

There is a potential fiscal risk with such an approach that has to be managed. The level of eligible expenditure resulting from the market response to the new incentive is unknown (Thomson and Webster 2011). Modelling of the probable take-up of such a mechanism and associated cost is required to determine the rate of the premium. This mechanism would be closed to new entrants after approximately a decade, subject to review.

Second, and of lesser quantitative importance, there would seem to be a case for addressing the common concern that Australia has an underdeveloped venture capital market by directing some funds towards venture capital programs such as the Renewable Energy Venture Capital program, which replaces the well-regarded Renewable Energy Equity Fund (see Wilkins 2008). Given that venture capital funds target companies that are engaged in prospective but highly risky applied research and development, the best option for public support of early-stage venture capital funds is to provide public co-investment with private partners. Like any matched funding approach, this expands the scale of activities that can be undertaken by private venture capital investors, and maintains incentives for fund managers to make good investment decisions (Murray 1999, Frontier 2009). High government returns from successful projects can be reinvested in similar activities until the need for expansion of scale has been met.

In the energy sector, this need has been covered for the time being by the additional allocation of $100 million to the Renewable Energy Venture Capital program—a more than five-fold increase on its predecessor. However, a similar program to provide venture capital support for high-risk endeavours in other areas warrants consideration by the Low-Emissions Innovation Council. If successful, the provision of capital in this way outside the energy sector could build up a similar scale to that for renewable energy.

Allocate additional funding for basic research by business through a premium on the proposed Research and Development Tax Incentive, with the limits to assistance to be determined.

5.2 Market-led programs for demonstration and commercialisation

The informational challenges of project assessment

Early movers that introduce the first fleet of demonstration and commercialisation projects should be rewarded for the spillovers—knowledge, skills, regulatory, support sector, social acceptance and financial sector—that they can be expected to generate. However, a number of practical issues arise in the administration of such a scheme (OECD 2010).

This paper recommends management of the practical issues by simple criteria, provision of matching funding when the criteria have been met, and governance that is independent of government.

The primary challenge for government is that the information asymmetries are significant, if not insurmountable (Wright 1983).

> While allocating resources in the context of imperfect information about future returns of different technologies is a hazardous exercise, doing so when those who stand to benefit from the provision of support possess considerably more information about actual conditions and possible future trajectories than the government is particularly hazardous (Johnstone and Hascic 2010).

Government must design demonstration and commercialisation programs with the expectation that applicants have all the incentives to overstate the benefits and understate the costs when faced with a beauty contest type approach. Whoever is tasked with assessing these should have (1) no incentive to over or underestimate merit according to any criteria (2) possess the skills and knowledge to undertake the assessment and (3) have access to the maximum information on which to base their assessment. Government must concede that if the committee or public service cannot plausibly claim better knowledge than the applicant with respect to any criteria, then these criteria should be omitted (Thomson and Webster 2011).

In part, explicit, narrow and objective assessment criteria have been sought to ensure proper process and to deliver value for money.[18] However, the necessarily strict probity standards can interact with overly specific and inflexible criteria in unproductive ways. The irony is that complex criteria intended to deliver value for money have ultimately resulted in high administrative costs and few successes.

In many cases, government itself directly bears the costs of meeting its own stringent criteria. For example, grants of $15 million were made to applicants for feasibility studies under the Solar Flagships program. Grant funding of $120 million was made for Carbon Capture and Storage Flagships pre-feasibility studies.

It is important to find the balance between minimising the information requirements for decision makers, but maximising the likelihood that the most appropriate projects are selected. Arms-length governance arrangements can play a big part in achieving this balance and reliance on market-led project selection is required.

Greater reliance on the wisdom of the markets

In 2008, the Review proposed a dollar-for-dollar matched funding scheme to support early movers. It was suggested that this should be made available for any project that met innovations and low-emissions tests, for which private investment commitments had been made. Co-contribution is important for aligning the incentives of grant recipients with government on technological feasibility, financial viability, and commercial viability (see Thomson and Webster 2011).

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[18] The Australian National Audit Office has previously highlighted the need for a more consistent and transparent approach to assessing and selecting projects (ANAO 2004) and more recently, it recommended that government apply a rigorous merit based assessment of applications for competitive grants (ANAO 2010).

While government and the bureaucracy may over time develop expertise, the process of selecting projects at the demonstration and commercialisation stage should rely on the wisdom of the market. If the economics of a project are promising, the project can be initially identified by the private sector.

Market-led project selection is only possible if programs are designed to capitalise on this via a simple but precise set of project selection criteria:

- Criteria 1: Will the technology contribute to lowering the cost of mitigation?
- Criteria 2: Does the project qualify as an early-mover innovation?
- Criteria 3: Are there expected spillovers associated with the project?

Innovation is risky. In designing and administering a scheme to support innovation, government must be comfortable with the failure of some projects. Simple criteria are likely to increase the number of projects that qualify for support; there will be more successful programs, but a significant number of projects will fail. Thomson and Webster (2011) for the Update have highlighted a potentially highly effective and efficient approach to assessing whether a project qualifies as a genuine early mover that generates spillovers. Rather than requiring the judgement of expert panels on such matters government could instead rely on a proxy indicator that is readily available.

One such proxy might rely on the tight criteria for the new Research and Development Tax Credit. If the new criteria are able to identify genuine research and development by business, so that projects that are able to claim a significant proportion of expenses under the tax credit are undertaking innovative activities, this proxy could be adopted, in place of at least part of the assessment by experts. For example, projects for which a pre-determined proportion of total expenditure qualifies for the research and development tax credit can be automatically deemed to be 'innovative' under Criteria 2 and generating spillovers under Criteria 3. In addition, the Government could adopt a sliding scale approach to matching using this objective and quantitative measure. This approach could provide recognition for the special value of globally over nationally innovative projects.

This approach draws on all the benefits of entitlement-based schemes.[19] First, the level of innovation would be self-assessed with compliance monitored via (random) auditing. Second, it would draw on the merit criteria of the Research and Development Tax Credit which has already been codified as a consistent, universally understood threshold of the desired activity. Third, this approach will not arbitrarily exclude good projects that were not anticipated at the time the program was set up; the Research and Development Tax Credit criteria are agnostic with respect to the detailed characteristics of technologies.

In summary, the matching grants approach proposed by the Review should be distinguished from the grant tendering programs that have been dominant in Australia to date. With market-led selection of projects through simple and predictable criteria, the approach of matching grants that I propose has much more in common with entitlement schemes (like the Research and Development Tax Credit) than with competitive grants.

Adopt the principle of allowing the market to self-select worthy projects at the demonstration and commercialisation phase.

Implement simple assessment criteria and explore possible proxy indicators that would reduce the informational requirements for funding approval.

[19] An alternative to piggy-backing on the research and development tax credit scheme is to adopt the requirements of another entitlement based scheme such as the Generally Agreed Accounting Principles (see Thomson and Webster 2011).

Flexible instruments to support demonstration and commercialisation

The Wilkins Review supported the 2008 Review's proposed basic criteria for providing innovation support but proposed that the government adopt a flexible approach whereby the mode of funding support and funding ratios are adaptable to industry and project needs;[20] Wilkins identifies inflexibility as a key limitation of existing programs (Wilkins 2008, p123). Various studies have suggested that the relevance and value of government policy to industry and project proponents varies according to the circumstances of individual firms (Ernst and Young 2010, Al-Juaied 2010, ACF 2010, UNEP SEFI 2008). Industry appears to be open to other modes of support (Thomson and Webster 2011) and this flexible approach is being contemplated by the Australian Centre for Renewable Energy in its *toolkit* approach.

This Update favours immediate reliance on lump-sum or multi-year grants, but recommends that the Low-Emissions Innovation Council examine the value of alternative mechanisms that confer benefits up to the same expected present value through disciplined processes.

A range of alternative instruments have been proposed in the literature and adopted overseas. These include operating subsidies, matching equity and partial loan guarantees.[21] Some financial instruments such as contracts for difference (or power purchase agreements in the electricity sector) go further than merely providing a subsidy for spillovers. Like the commercial structure of some public-private partnership contracts, these instruments can have the added effect of inappropriately insulating projects from legitimate commercial risks. In addition to encouraging inefficient levels of investment, this also exposes government to potentially open-ended fiscal risks; the experience of the NSW government with its premium feed-in tariff serves is a cautionary tale.

An up-front grant was envisioned to be the primary format of support in the 2008 Review. In the first instance, grants remain the simplest way of delivering support for demonstration and commercialisation. Grants are easily managed and are capped to ensure that expenditure does not exceed the allocated funds.

The Update is of the view that the proposed Low-Emissions Technology Council should be invited to assess the case for introducing additional funding instruments, alongside grants. If other instruments are contemplated, the level of support should be calculated based on a 'grant equivalent' cost—the level of support should be consistent regardless of the instrument. For example, an ongoing operating subsidy can be calculated in equivalent net present value terms. The equivalent cost of a loan guarantee will be much harder to calculate given that it has to be a contingent liability based on the actuarial risk of the portfolio of loans being guaranteed. Significant financial and commercial expertise would be required.

The new governing body proposed in Section 5.4 would be asked to review the case for expanding the set of funding instruments applied to its task.

There is no place for artificial time constraints or funding rounds. These instruments for support should be available when a case has been made for their application and when they are needed. This will ensure that applicants are assessed objectively against a set of fixed criteria rather than resulting in a beauty contest between projects. From the applicant's perspective, this significantly reduces the uncertainty regarding the availability of funds (Thomson and Webster 2011).

[20] Proposals for a more flexible approach accord to a degree with the literature on credit rationing in emerging markets. In new sectors or industries, there may be learning curves among creditors that need to be overcome before creditors are sufficiently experienced and informed to price and select risks appropriately.

[21] Loan guarantees that provide security for 100 per cent of the loan amount should not be supported. This would remove the incentive for the creditor to carry out its due diligence and risk assessment of individual applicants/projects, thereby exposing government to significant liabilities.

It will not be possible to anticipate precisely the rates of utilisation of matching grants. They may be high—in contrast to rates of utilisation of funding to current programs. To secure budget neutrality within the carbon pricing arrangements, the Government will need to specify limits on total funding. As commitments under the scheme approach the announced limits, the Government would either announce a date of closure of the scheme, or lift the limits.

Provide matching support in the form of up-front grants, but review the case for expanding the set of funding instruments.

Adopt an 'open for business' approach to demonstration and commercialisation support rather than a series of competitive funding rounds.

5.3 A substantial long-term funding commitment to innovation in low-emissions technologies

The required level of global innovation support

Innovation is a global endeavour. Technologies, products and processes developed in one country provide benefits to the rest of the world. In other words, public investment in innovation to correct for domestic market failure also creates spillover benefits overseas. While some countries have identified large national advantage in being at the forefront of global innovation in particular areas, some countries may seek to free-ride on the efforts of others.

There are good reasons for high-income countries to play their proportionate parts in a global innovation effort. That part will be most productive if each country contributes in areas in which it has 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 which hold out the possibility of high returns.

As Jagdish Bhagwati (cited in Garnaut 2008, p240) has argued influentially in the Indian discussion, a commitment to low-emissions innovation by developed countries can be accepted by developing countries as a way of accounting for the historical responsibility of developed countries in exhausting much of the world's capacity to emit greenhouse gases. This adds to the case for developed countries to accept minimum commitments to provide fiscal support for research, development and commercialisation of new technologies, whether at home or in developing countries.

The Cancun outcome contained an agreement that developed countries would provide a minimum level of support for technology transfer to developing country (see Update Paper two [*Progress towards effective global action on climate change*]). To the extent that the technology transfer embodies innovation—for example, the development of demonstration and first commercial plants for Carbon Capture and Storage—it could count towards the Low-Emissions Technology Commitment as well.

In 2008, the Review proposed that high-income countries commit an annual global amount in the order of US$100 billion in public funding for low-emissions research, development and commercialisation of new, low-emissions technologies. The $100 billion was based on a range of studies.[22] Countries' commitments would apply as a percentage of GDP above a threshold of per capita income, so that a country only just entering the group of high-income countries would initially have minimal funding

[22] For estimates of the required global investment in energy research and development to support, the Review drew on the following estimates: US$30-100 billion per year (Kammen and Nemet 2005) and US$50 billion per year (Bosetti et al. 2007) to reach a 550ppm stabilisation target; and US$10-100 billion per year to reach a 450 ppm target (IEA 2008). These proposals were specific to investment required to lower emissions in the energy sector.

commitments. This approach provides for a fair and equitable spread of contributions, and allows for change over time to reflect economic circumstances.

Australia's Low-Emissions Technology Commitment under the proposed formula[23] was calculated at $2.8 billion per annum. Since 2008, other studies have attempted to quantify the required level of research, development and demonstration investment, particularly in relation to energy. Various studies have concluded that spending on low-emissions energy research, development and demonstrations needs to increase by between three and ten times current levels (see Table 3) (ATSE 2008).

These estimates support the Review's position that global funding by governments for low-emissions research, development and commercialisation needs to increase to several times the current level. A global commitment by governments in the order of US$100 billion per year continues to be an appropriate target.

Recent global spending on energy research, development and demonstration continues to fall well short of the levels suggested by the Review and other recent studies. This is part of a declining trend identified in the 2008 Review, which has been significantly reversed with recent green stimulus programs (discussed in Section 3). As an indicator of how present day expenditure measures up to the proposed Low-Emissions Technology Commitment, Box 6 discusses recent spending by governments of selected countries on research, development and demonstration in the energy sector. The figure for Australia of $150 million does not reflect recent increases which would take the level of current investment in energy research, development and demonstration to around $500 million (0.5 per cent of GDP). Nor does it reflect the substantial increases written into the forward estimates.

Australia's Low-Emissions Technology Commitment

Based on updated figures, Australia's contribution to the Global Low-Emissions Technology Commitment would be $2-3 billion per annum (in today's dollars). We suggest aiming for the mid-point of that range. Appropriate accounting arrangements will be required to track the level of funding in policies and programs relevant to mitigation across government to ensure accurate acquittal against Australia's commitment.

All of the funds allocated via relevant Commonwealth and State innovation support programs to date would count towards the Low-Emissions Technology Commitment. Matching funds for relevant research by industry research and development corporations, basic research and development grants, as well as the premium on the tax incentive and commitments through all existing mechanisms to basic research would all be included. Expenditure by the Australian Government on technology development and transfer programs outside Australia would be included to the extent they involve innovation—some of which may be funded from the foreign aid budget (see Update Paper two [*Progress towards effective global action on climate change*]).[24]

[23] With an annual global amount of US$100 billion and the World Bank high-income threshold at the time of US$11,000 per capita, the 50 richest countries (accounting for two-thirds of global GDP) would contribute on average 0.24 per cent of their GDP. Australia's annual commitment based on 2008 data would be $2.8 billion, or 0.26 per cent of GDP (Garnaut 2008). On the same basis, the commitment today would be in the range of $2-3 billion.

[24] The Copenhagen Accord contained a collective commitment by developed countries to jointly mobilise a long-term financing goal of USD100 billion a year by 2020 to support developing country action on mitigation, adaptation, technology development and transfer and capacity building. This was confirmed in the Cancun Agreements. Funding for joint projects between Australian firms and developing countries in developing countries that are eligible for funding through Australia's Low-emissions Technology Commitment should be counted towards Australia's long-term financing commitment (see Update Paper two [*Progress towards effective global action on climate change*]).

Table 3: Recent estimates of requirements for increasing investment in low-emissions technology research and development

Source	Estimated investment requirement	Methodology
Academy of Technological Sciences and Engineering (2008)	Public and private investment in electricity generation research and development required in Australia is around $500 million by 2015. A further $6 billion is required by 2020 (approximately $500 million per year) for technology demonstration.	Australian and State Government funding for low-emissions energy research, development and demonstration, if matched with funds from other sources, would deliver total investment of less than $500 million per year, which is inadequate based on International Energy Agency and Australian technology scenarios.
Brookings Institution (2009)	Increase United States federal government support for energy research and development to US$20-30 billion per year.	Increase funding to levels comparable with health, defence and space exploration.
International Energy Agency (2010)	US$50-100 billion of annual investment in research, development and demonstration is needed to drive the development and deployment of the low carbon energy technologies required to shift the world toward a 450ppm trajectory. Given existing annual public spending of US$10 billion, the shortfall ranges from US$40–90 billion per year, half of which is expected to flow from government sources.	Based on detailed examinations in 2009 and 2010 of global gaps in energy research, development and demonstration investment.
United States President's Council of Advisors on Science and Technology (2010)	Increase United States federal government support for energy research, development, demonstration and deployment to US$16 billion per year, with US$12 billion of the total allocated to research, development and demonstration primarily through competitive programs.	Based on recommendations from the American Energy Innovation Council, and representing approximately triple current Department of Energy funding for energy science and technology.
European Commission (2011)	Additional public and private investment in low-emissions research, development and demonstration of US$ 70 billion over the next 10 years is required to support the European Union objective of reducing emissions by 80-95 per cent by 2050 compared to 1990 in order to keep climate change below 2ºC. Annual funding would need to increase from US$4.2 billion per year to US$11.2 billion per year over the next 10 years.	Based on full implementation of the European Commission's Strategic Energy Technology Plan, addressing gaps between existing public and private sector investment and the levels required to achieve targets for priority technologies.
WWF (2011)	Increase global energy research and development investment from US$ 91 billion in 2010 to about US$238 billion in 2040.	Most spending is directed to energy demand, including transport, with an increased proportion of funding going to energy supply, particularly power and renewable fuels, after 2030.

Note: The estimates presented in this table show considerable variation, because, for example, some cover public funding only while others include private sources, and coverage across the spectrum of research, development, demonstration and deployment is not consistent.

Sources: ATSE 2008, Duderstadt et al. 2009, IEA 2010, PCAST 2010, EC 2011, Duderstadt et al. 2009, IEA 2010, PCAST 2010, WWF 2011.

Box 6: Recent expenditure on innovation in the energy sector

For comparison, Table 4 also provides an indication of the level of contributions to a $100 billion international low-emissions technology commitment, based on more recent (2009) economic and population data. Even for these countries—which are among the largest investors in energy research, development and demonstration—recent investment levels do not approach the average 0.53 per cent of GDP required from contributing high income countries.

Table 4: Government investment in energy research, development and demonstration, selected countries

Country	Energy research, development and demonstration funding* (US$ billion)	Funding as a proportion of GDP (per cent)	Indicative** proportionate contribution to a $100 billion Low-Emissions Technology Commitment (US$ billion)
Australia	0.15	0.02	2.39
France	1.29	0.05	6.76
Germany	0.78	0.02	8.46
Japan	4.04	0.07	12.76
United Kingdom	0.41	0.02	5.17
United States	11.76	0.08	37.59

Note: *All estimates are for 2009 with the exception of France, where the estimate is for 2008 (2009 data unavailable).

** Actual contributions by each country would change over time with changes in GDP, population, exchange rates and the high-income threshold applied by the World Bank.

Sources: International Energy Agency Data Services 2011, World Bank 2010.

The United States President's Council of Advisors on Science and Technology (2010) reported that United States Government spending on energy research, development and demonstration as at 2007 was about 0.03 per cent of GDP, and suggested that an increase to 0.08 per cent would be more in line with overall energy expenditure (PCAST 2010). Table 4 shows that the large, but possibly temporary, increase in investment through stimulus spending allowed this level to be reached in 2009. Furthermore, this investment would need to increase by more than three times to meet the indicative commitment suggested by the Review.

Over the next ten years, revenue from the carbon price should be used to add to existing commitments, and lift Australia to the proposed $2-3 billion annual commitment. Existing programs under the Clean Energy Initiative and other policies should be retained until current processes have been completed and topped up if required to deliver their intended outcomes within current processes.

There are good reasons for a funding profile that increases over time from current to the proposed levels. In the short to medium term, substantial expenditures will be made from existing commitments, and the new Business Tax Credit for general research and development will be introduced. It will take time (hopefully not too much) to establish strong and independent governance arrangements to ensure the most productive use of new funds.

Government will need to set limits on annual expenditure so as to secure the budget neutrality of the carbon pricing arrangements as a whole. The Low-Emissions Innovation Council would be responsible for the design of the various programs and set the fiscal parameters of each scheme to ensure budget neutrality in conjunction with the Treasury and Finance Departments. The total expenditure on the commitment would rise gradually from current levels over the next five years, to a plateau of about $2.5 billion per annum. This represents roughly a doubling of current expected expenditure. It would stay on that plateau for about five years. Expenditure would then fall gradually from that plateau when the special need for accelerated research, development and commercialisation in relation to low-emissions technologies has been met, 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—it is expected that the special case for higher funding for innovation in low-emissions technologies (as discussed in Section 2) will have run its course. However, this should be assessed closer to the time. Beyond this transitionary period, funding for innovation for low-emissions technologies can be made through the economy-wide measures available generally to support research and development.

Adopt a Low-Emissions Technology Commitment with a funding pledge that ramps up to $2 to $3 billion per annum for the quantum of public support for innovation.

Expenditure for innovation activities in any sector relevant to lowering emissions in Australia or overseas would count towards this commitment.

An early focus on basic research

An approach which favours the use of discrete categories of funding leaves the Government open to continued lobbying from those groups that do not benefit from any one funding category (Wilkins 2008, OECD 2010). It also removes the opportunity to compare returns from support for innovation across related but separate categories. The Low-Emissions Technology Commitment should therefore not be technology specific. If the Government develops a strong preference for allocating revenue to particular sectors or technologies, it should seek advice from the Low-Emissions Innovation Council (proposed below), and other relevant bodies such as the Productivity Commission and the learned academies.

However, the Government will need to decide on how funds are divided between the key phases of the innovation chain. To date, there has been a significant allocation of public funds to support demonstration and commercialisation activities. As discussed above, the level of current investment in energy research, development and demonstration is around $500 million and rising through to 2016-17 under the government's Clean Energy Initiative. Much of these funds will be carried forward in future years given the high level of unspent allocations to date. Government funding for basic research on the other hand, at least in the energy sector, has lagged behind.

The basic research and the commercialisation components of the Low-Emissions Technology Commitment should both be increased strongly as soon as the institutions and the capacity can be put together to apply the funds effectively. Much of the basic research capacity is already in place or can be quickly assembled in established institutions. The capacity for effective commercialisation will build up more slowly. Therefore funding for basic research could rise rapidly and represent a relatively high proportion of the new expenditure in the early years, with commercialisation increasing to a high proportion of growth after the first few years or so.

An early focus on basic research and development will allow government to establish the proposed governance, administration and programmatic elements of demonstration and commercialisation policy. Opportunities to further improve policies and programs that support the demonstration and commercialisation of low-emissions technologies in Australia are discussed in Section 4.

Focussing funds on basic research and development at the introduction of a carbon price regime will accelerate the development of the skills base. An increase in the level of basic research and development based in universities and other institutions with joint research and training activities will increase the number of trained graduates required for the deployment of new technologies. This could also alleviate the shortages of high-level skills that continue to be sustained by the mining boom.

If the additional funds allocated to the Low-Emissions Technology Commitment are left unspent, then the mechanisms should be reviewed and refocussed, but the allocation should be maintained.

The Low-Emissions Technology Commitment should not allocate specific proportions or quantums to particular technologies but a larger initial allocation towards basic research which graudally decreases as a proportion over time is warranted.

5.4 Governance arrangements

New or modified governance arrangements are required to ensure that additional funds for basic research, demonstration and commercialisation are used effectively. While a number of steps have been taken towards stronger and more independent governance arrangements, the recommendation to establish a new Low-Emissions Innovation Council remains relevant today.

The proposed Low-Emissions Innovation Council would also ensure a technology neutral approach by having oversight of programs across all areas of innovation relevant to mitigation including: energy and electricity generation; energy efficiency; transport; urban planning and design; agriculture, forestry and biosequestration more generally; and mining.

Given the broad and diverse scope of such a body, its membership should draw on the diverse expertise of the learned academies of science, engineering and the social sciences, the Universities and business. The Advanced Research Projects Agency-Energy in the United States could be an appropriate template for the Council, with an appropriate broadening of skills and capacities in line with the wider disciplinary mandate proposed for the Australian Council.

The Council would be responsible for administering the proposed policies and programs outlined above, across basic research, commercialisation and demonstration. This includes the design of the various parameters of each scheme to ensure budget neutrality in conjunction with the Australian Treasury and Finance Departments.

Institutional leadership and strategic selection of publicly funded projects in basic research

The 2008 Review proposed that the Low-Emissions Innovation Council would be modelled on the National Health and Medical Research Council. The National Health and Medical Research Council is a national organisation with diverse responsibilities in health and medical research, including the allocation of research funding, fostering medical and public health research and training, and the development of health policy advice.

Like the National Health and Medical Research Council, the proposed Low-Emissions Innovation Council would allocate public funding for early research. This recommendation could be implemented by the Low-Emissions Innovation Council delegating all or part of this responsibility to the Australian Research Council. At the very least, the Low-Emissions Innovation Council would direct a portion of its funding through existing channels, such as the Australian Research Council Linkage Grants program.

In addition, the Low-Emissions Innovation Council could also be expected to guide the national development of Vocational Education and Training courses and of production of university graduates at first and higher degree levels in areas relevant to low-emissions technologies throughout Australia.

Given recent reforms towards demand-driven funding in higher education, it is envisaged that the role of the Council will primarily be in the identification of new labour market gaps and potential areas of increased provision.

Australia's geographic distance from major markets and information flows is a source of potential weakness for business innovation (OECD 2010). The Low-Emissions Innovation Council would address this weakness by promoting linkages across relevant early research activities within Australia, in the Asia Pacific region and more widely.

In summary, at the basic research phase of the innovation chain, the Council would be charged with:

- applying the dual criteria of comparative advantage research and national interest to target funding at appropriate areas for research and development and ensuring that basic research in Australia is connected to relevant activities overseas;
- supporting the delivery of new skills relevant to Australia's transition to a low-emissions economy; and
- determining the parameters of the premium to the proposed Research and Development Tax Incentive (in conjunction with the Australian Tax Office and AusIndustry).

Establish a new Low-Emissions Innovation Council to oversee and direct Australia's basic research and development effort and to support the delivery of new skills relevant to the transformation of relevant sectors.

Task the Low-Emissions Innovation Council with responsibility for ensuring that Australia's domestic research and development activities are connected to relevant activities overseas.

Independent governance arrangements for demonstration and commercialisation programs

A theme of the 2008 Review was that processes of resource allocation and complex decision making must be insulated from political pressures through good governance. The case for stronger and independent governance arrangements in the administration of policies and programs for demonstration and commercialisation has been reaffirmed in various recent reports.

> Both bureaucrats and the Ministers they serve are not best placed to deliver on these needs. Ministers in particular will regularly be called upon by their constituents to make decisions in pursuit of other objectives which detract from Australia's interest in building a portfolio of technologies. The Review considers that greater use of independent decision making in how public support for low-emissions technology development and demonstration is allocated would be appropriate (Wilkins 2008).

In addition, independent bodies will be better placed to deal with the real complexities in the management and administration of grants. A well-governed body can be more flexible in dealing with the administrative and contractual challenges once grants are awarded.

The political economy experience in the United States has identified similar issues. Although members of Congress have proved willing to support substantial funding for energy research, development and demonstration programs over the past three decades, they also have sought to influence the research, development and demonstration selection and development process in order to benefit their home districts (Ogden et al 2008).

In recognition of the need for sound governance arrangements, the Academy of Technological Sciences and Engineering (ATSE 2008) has recommended the formation of an overarching Energy

Research Council to identify and fund research, development and demonstration proposals. The Wilkins Review recommended establishing a new entity modelled on the UK's Carbon Trust to act as a buffer between Government and those seeking public support for technology development and demonstration projects (Wilkins 2008).[25] Both the Cutler (2008) and Wilkins (2008) reviews also identified the opportunity to strengthen governance arrangements by improving program coordination and where possible consolidating the administration arrangements to capitalise on economies of scale and scope and shared expertise.

Programs in the Australian Department of Innovation, Industry, Science and Research portfolio are generally administered at arm's length by the AusIndustry Division, with decision making responsibilities being allocated to independent boards as in the case of Commercialisation Australia and Innovation Australia. With the establishment of bodies like the Carbon Trust, the Australian Solar Institute[26] and more recently, the Australian Centre for Renewable Energy to administer the $5.1 billion Clean Energy Initiative—there is a trend towards greater independence in program administration as well as program consolidation. The Australian Centre for Renewable Energy has a high degree of independence. In particular, it has been given the opportunity to exercise discretion with the allocation of funds, the approach to providing financial support and the areas which will receive such support (ACRE 2010).

There are two potential issues that need to be considered. First, the Australian Centre for Renewable Energy is ultimately an advisory board and it does not share the same level of control and independence as an independent incorporated entity like the Australian Solar Institute. In this regard, the potential for political interference remains. Second, in order to capitalise on good governance arrangements, fragmentation in the administration of new programs must be avoided; the creation and oversight of the $652 million Renewable Energy Future Fund by the climate change portfolio is a case in point.

Strengthen the administration of policies and programs for supporting demonstration and commercialisation by increasing Australian Centre for Renewable Energy's independence.

The administration of other programs that do not fall in the renewable energy category do not have the benefit of an overarching body like Australian Centre for Renewable Energy. While cleaner fossil fuel based technologies and renewable energy technologies are quite different, the differences are no more pronounced than the internal differences between different renewables. A truly comprehensive and neutral energy innovation governing body should straddle the renewable-fossil fuel divide (just like the Clean Energy Initiative). The Government should therefore consider expanding the Australian Centre for Renewable Energy's remit to encompass all clean energy technologies.

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. The Low-Emissions Innovation Council would be established as the overarching governing body.

In the short term, expand the Australian Centre for Renewable Energy's remit to include all low-emissions energy technologies.

In the longer term, move the Australian Centre for Renewable Energy into the overarching governing arrangements of the Low-Emissions Innovation Council.

[25] It was envisioned that the Australian Carbon Trust would consolidate all of the Government's disparate low-emissions technology programs (Clean Business Australia – Climate Ready, Energy Innovation Fund, National Clean Coal Fund and Renewable Energy Fund), however, its final remit turned out to be a specific focus on issues related to energy efficiency.

[26] The Australian Solar Institute is an independent company created under the *Commonwealth Authorities and Companies Act (CAC Act) 1997*.

6. Conclusion

Technological change can substantially reduce the costs of global and Australian transition to a low-emissions economy. We cannot anticipate the shape or the extent of that change in advance of its unfolding 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 entities to invest 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 the carbon price. The carbon price increases the profitability of investment in innovation.

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 or twelve years from the commencement of carbon pricing, about one fifth 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.

Australia can play a useful part in developing some new technologies that are important on a global scale—for example, through its strengths in applied biological and geophysical sciences. It can also do much good for itself by paving the way for rapid application of appropriate new technologies from abroad.

The policies suggested in this paper can support low-cost transition to a low-emissions economy in Australia, while making an appropriate and proportionate contribution to lowering the costs of the transition in the world as a whole.

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