18

THE INNOVATION CHALLENGE

Key points

Basic research and development of low-emissions technologies is an international public good, requiring high levels of expenditure by developed countries.

Australia should make a proportionate contribution alongside other developed countries in its areas of national interest and comparative research advantage. This would require a large increase in Australian commitments to research, development and commercialisation of low-emissions technologies, to more than $3 billion per annum by 2013.

A new research council should be charged with elevating, coordinating and targeting Australia's effort in low-emissions research.

There are externalities associated with private investment in commercialising new, low-emissions technologies.

To achieve an effective commercialisation effort on a sufficiently early time scale, an Australian system of matching funding should be available automatically where there are externalities associated with private enterprise investment in low-emissions innovation.

Research in adaptation technologies is required. Existing arrangements are well placed to meet immediate priorities.

The successful development and deployment of new technologies across sectors will be critical to minimising the costs of adjustment to the emissions trading scheme.[1] This will be a global effort. Australia will contribute proportionately, focusing on areas of research, development and commercialisation of new technologies, according to its comparative advantage and national interest.As other countries adopt similar constraints on emissions, there will be new opportunities for expansion in sectors where Australia can develop an international comparative advantage. Specifically, there may be significant sequestration opportunities in forestry and agriculture, and in parts of the low-emissions energy sector.

A variety of new technologies and practices are potential contributors to Australia's mitigation task. They include:

- **energy efficiency**—electrical equipment, fixed appliances, and building materials and design
- **electricity generation**—geothermal (hot rocks), improved generation efficiency (e.g. coal drying), and solar (photovoltaic and thermal)
- **transport**—lower-emissions vehicles, second- and third-generation biofuels (including from mallee and algae) and biomass, and electric cars
- **agriculture and forestry**—anti-methanogen technologies for livestock producers, altered savanna management, and nitrification inhibitors
- **sequestration**—soil sequestration (biochar and mallee), geosequestration and algal sequestration.

The role of new technologies will also be important in lowering the cost of adapting to climate impacts. Commercial agriculture in Australia often requires imported agricultural technologies to be adapted to Australian conditions, with high levels of government participation in research and the dissemination of information (Raby 1996).

Reliable information about the impacts of climate change will be needed for the continued development of new adaptation technologies. Those areas that will play a direct and significant role in Australia's adaptation challenge include:

- **agriculture**—use of improved seasonal forecasts, heat tolerant crop cultivars, and different methods of crop and livestock management
- **the built environment**—more resilient building materials, climate-appropriate building design and more efficient heating, ventilation and air-conditioning systems
- **biodiversity**—connectivity corridors and conservation methods.

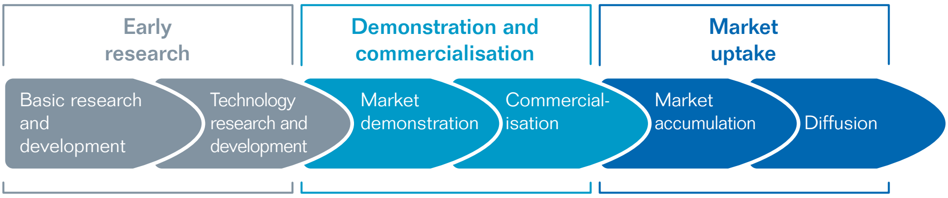
Some technologies, such as those that improve the thermal properties and energy efficiency of buildings, contribute to both the adaptation and mitigation efforts.

18.1 What is innovation?

Although it entails simplification, the 'innovation chain' concept can help identify policies appropriate for different stages of development (Foxon et al. 2008).

For economic analysis and policy development purposes, the Review adopts a simplified model of the innovation chain, as shown in Figure 18.1, in which there are three distinct phases.

Figure 18.1 The innovation chain



Source: Adapted from Grubb (2004).

Early research—Contributions are made to basic science and knowledge, usually at research institutions at a laboratory scale, with few immediate commercial returns. The knowledge and information generated tend to be of benefit globally, are difficult to keep secret, and can be easily disseminated at low cost.

Demonstration and commercialisation—The new knowledge is applied to the real world through pilot, demonstration and first commercial-scale projects. These activities require research bodies or firms to take on substantial risk as the technology requires proof in the intended operating environment and may not be cost competitive at first—even in cases that later turn out to be commercially successful. Some studies call this phase 'the valley of death', where most technologies fail either technically or financially (Grubb 2004; Murphy & Edwards 2003).

Market uptake—Once new knowledge becomes embodied in a tested product or service, it is sold to the open market. Technologies at the market uptake stage are able to compete with other mature products in the marketplace, with successful instances being associated with falling costs as market share expands.

18.1.1 How will an emissions trading scheme affect technological development?

As the emissions trading scheme raises the costs of greenhouse gas–emitting activities, new and existing low-emissions technologies will become more profitable. Mature technologies will be most immediately affected by the demand–pull effects of an emissions trading scheme.

An emissions trading scheme will spur private sector research and development activities by creating the long-term demand–pull for more low-emissions products and processes. However, there may be only limited impacts on early research activities since most early research is publicly funded. Changes to funding are dependent on how quickly funding resources are allocated to new research areas.

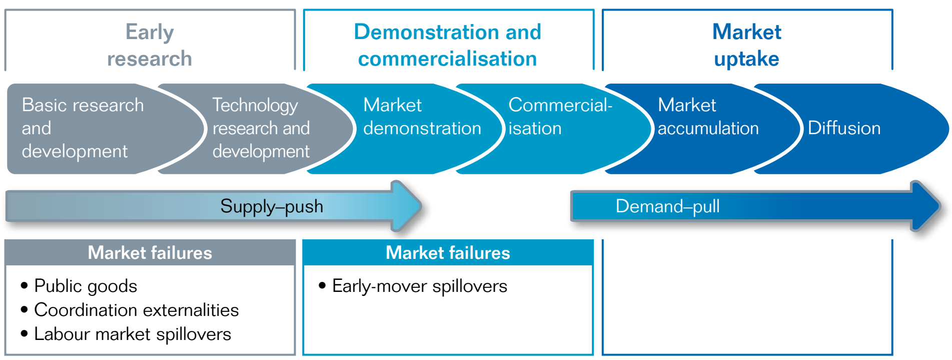
Both public and private research and development will have a large impact on the economy-wide cost of emissions reductions in the medium to long term. Over time, technological change and development will bring down the cost of various low-emissions technologies.

18.1.2 Barriers to an efficient market response

While an emissions trading scheme and projected climate impacts will both 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. Similarly, inadequate investment in developing superior adaptive technologies could result in a more costly adaptation response.

These market failures are most important in the early research and demonstration and commercialisation phases of the innovation chain (see Figure 18.2). There are some externalities associated with the early adoption of proven technologies, but the emissions trading scheme and better research and dissemination of knowledge about impacts will create enough demand–pull for new technologies so that generally there will be no need for any additional support for innovation at the market uptake stage.

Figure 18.2 Market failures along the innovation chain



Correction of market failures justifies government policy intervention. Economic studies have emphasised the role of innovation policy in delivering least-cost emissions reduction (Stern 2007; Productivity Commission 2007a; Jaffe et al. 2005). This rationale for government intervention holds true even in the absence of climate change, but as the emissions trading scheme delivers quick and profound shifts in the economic context, there will be a special requirement for high rates of technological improvement in low-emissions technologies. The emissions trading scheme will raise the opportunity cost of an inadequate market response to incentives for new technologies.

The required adaptation response is less likely to face the same time pressures. The impacts of climate change are likely to be felt more gradually, suggesting that the adaptation effort can be managed within established research and development funding practices. The cost of market failures in the development of new adaptation technologies should not be expected to add significantly to Australia's total adaptation costs.

There is a risk that undisciplined innovation policies will become the focus of strong pressures on the political process for unjustified payments to industries and firms (Banks 2008). Government must therefore ensure that innovation schemes address material market failures that yield net benefits to society and that processes of resource allocation are insulated from political pressures. Any justifications for policy outside the market failure rationale should be rejected (see Box 18.1).

Such a rationale, however, is not sufficient to dictate government intervention—two additional requirements should also be met. The proposed measures need to target the problem and the cost of a market failure needs to be more than the cost of government intervention, with all of its political economy and other risks and costs.

Box 18.1 Wrong arguments for innovation policy in the context of an emissions trading scheme

Some rationales for government intervention in the area of innovation do not have a sound economic basis. A credible emissions trading scheme would address the issues of environmental integrity and urgency of action. The case for public support for new technologies related to climate change should require the correction of material market failures that would otherwise increase the cost of mitigation where benefits of intervention clearly exceed costs.

Some mistaken arguments for innovation policy in this context include:

- *There will not be enough innovation or time to develop new technologies for Australia to meet its national targets successfully.*
  The cap on emissions in an appropriately designed emissions trading scheme is binding, such that emissions reductions will have to be delivered regardless of the technologies available. Ultimately, this cap may be met through reductions in consumption of emissions-intensive goods and services, if need be, in the short term.
- *The permit price will be low initially and therefore will not drive much innovation.*
  Where there is a domestic emissions trading scheme supported by a global agreement, there is no reason for the permit price to be uneconomically low with the anticipated future scarcity of permits. If this seems to be the case, then it may reflect market optimism that suitable new technologies will be available in the future. If this is not the expectation, then the incentive would be to hoard permits for future use when scarcity, and therefore prices, were higher.
- *We need to invest in innovation to lessen the impact of the carbon constraint.*
  Investing in innovation when there are no requisite market failures requiring correction is likely to lead to greater economic cost, not less.

18.2 Ensuring optimal levels of early research

18.2.1 Market failures in early research

Early research is characterised by substantial spillovers arising from the non-excludable or non-appropriable nature of knowledge. In most cases, once new basic knowledge is created, it is impossible to exclude others from sharing the benefits (Arrow 1962). This is the strongest rationale for government intervention at the early research phase of the innovation chain (Productivity Commission 2007b). Excludability is further diminished by the typically low incremental costs of diffusion (Stephan 1996), especially when knowledge is transparently embodied in a product or process, readily codified and easily diffused (Productivity Commission 2007b). In addition, knowledge is non-rivalrous—once created, many individuals or firms can use and apply it, thus making it a public good.

Externalities from early research

There is evidence both nationally and internationally that collaboration yields measurable benefits for participating individuals and organisations. In Australia, an analysis of Australian Bureau of Statistics data found that businesses that engage in collaboration are more likely to achieve higher degrees of innovation (Department of Industry, Tourism and Resources 2006). However, in some cases, the costs of negotiating an agreement are sufficient to prevent a coordinated approach from happening.

Early research activities often have the added benefit of being vehicles for education and training because those who conduct research also usually teach. Therefore a shortfall in early research and development funding could also result in medium- to long-term skills shortages. The Productivity Commission (2007b) found that the benefits of research and development in both universities and public sector research agencies are high, due to their orientation to public good research and their role in the development of high-quality human capital for the Australian economy.

18.2.2 Are current policies sufficient?

Like most developed countries, Australia has an established institutional framework for allocating research funding across the economy.

Early research in low-emissions technologies

The Productivity Commission (2007b) recently highlighted the expanding need for public good research in the light of future environmental, energy and climate challenges as a potential stress on the Australian innovation system.

Despite being among Australia's stated national priority research areas (DEEWR undated), funding for energy supply research has increased only marginally off a low base (ABS 2008a). Australia's expenditure on energy supply technologies ranks low among OECD countries (based on OECD 2008). Internationally, energy-related research and development is dominated by just a few countries (based on OECD 2008) whose research activities and priorities are likely to determine the global range of future low-emissions technologies.

Falling levels of investment in early research in mitigation have been a global phenomenon (see Figure 10.1). For example, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007: 20) found:

> Government funding in real absolute terms for most energy research programmes has been flat or declining for nearly two decades (even after the UNFCCC came into force) and is now about half of the 1980 level.

The low levels of government expenditure on research and development in key areas like energy supply, juxtaposed with the rising importance of low-emissions energy technologies for Australia's mitigation effort, suggest that current funding levels do not reflect the priority required to meet the rapidly changing pattern of demand established by an emissions trading scheme.

It is important that this issue be looked at from an international perspective since research has global spillovers. The Review proposes that high-income countries support an International Low-Emissions Technology Commitment, suggesting an indicative global figure for this fund of $100 billion per year, and an indicative Australian expenditure of $2.8 billion (section 10.1).

Early research in adaptation technologies

Research in adaptation technologies is critical for the agriculture sector as impacts will be increasingly severe in a future without mitigation. New technologies and practices will also be required to support the private adaptation response of households and businesses in Australia.

Early research in agriculture is an area of strength in Australia. In 2006–07, 22 per cent of all government expenditure on research and development could be attributed to research in plant and animal production and primary products, while environmental management accounted for a further 18 per cent (ABS 2008a). Australian research publications in plant and animal sciences, ecology and environment and agriculture were relatively numerous, accounting for more than 4 per cent of the total world publication in these fields in the period 2000 to 2004 (Productivity Commission 2007b).

The Review has not examined the adequacy of the early research effort in other sectors relevant to adaptation, such as the built environment sector, and areas likely to be affected by the increasing scarcity of water. Various research organisations are already undertaking work on improving our technological responses to the effects of climate change,[2] but better outcomes in the resilience of buildings, energy efficiency and water efficiency will require greater uptake of existing technologies rather than further research and development of new technologies. Market failures associated with the uptake of available solutions by households and businesses are discussed in Chapter 17.

18.2.3 New institutions to drive early research

The significant challenge of deep cuts to emissions suggests that Australia's research agenda needs to focus more strongly on early research into low-emissions technologies, to shorten the lag between the introduction of the emissions trading scheme and the response of the research community.

In the past, government has managed the issue of priority by establishing institutions, including the Australian Research Council, that allocate resources according to strategic importance and national capability. There is a case for a specialist research body related to low-emission technology, to elevate, coordinate and target Australia's effort in this field. Such a body could operate in a similar way to the National Health and Medical Research Council (NHMRC),[3] overseeing a large expansion of effort in early research for low-emissions technologies, and operating independently to correct market failures.

Like the NHMRC, the proposed research council could have three mutually reinforcing core functions:

- allocating public funding for early research based on clearly established criteria (see section 18.2.5)
- promoting linkages across relevant early research activities within Australia and with research activities in the Asia–Pacific region, and being alert to opportunities for international cooperation
- guiding training in low-emissions technologies throughout Australia, including the development of research training through higher degrees.

18.2.4 Sources of additional funding

One possible source of additional funding for allocation by the proposed research council is the consolidation and reallocation of existing funds now allocated to related research areas. However, there are good reasons for not reallocating all existing funding. First, it is important to maintain continuity in the allocation of existing funds. Second, it is beneficial to maintain some plurality of funding sources. General institutions can co-exist with specific funding bodies, so that no one body holds the purse strings for all the funding in any one area. Some existing funding arrangements may continue on this basis, but a review of all programs may be warranted to identify those that are yielding below-average returns on investment.

Additional funds for early research in low-emissions technologies could come from the revenue from the auctioning of emissions permits. The allocation of a consistent level of annual permit revenue towards this public good research could form the major portion of funds to be allocated by the proposed research council. It is sensible to use permit revenue to fund early research because there are potentially strong links between the early research effort, the long-term cost of mitigation and the carbon price.

All commitments of funds for early research would qualify under the International Low-Emissions Technology Commitment proposed in section 10.1, alongside expenditure on matching funding for investment in commercialisation of new, low-emissions technologies.

18.2.5 Criteria for funding early research

The allocation of resources to innovation in general is complicated by two trade-offs. First, there is a trade-off between the desire to provide technology-neutral support in order to avoid distorting the selection of technologies by the market; and the competing desire to concentrate resources on more promising areas. Policies to assist innovation must find the right balance between providing technology-neutral and technology-specific support, and between encouraging options and maximising returns.

Second, funding decisions must balance the role of knowledge generation within Australia and the adoption of ideas and technologies from the global research effort. Technologies with broad application and commercial potential are likely to be developed outside Australia, and it will sometimes be preferable for Australia to be a technology taker rather than duplicating the international research effort.

Despite the desire to avoid 'picking winners', there is inevitably a good deal of discretionary judgment in decisions on allocation of public funding for early research. The proposed research council should be guided by criteria that ensure funds are allocated to areas likely to result in the highest economic value. Two important criteria should underlie any funding decisions in early research: (1) Is this area of research of national interest? (2) Is this an area of early research where Australia has a comparative advantage?

The criteria for both national interest and comparative advantage can be expected to shift over time. The funding allocation should be subject to a transparent and independent process of periodic evaluation and review (Productivity Commission 2007b), with swift termination of funding for projects that no longer meet the criteria.

Criterion 1: National interest

Australia should only fund early research aligned with its national interest. In the case of climate change mitigation, considerations should be based on both current circumstances and future projections, and could include:

- **Australia's emissions profile**—The high emissions intensity of electricity generation and the high levels of emissions from agriculture are two examples of unusual characteristics of Australia's emissions profile.
- **Technological solutions particular to local conditions**—Many technologies can be adopted from overseas and applied to the Australian context. The deployment of wind turbines from Europe and any future use of nuclear power are examples. However, some technologies will be subject to local factors, including geography, geology and climatic conditions.
- **Sources of Australia's economic prosperity**—Sectors that are important sources of economic prosperity today or could become sources of economic advantage in the future have a broad strategic value for Australia.

- **Technologies that build on Australia's natural resources**—Australia is in a unique position among developed countries of having an abundance of a wide range of natural resources that are relevant to low-cost transition to a low-carbon economy (for example, solar, wind and geothermal sources of energy).

Box 18.2 Examples of areas of national interest

Technological solutions in carbon capture and storage, soil sequestration, solar technologies, algal biosequestration and geothermal energy are among the areas in which Australia has disproportionately strong opportunities and interests. The successful development of these technologies could be expected to have exceptional value within Australia.

Table 18.1 Brief assessment of two technology categories against criteria for national strategic interest

	Carbon capture and storage for coal-fired electricity generation	Algal biofuels
Australia's particular emissions profile	Coal-fired electricity generation is a major contributor to Australia's high emissions intensity of energy.	Some algal biosequestration processes could absorb emissions from coal-fired electricity generation and metals smelting.
Technological solutions particular to local conditions	Australia has a variety of geological formations that are suitable for long-term geosequestration.	Few other developed countries have the required natural conditions.
Sources of Australia's economic prosperity	Any proven technology that cost-effectively reduces the emissions from coal-burning will be in high demand in the future when climate change mitigation becomes a global priority. Carbon capture and storage will also maintain the value of Australia's coal resources as a commodity both for domestic consumption and export.	Algal biofuels could provide energy security and economic growth as they have a higher yield per hectare than traditional crops, with much higher energy returns. Algal biofuels could also prove competitive with fossil fuels in light of increasing global scarcity.
Technologies that build on Australia's natural resource advantage	The abundant availability of coal, and subsequently low energy prices are sources of comparative advantage for Australia. The export of coal itself is a significant contributor to Australian GDP.	There are several regions around Australia that could potentially provide the intense insolation and saline and other non-productive land needed to cultivate algae for biofuel production at a large scale.

Criterion 2: Comparative advantage

Australia should only undertake early research in areas where it has a comparative advantage. There are no perfectly objective measures for comparing different fields and disciplines. The proposed research council would therefore need to consider a range of proxy indicators of comparative advantage when making funding allocation decisions.

In some instances, the absence of any comparative advantage should be clear. For example, although the export of uranium is one source of economic prosperity in Australia (and therefore an area of national interest), Japan and France outspend Australia by a factor of 300 and 150 respectively on nuclear energy research (Commonwealth of Australia 2006), suggesting that early research in nuclear generation is not an area in which Australia is likely to have a comparative advantage.

Australia's demonstrated strength in agricultural research is an example of an area of clear comparative advantage.

18.3 Rewarding early movers

The early movers of a new industry are those that undertake the first demonstration and commercialisation projects. The spillovers from these early-mover activities mean that in the absence of government intervention, there will be suboptimal levels of private investment in demonstration and commercialisation projects.

18.3.1 Spillovers from early movers

In most new industries, the early movers bear all the costs of demonstrating and bringing a new technology to market, while later movers share in all the associated benefits that spill over directly from the early movers' investments. These spillovers can result in a strong disincentive for any firm to be a pioneer and result in an undersupply of demonstration and commercialisation activities. For some new industries, multiple spillovers may result in no activity at all.

There may be secondary mechanisms through which these spillovers are internalised. Early movers may reap the benefit from early gains in the form of brand reputation, product recognition and early leads in market share. These benefits may provide sufficient incentives to bear the upfront costs if the remaining spillovers are relatively small.

Research and development spillovers are both prevalent and important (Griliches 1992). There are five main types of spillovers that result from early mover activities.

- **Knowledge externalities**—Early movers who make the initial high-cost investment to demonstrate or apply new technologies can generate substantial contributions to the knowledge base of an industry, which later benefits the industry more widely. These knowledge and information benefits over the long run have been observed in the steep decline in the costs of new technologies during the demonstration and commercialisation stages.

  While 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).

Furthermore, patent rights are not self enforcing. Remedying breaches often requires costly legal action (Martin & Scott 1998).

- **Skills spillovers**—Early movers contribute to the future of all firms in an industry by bearing the upfront costs to develop appropriate technical skills and capacity and associated training courses. This has a positive lingering effect in the labour market and later movers are able to draw on this pool of skilled labour.
- **Regulatory and legal spillovers**—Early movers may bear the large upfront costs of working with government and other industries to develop new regulations and standards. This could include significant costs associated with resolving legal disputes regarding new regulatory frameworks with government and other industries. Later movers benefit from regulatory clarity and have established avenues for secure agreements and contractual arrangements.
- **Support sector externalities**—The development of supporting industries inevitably requires some additional investment by early movers—for example, to identify suppliers with appropriate manufacturing capabilities, develop suitable products and product standards with those suppliers, and test new parts and components. Firms that enter the market at a later stage are able to benefit from an established supply chain without having had to bear the upfront costs.
- **Social acceptance spillovers**—Communities can be apprehensive of new technologies that are intrusive, potentially dangerous, or simply not yet fully understood. An early-mover firm looking to commercialise such a technology will often bear the costs of demonstration projects and communication and information exercises to increase people's confidence in the safety and effectiveness of its particular technology. The higher level of social acceptance is enjoyed at no cost by later movers promoting similar technologies.

18.3.2 Are current policies sufficient?

Current programs for the demonstration and commercialisation of low-emissions technologies

The Productivity Commission (2007b) noted that the emphasis on innovation in Australia has moved towards demonstration and commercialisation projects. Many recent low-emissions research and development policies have targeted the market uptake stages of the innovation chain (see Table 18.2). This could be because the scarcity of funds intensifies the pressure to focus resources 'downstream' on shorter-term applied research aimed at the deployment of mature and commercial technologies and because of political economy distortions.

Table 18.2 Research and development programs in Australia targeting low-emissions technologies

Policy/fund name	Description	Funding
Low Emissions Technology Demonstration Fund	Supports the commercial demonstration of technologies that have the potential to deliver large-scale greenhouse gas emissions reductions in the energy sector.	$410 million over 11 years
Renewable Energy Development Initiative	A competitive merit-based dollar-for-dollar grants program supporting renewable energy innovation and commercialisation.	$100 million over seven years
Solar Cities	Demonstrates how solar power, smart meters, energy efficiency and new approaches to electricity pricing can be combined.	$93.8 million over nine years
Energy Technology Innovation Strategy (Victorian Government)	Assists the commercialisation of coal drying, coal gasification and geosequestration technologies, distributed generation energy efficiency, and renewable and enabling technologies. This funding supports some Low Emissions Technology Demonstration Fund projects.	Up to $369 million
Queensland Future Growth Fund	Supports the deployment of low-emissions coal and renewable energy technologies. Will operate separately from the Queensland state budget.	$350 million
Green Car Innovation Fund	Aims to support the manufacturing of low-emissions vehicles in Australia. Will operate on a matched funding basis at a ratio of 1:3 public : private.	$500 million over five years
National Low Emissions Coal Fund	Aims to reduce greenhouse gas emissions and secure jobs in the coal industry by stimulating investment in clean coal technologies with matched funds at a ratio of 1:2 public : private.	$500 million over seven years
Renewable Energy Fund	Targets renewable energy demonstration projects with private sector funds matched at a ratio of 2:1 public : private. Funding distributed through competitive grants, based on the goal of encouraging a range of technologies across a range of geographic areas. Fifty million dollars has been earmarked for dollar-for-dollar matched funding for private investors in the geothermal industry.	$500 million over seven years
Energy Innovation Fund	Investments targeted equally towards the Australian Solar Institute (solar thermal), photovoltaic research and development, and general clean energy research and development, including energy efficiency, energy storage technologies and hydrogen transport fuels.	$150 million over four years

Sources: Prime Ministerial Task Group on Emissions Trading (2007); Australian Treasury (2008).

Many of these industry support programs have the effect of providing incentives for early movers, but there is a conspicuous absence of a targeted technology-neutral program for dealing with the spillovers discussed in section 18.3.1.

The Productivity Commission (2007b: 371) found that this issue of poorly targeted policy was characteristic of technology programs in Australia more generally:

> Australia's current suite of business programs do not target rationales for public support (additionality and spillovers) effectively and, as a consequence, involve substantial transfers from taxpayers to firms without attendant net benefits. The need to raise taxation revenue to fund these transfers creates large efficiency losses.

Current programs for the demonstration and commercialisation of new adaptation technologies

Rural research and development corporations and companies are a major vehicle for driving the development of new adaptation technologies in the agriculture sector. Under the Rural R&D Corporations program, such corporations commission agricultural research and development on a competitive basis among public and private providers using funds from levies on production and matching Commonwealth grants.

This basic model was established in 1989 with the aim of correcting the spillovers by collecting compulsory industry levies for industry research and development (CRRDCC 2008). Without these levies, it is not likely that individual and voluntary agricultural associations would be able to capture enough of the spillover benefits and they would therefore fail to justify the level of research and development investments currently undertaken by the rural research and development corporations. This model allows for a targeted approach to fund allocation by industry and promotes accountability, allowing levy payers to contribute to decisions on the rural corporations' strategies, including on the amount of the levy collected.

The Rural R&D Corporations program is in essence a matched funding scheme with two main sources of funding: (1) levies from producers and (2) matching funds from government at an average ratio of 1.5:1 private to public investment.[4] The government contribution, in part, assists in overcoming some of the market failures associated with demonstration and commercialisation activities, which would not otherwise occur.

The investment of $511 million in this program in 2004–05 is expected to deliver gross private and social returns of around $1.65 billion to Australia over five years (CRRDCC 2006). Benefits include improvements in on-farm production; the development of new products for emerging markets; better management and use of water and natural resources; building and developing rural skills; building research and development capacity; and improving biosecurity (CRRDCC 2006).

Agricultural research in Australia is undertaken by public sector research organisations, notably the CSIRO, cooperative research centres, universities and agencies within the primary industries portfolios at federal and state levels. The demand for new technological solutions in the light of future climate change impacts will test the research capabilities of these institutions.

Overall, the shortfall in demonstration and commercialisation activities for new adaptation technologies is likely to be much smaller than that for low-emissions technology, given that there has been longstanding demand for adaptation technologies.

18.3.3 Supporting early movers with a matched funding scheme

The externality benefits from early-mover activities will vary widely and on a case-by-case basis. Different projects in different contexts will generate different types of spillovers at various levels. The prohibitively high administration and compliance costs of quantifying spillovers on a case-by-case basis means that such an approach would not be viable.

There are a variety of vehicles through which compensation for these spillovers could be provided. These can be classed into three broad categories, as set out in Table 18.3.

Table 18.3 Mechanisms for directly subsidising positive externalities in demonstration and commercialisation

Category	Instrument	Description
Tax instruments	Tax rebates or concessions	Tax concessions allow companies to claim a deduction of R&D-related expenditure, usually for a proportion beyond the actual expense incurred (i.e. more than 100 per cent).
	Accelerated depreciation	For research projects with high capital costs, approved accelerated depreciation of assets is an alternative tax concession.
Niche market creation	Technology target schemes	Policies such as mandated targets may establish guaranteed markets for particular categories of goods or services.
	Guaranteed revenue	Policies such as regulated prices or tariffs can provide innovators with revenue certainty.
	Government patronage	Government may itself provide a niche market for new products through its internal procurement policies or through advance purchasing contracts.
Direct funding	Competitive grants	Competitive grants are a common means by which government subsidises specific projects selected by merit based on defined criteria.
	Income-contingent loans	Income-contingent loans compensate innovators for spillovers through government assuming some of the short-term exposure to risk.
	Matched funding	Matched funding stimulates demonstration and commercialisation activities by lowering the costs associated with being the first mover by some fixed proportion.

Among these many instruments, matched funding is the preferred option based on a range of criteria.[5]

- **Simple and targeted**—Matched funding can be simple and directly targeted in its design to address specific spillovers.
- **Technology neutral**—Matched funding can be technology neutral across the whole range of economic sectors and has the potential to allow for all technological possibilities.
- **Maintains risk exposure**—By leveraging private funds, a matched funding scheme would ensure that applicants continue to bear and manage the potential risks associated with bringing a new technology to market. Moreover, it is unnecessary for applicants to demonstrate technical feasibility, commercial competitiveness or the pathway to uptake and diffusion as these criteria are implicit in the matched funding approach. The private investment would not be made unless a project is expected to earn a return in the long run.
- **Capped expenditure**—Matched funding can be designed so that the total expenditure does not exceed an imposed budget constraint.
- **Transparency, impartiality and independence**—The body or institution that administers a matched funding scheme should operate at arm's length from government to ensure that it is insulated from the political process.

18.3.4 Funding sources for a matched funding scheme

The preferred matched funding scheme could be paid for from three sources.

- **Reallocation from existing funds**—This would occur if, after review, existing programs were shown to be inefficient in compensating firms for the external benefits they generated. If consolidated, the schemes listed in Table 18.2 could benefit from (1) more efficient administration, (2) easier access for business, and (3) more consistent application of criteria.
- **Industry levies**—Matched funding schemes could be augmented by funds collected by individual industries. Given that most of the spillover benefits from early movers are likely to accrue to later movers within the same industry, these levies should be set aside strictly for new technologies within the source industry. Compulsory levies have been the established way of funding research and development in many rural industries for several decades.

  Levies on the coal industry for investment in the development and commercialisation of carbon capture and storage technologies are another example. The futures of Australia's domestic-oriented and export coal industries are both dependent in the long term on the success of carbon capture and storage. The Coal 21 Fund will raise an estimated $1 billion over the next decade from voluntary levies of 20 cents per tonne on black coal production.[6] While this is not an insignificant sum, it is relatively low when compared to the voluntary investment by some agricultural industries. If this fund were to be extended to be comparable to the contributions from sales revenue to research and development in the agricultural sector through the rural research and development corporations, and if the levy were confined only to exports, it would generate around $250 million per year. This would not seem to be an excessive allocation to research into technologies that are going to be necessary to secure the future of the domestic and export elements of the coal industry.

- **Auction revenue from the sale of emissions permits**—There is a strong policy rationale for a substantial amount of permit revenue to be allocated to matched funding of demonstration and commercialisation projects for low-emissions technologies.

18.3.5 Criteria for early-mover support

In any policy that targets early-mover spillovers, an accurate and simple set of criteria for a project to qualify is required. If the criteria are satisfied, funding should follow automatically. The criteria must be based on the answers to three key questions:

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

In assessing a project against the criteria, government needs to balance the accuracy of the assessment process against the associated complexity and transaction costs.

The balance of considerations strongly favours simplicity and low transaction costs. The more complex the criteria, the more dependent the assessment process will be on the subjective judgments of the assessing panel. Simple criteria would be more objective and transparent.

Criterion 1: Lowering the cost of mitigation

Applicants must demonstrate the relevance of their technology to the mitigation challenge. Technologies that contribute to the delivery of existing goods and services at lower emissions intensity would qualify, even if emissions reductions are not the primary aim of the new technology, as long as the potential contribution to emissions reductions are material.

Choosing the appropriate cut-off level so as to select only those technologies that can be expected to make material differences at a reasonable economic cost will require specialist technical advice.

Criterion 2: Early-mover innovation

Pilot, demonstration or first commercial-scale projects should qualify for support. Determining whether or not a project falls into one of these three categories is not a straightforward exercise. Project proponents have the incentive to expand the scope of non-innovative projects at the margins to increase the chances of qualifying for funding, while other projects using non-novel technologies may in fact be making a significant contribution to the state-of-the-art knowledge at a highly technical level.

Given these difficulties, this determination should be made by an independent panel of experts that would assess whether a particular project is materially different from current available technology. Assessment would involve two stages:

- **Selection of an appropriate comparator**—'Current available technology' can be defined as a technology that is currently contributing to the production of commercial goods or services in Australia or overseas.
- **Technical judgment of material difference**—The panel should consider the characteristics, scale and context of the technology or technologies being proposed and assess these against the comparator.

Criterion 3: Expected spillovers of the project

Given the difficulty in attempting to quantify the size of different spillovers on a case-by-case basis, government will need to base its assessment on a proxy measure. The straightforward proxy is the assessment of whether or not a particular project, if successful, would be a genuine early mover.

A second method for identifying early movers would be to adopt a scalar measure of quantity, and an associated cut-off point for the 'first fleet' of early movers. For example, to determine whether a centralised electricity generation plant is part of a first fleet, the panel could assess whether the proposed plant is part of the first five of its kind or within the first 1000 megawatts of its kind, whichever is less.

18.3.6 What is an appropriate ratio for matched funding?

For a matched funding scheme, the difference between the private and social rates of return[7] may be a good proxy indicator for the estimated spillovers from demonstration and commercialisation activities in general. Table 18.4 shows that estimates of the private rate of return on research and development spending by firms tends to be much lower than the social rate of return, which is often more than twice that of the private rate.

This suggests that it could be appropriate for the proposed matched funding scheme to be based on a ratio of between $0.50 to $1.50 of public funding per dollar of private funding. Many matched funding schemes currently use a ratio of between 1:1 and 1:3 (see Table 18.4). Dollar-for-dollar matched funding is consistent with the evidence base.

The ratio of matched funds should not be varied based on criteria such as the level of expected emissions reduction. Doing so would reward investors on the basis of fine judgments about matters that in their nature are difficult to quantify.

It is likely that in the early years of the emissions trading scheme the funds allocated from the permit sales revenue towards research, development and commercialisation will not be exhausted, as the market will need time to assess and put forward appropriate candidate technologies. There will also be lags in the approval process. In this scenario, funds should be allowed to accumulate for use in future years.

Table 18.4 Estimates of private and social rates of return to private research and development spending

Studies	Private rate of return (%)	Social rate of return (%)
Minnasian (1962)	25	–
Nadiri (1993)	20–30	50
Mansfield (1977)	25	56
Terleckyj (1974)	27	48–78
Sveikauskas (1981)	10–23	50
Gotto & Suzuki (1989)	26	80
Mohnen & Lepine (1988)	56	28
Bernstein & Nadiri (1988)	9–27	10–160
Scherer (1982, 1984)	29–43	64–147
Bernstein & Nadiri (1991)	14–28	20–110

Source: Griliches (1995: 72).

On the other hand, it is also likely that in at least a few years, demonstration and commercialisation activities will be at a peak and the claims for funds will be above the annual allocation, even after allowing for the surplus of funds accumulated in the early years. The funding scheme should include measures that automatically reduce the rate of matching once the budgeted level of expenditure has been exceeded.

18.4 Overcoming barriers from technological lock-in

If the deep cuts necessary for the stabilisation of atmospheric greenhouse gas concentrations are to be achieved, far-reaching innovation will be needed. Technological lock-in however is an obstacle to such innovation (Foxon et al. 2008).[8]

Analysis of innovation systems suggests that it is important to create a long-term, stable and consistent strategic framework to promote investment in low-emissions technologies (Foxon et al. 2008; Stern 2007). High policy uncertainty on the other hand can create the incentive to delay investment and raise investment thresholds in an already high-risk environment (Blyth & Yang 2006). A clear, credible and consistent policy framework will provide investors with long-term signals, and incentives to deal with the challenge of technological lock-in, accelerating Australia's technological transition to a low-carbon economy (Foxon et al. 2008). The most important overarching policies for creating investor confidence and overcoming technological lock-in are the long-term emissions trajectory and the emissions trading scheme. Policy certainty and long-term investment signals can be backed up by strengthened international policy action that enhances domestic policy credibility (Blyth & Yang 2006).

Notes

1 In this chapter, the term 'low-emissions technologies' refers to those technologies that reduce the emissions intensity of existing technologies, reduce the need for emissions, or capture and sequester greenhouse gases.

2 For example, the CRC for Construction and Innovation (soon to become the Sustainable Built Environment National Research Centre) has developed resources such as 'Your Building'. In addition, work is being undertaken by the Australian Building Codes Board and Standards Australia to ensure building materials are manufactured to be resilient to climate change impacts.

3 The NHMRC 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.

4 In 2004–05, the rural research and development corporations invested $511 million, of which about 60 per cent was funded by industry. Gross value of production for agriculture in 2006–07 was $36.1 billion (ABS 2008b). Therefore the proportion of industry expenditure on research and development was 0.85 per cent of gross value of production. Note that matched government funding is typically limited to 0.5 per cent of gross value of production (CRRDCC 2006).

5 For a discussion of a range of other key design principles for business research and development programs, see Productivity Commission (2007b: Chapter 10.2).

6 The Coal 21 Fund is the Australian black coal mining industry's funding commitment to research, development and demonstration of clean coal technologies.

7 The private rate of return is the benefit a firm receives on its investment, while the social rate of return is the broader benefit that accrues to both the firm and society more generally. The difference is therefore the spillover benefit that the firm is unable to appropriate.

8 Technological lock-in occurs when incumbent technologies benefit from positive feedbacks that come from being the status quo to the extent that superior technologies struggle to displace inferior incumbents.

References

ABS (Australian Bureau of Statistics) 2008a, *Research and Experimental Development, Government and Private Non-Profit Organisations*, *Australia, 2006–07*, cat. no. 8109.0, ABS, Canberra.

ABS 2008b, *Value of Agricultural Commodities Produced, Australia, 2006–07,* cat. no. 7503.0, ABS, Canberra.

Arrow, K. 1962, 'Economic welfare and the allocation of resources for invention', in R. Nelson (ed.), *The Rate and Direction of Inventive Activity*, Princeton University Press, pp. 609–26.

Australian Treasury 2008, Budget Measures, *Budget Paper No. 2 2008–09*, Commonwealth of Australia, Canberra.

Banks, G. 2008, Colin Clark Memorial Lecture, University of Queensland, Brisbane, 6 August.

Blyth, W. & Yang, M. 2006, *Impact of Climate Change Policy Uncertainty in Power Investment*, document no. IEA/SLT (2006) 11.

Commonwealth of Australia 2006, *Uranium Mining, Processing and Nuclear Energy: Opportunities for Australia?* Department of the Prime Minister and Cabinet, Uranium Mining, Processing and Nuclear Energy Review (UMPNER), Canberra.

CRRDCC (Council of Rural Research and Development Corporations) 2006, *The Benefits of Rural R&D*, prepared by the Council of Rural Research and Development Corporations' Chairs, Rural R&D Corporations, Canberra, 5 September.

CRRDCC 2008, *Council of Rural Research and Development Corporations' Chairs, Submission to the National Innovation System Review*, Rural R&D Corporations, Canberra, April.

Department of Industry, Tourism and Resources 2006, *Collaboration and Other Factors Influencing Innovation Novelty in Australian Businesses: An econometric analysis*, Commonwealth of Australia, Canberra.

DEEWR (Department of Education, Employment and Workplace Relations) undated, *The National Research Priorities and Their Associated Priority Goals*, DEEWR, Canberra.

Foxon, T., Gross, R., Pearson, P., Heptonstall, P. & Anderson, D. 2008, *Energy Technology Innovation: A systems perspective*, report for the Garnaut Climate Change Review, Imperial College Centre for Energy Policy and Technology, London.

Fri, R.W. 2003, 'The role of knowledge: technological innovation in the energy system', *The Energy Journal* 24(4): 51–74.

Griliches, Z. 1992, *The Search for R&D Spillovers*, National Bureau of Economic Research Working Paper Series, No. 3768, NBER, Stanford, California.

Griliches, Z. 1995, 'R&D and productivity', in P. Stoneman (ed.), *Handbook of Industrial Innovation*, Blackwell, London, pp. 52–89.

Grubb, M. 2004, 'Technology innovation and climate change policy: an overview of issues and options', *Keio Economic Studies* 41(2): 103–32.

IPCC (Intergovernmental Panel on Climate Change) 2007, *Climate Change 2007: Mitigation of climate change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, B. Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer (eds), Cambridge University Press, Cambridge and New York.

Jaffe, A.B., Newell, R.G. & Stavins, R.N. 2005, 'A tale of two market failures: technology and environmental policy', *Ecological Economics* 54(2–3): 164–74.

Martin, S. & Scott, J. 1998, *Market Failures and the Design of Innovation Policy*, <www.mgmt.purdue.edu/faculty/smartin/vita/csda4.pdf>.

Murphy, L.M. & Edwards, P.L. 2003, *Bridging the Valley of Death: Transitioning from public to private sector financing*, National Renewable Energy Laboratory, Colorado.

OECD 2008, OECD Stat Beta Version, 'Gross domestic expenditure on R&D by sector of performance and socio-economic objective', <http://stats.oecd.org/wbos>.

Productivity Commission 2007a, *Productivity Commission Submission to the Prime Ministerial Task Group on Emissions Trading*, Productivity Commission, Canberra.

Productivity Commission 2007b, *Public Support for Science and Innovation*, research report, Productivity Commission, Canberra.

Prime Ministerial Task Group on Emissions Trading 2007, *Report of the Task Group on Emissions Trading*, Department of the Prime Minister and Cabinet, Canberra.

Raby, G. 1996, *Making Rural Australia: An economic history of technical and institutional creativity, 1788–1860*, Oxford University Press Australia & New Zealand, Melbourne.

Stephan, P.E. 1996, 'The economics of science', *Journal of Economic Literature* 34(3): 1199–35.

Stern, N. 2007, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge.