# 16 RESEARCH, DEVELOPMENT AND INNOVATION

## 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 over $3 billion per annum.

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 grants should be available where private investors demonstrate externalities, low emissions and innovation.

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

The successful development and deployment of new low-emissions technologies across all sectors will be important in minimising the costs of adjustment to the emissions trading scheme.[1] As other countries adopt similar constraints on emissions, there will be new opportunities for expansion in sectors where Australia is able to develop an international comparative advantage.

Australia is particularly well positioned to develop and deploy a wide range of new mitigation technologies, particularly in the energy sector (Energy Futures Forum 2006). Although the potential for emissions reductions may initially appear to be concentrated in some sectors, if tighter emissions caps are implemented in the long term, new low-emissions technologies will be important right across the economy.

A wide variety of new and existing technologies were highlighted in submissions to the Review as being potential contributors to Australia's mitigation task. A selection of these is set out on in Table 16.1.

### Table 16.1 Technologies relevant to mitigation cited in submissions to the Review

| Industry | Technology type | Organisation/individual |
|---|---|---|
| **Electricity generation** | Geothermal (hot rocks) | Australian Geothermal Energy Group, Australian Geothermal Energy Association Geodynamics Ltd, Geogen Pty Ltd |
| | Improved generation efficiency (e.g. coal drying) | Australian Academy of Technological Sciences and Engineering, Anglo Coal Australia Pty Ltd |
| | Solar (photovoltaic and thermal) | Australia and New Zealand Solar Energy Society, Australian Academy of Technological Sciences and Engineering, Andrew Blakers, Beyond Zero Emissions, Barrie Pittock |
| | Other energy | BioEnergy Australia |
| **Transport** | Lower-emissions vehicles | Australia Automobile Association, BusVic |
| | Second and third generation biofuels and biomass | BioEnergy Australia, Environmental Health Central Australia, NSW Department of Premier and Cabinet, NSW Department of Primary Industries, MDB Biodiesel Ltd. |
| | Electric cars | Centre for Education and Research in Environmental Strategies (CERES), Australian Academy of Technological Sciences and Engineering, GetUp |
| **Sequestration** | Soil sequestration (biochar) | Tim Flannery, Department of Agriculture and Food WA, WSN Environmental Solutions, BEST Energies Australia, Beyond Zero Emissions |
| | Geosequestration | Australian Coal Association, BP Hydrogen Energy Australia Pty Ltd, Santos Ltd, ZeroGen Pty Ltd, Australian Energy Company Ltd |
| | Algal sequestration and biofuels | MDB Biodiesel Ltd, NSW Department of Primary Industries |

Note: The categories in this table are illustrative only based on the general content of submissions. The table is not to be taken as a comprehensive, representative or exhaustive summary of the arguments presented. Please refer to the full submissions on the Review website for details.

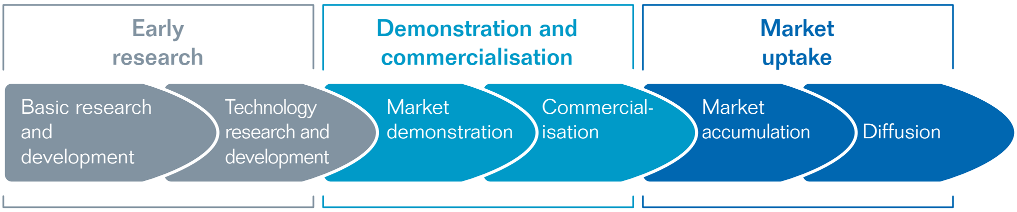
Emissions reductions could come from any and all sectors, including energy, transport, construction, agriculture, waste and forestry. Compared to the cumulative wisdom of the many market participants, governments will never be well placed to foresee the successes and failures of new goods, services and processes. Current official views of the relative merits of different technologies therefore should not be a factor in the policy development process. However, government must be mindful of the potential need for new institutions, regulatory frameworks or infrastructure as a result of new technologies (see Chapter 17).

## 16.1 What is innovation and how does it happen?

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

For the purposes of economic analysis and policy development, the Review has adopted a simplified model of the innovation chain as shown in Figure 16.1. The three distinct phases of the innovation chain are discussed in greater detail below.

**Figure 16.1 The innovation chain**




Source: Adapted from Grubb (2004).

**Early research:** In this phase, 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. Due to the stochastic nature of new discovery, there are also benefits for society when early research is coordinated or collaborative.

**Demonstration and commercialisation:** The new knowledge generated by early research is applied to the real world through pilot, demonstration and first commercial-scale projects. These activities tend to be capital intensive in nature, requiring research bodies or firms to take on substantial risk since the technology is yet to be proven in the intended operating environment. Because the technology may not yet be cost-competitive (even after factoring the impact of a price on emissions), commercial returns are problematic. Projects must therefore rely on high-risk venture capital funding, government support, niche market support or philanthropic patronage. Some studies have termed this phase 'the valley of death', where most technologies fail either technically or financially (Grubb 2004; Murphy & Edwards 2003).

**Market uptake:** Once new knowledge is converted into a tested product or service, it is sold to the open market. Technologies at the market uptake stage are technically proven and therefore able to compete with other mature products in the marketplace.

### 16.1.1 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 affected by the demand–pull effects of an emissions trading scheme.

An emissions trading scheme will also 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 the funding bodies respond through the reallocation of resources 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.

Note that over time technological change and development will naturally bring down the cost of various low-emissions technologies once they have been deployed. This has been the case, for example, with the internal combustion engine and fossil-fuel based generators over the past century.

In the case of energy technologies, rising fossil fuel scarcity will go a considerable way towards making some low-emissions technologies competitive, even in the absence of a carbon price. However, high fossil fuel prices can never make sequestration of emissions as cheap as free release into the atmosphere.

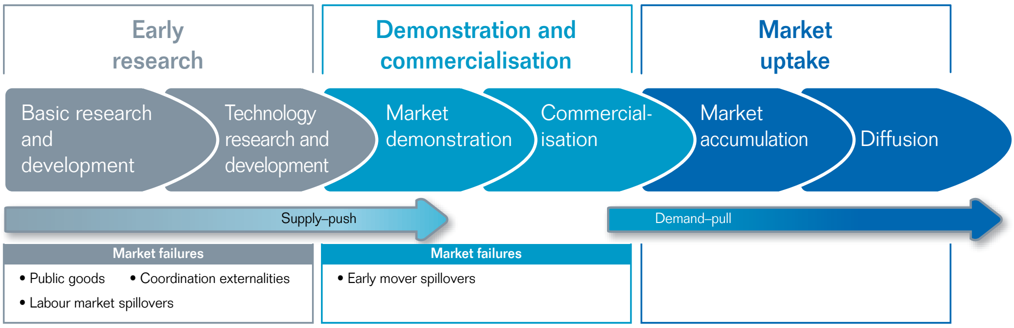
### 16.1.2 What are the barriers to an efficient market response?

While an emissions trading scheme will drive both the development and uptake of new low-emissions technologies, market failures that impinge on the efficient and competitive function of markets for new ideas and technologies may result in suboptimal levels of investment in innovation. These market failures stem from the special characteristics of ideas and knowledge, as well as the unique processes of knowledge creation.

If, as a result of market failures, there are suboptimal levels of investment in low-emissions technologies, then inferior, more expensive substitutes will need to be deployed to reduce emissions. This inefficient response will lead to a carbon price that is higher than it would otherwise be.

These market failures are most important in the early research and demonstration and commercialisation phases of the innovation chain (see Figure 16.2). The emissions trading scheme will create sufficient demand–pull for new low-emissions technologies, and thus there is generally no need for any additional support for innovation at the market uptake stage.

**Figure 16.2 Market failures along the innovation chain**




Correction of these market failures is a strong economic justification for 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 the climate change challenge, 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.

Any justifications for policy outside the market failure rationale should be rejected (see Box 16.1).

**Box 16.1 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, such that the remaining rationale for technology policy should only be the correction of material market failures that could increase the cost of mitigation. Some wrong arguments for innovation policy in this context include:

- *There will not be enough innovation or time to develop new technologies for Australia to successfully meet its national targets.*

The cap on emissions 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, if need be, in a very short time.

- *The permit price will initially be low and therefore will not drive much innovation.*

There is no reason for the permit price to be uneconomically low with the anticipated future scarcity of permits. If it seems to be the case, then this 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, are 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.

## 16.2 Ensuring optimal levels of early research

### 16.2.1 What are the market failures in early research?

#### Public good nature of 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 benefiting from that knowledge (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 often relatively low incremental costs of diffusion (Stephan 1996). This is especially the case when the knowledge is transparently embodied in a product or process, readily codified and easily diffused (Productivity Commission 2007b). In addition, knowledge is non-rivalrous in nature in that, once it is created, many individuals or firms can use and apply it, thus making it a public good.

### Externalities from coordination

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 significantly more likely to achieve higher degrees of innovation (Department of Industry, Tourism and Resources 2006).

Currently in Australia, the cooperative research centres are the most direct approach to encouraging collaboration in early research.[2] Many of these centres, particularly those in the mining and energy sector and the manufacturing sector, undertake collaborative research in areas that are potentially relevant to climate change mitigation: advanced automotive technology, construction innovation, sustainable resource processing, coal in sustainable development and greenhouse gas technologies.

### Positive externalities that spill into the labour market

The supply of skilled labour in some industries is closely tied to early research activities. 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 labour market shortages. Even if the research itself does not result in immediate and significant direct economic benefits in the form of new technologies, the concurrent expansion and development of the labour force may still yield a substantial indirect economic benefit in the long run.[3] The Productivity Commission (2007b) found that the benefits of research and development in both universities and public sector research agencies is high, due to their orientation to public good research and their role in the development of high-quality human capital for the Australian economy.

## 16.2.2 Are current policies targeting early research sufficient?

Like most developed countries, Australia has an established institutional framework for allocating research funding across the economy. The Productivity Commission (2007b) has recently highlighted the expanding need for public good research in the light of future environmental, energy and climate challenges as one of the potential stresses on the Australian innovation system.

For example, 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 in recent years (ABS 2006). Australia's expenditure on energy supply technologies, in general, 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) such that the research activities and priorities of a small number of countries are likely to determine the global range of low-emissions technologies in the future.

In the absence of incentives flowing from a carbon constraint, falling levels of investment in early research in areas important to the mitigation challenge have been a global phenomenon (see Figure 13.1 in Chapter 13). For example, the Fourth Assessment Report of the IPCC 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' (IPCC 2007: 20).

These are imperfect indicators for low-emissions research since there can be many reasons for declining levels of early research funding in any one area; there is no definitive data on early research funding for low-emissions technologies.

The Review is of the view that 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 placed on the issue by both the government and Australians more generally.

It is important that this issue be looked at from an international perspective since research is an international public good. Section 13.1 recommends that high-income countries support an International Low Emissions Technology Commitment, requiring them to allocate a small proportion of GDP to research, development and commercialisation of new, low-emissions technologies and technology transfer, at home or abroad. The chapter provided an indicative global figure for this fund of $100 billion per year, and an indicative Australian share of $2.8 billion.

### 16.2.3 New institutions to drive early research in mitigation technologies

The significant challenge of deep cuts to emissions suggests that Australia's early 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.

Government has long attempted to resolve the issue of how much priority is appropriate for each area of research by establishing institutions, such as the Australian Research Council, that allocate resources according to strategic importance and national capability. This reprioritisation could be achieved through the creation of a new institutional body or structure charged with elevating, coordinating and targeting Australia's effort in low-emissions research. Such a body could operate in a similar way to the National Health and Medical Research Council (NHMRC[4]). It could oversee a new push in early research for low-emissions technologies, operating independently to correct the market failures discussed above.

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

- allocating public funding for early research across relevant areas based on clearly established criteria (see section 16.2.5)
- coordinating relevant early research activities within Australia and promoting links with research activities in the Asia–Pacific region and globally by pursuing and forging partnerships between organisations, or through funding criteria in favour of collaborative research programs
- guiding training in low-emissions technologies throughout Australia, including the development of higher education programs. New tertiary programs could include courses that develop interdisciplinary expertise for businesses to manage the implementation of emissions compliance, as well as the technical skills for the development and adoption of new technologies.

### 16.2.4 Where could additional funding for early research come from?

One possibility is that existing funds allocated to relevant research areas could be consolidated and reallocated by the proposed research council. However there are good reasons for not reallocating all existing funding. Firstly, it is important to maintain the continuity in the allocation of existing funds. Secondly, it is beneficial to maintain some plurality of funding sources; general institutions can co-exist with specific funding bodies, thereby ensuring 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 limited 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 public good research in fields relevant to low-emissions technologies 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 strong links between the early research effort, the long-term cost of mitigation and the carbon price. More early research in low-emissions technologies should, over time, lower the long-term cost of mitigation and thus the carbon price.

All commitments of funds for early research would qualify under the International Low Emissions Technology Commitment proposed in section 13.1.

### 16.2.5 Criteria for allocating funds for 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; between encouraging options and achieving increasing 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. In many of these areas it will be sensible 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 therefore should be guided by clear criteria to ensure that funds are allocated to areas that are likely to result in the highest economic value for Australia. There are two important criteria that need to underlie any funding decisions in early research: (1) Is this area of research of national interest to Australia? (2) Is this an area of early research where Australia has a comparative advantage?[5]

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

#### Criterion 1: Is this area of research of national interest to Australia?

Australia should only fund early research that is well 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 (see Chapter 8 for some indicators).
- **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 is one example. However, some technologies will be subject to local factors such as geographical contours, geological formations, and climatic conditions and variations.

### Box 16.2 Examples of areas of strategic interest for Australia

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

#### Table 16.2 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 highly demanded 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 it has 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. |

- **Sources of Australia's economic prosperity:** Sectors that are important sources of economic prosperity today or could become sources of economic competitiveness in the future are areas of research that coincide with a broader strategic interest for Australia.

- **Technologies that build on Australia's natural resource advantage:** Australia is in a unique position among developed countries of having a per capita abundance of a wide range of natural resources. Research that focuses on new technologies and processes which allow these resources to be exploited should score more favourably under this criterion.

#### Criterion 2: Is this an area of early research where Australia has a comparative advantage?

Australia should only undertake early research in areas where it has a comparative advantage. The Review recognises, however, that it is difficult to determine what exactly Australia's core areas of comparative advantage are in early research as 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 very clear. For example, although the export of uranium is one source of economic prosperity in Australia (and therefore an area of national interest), the fact that Japan and France outspend Australia by a factor of 300 and 150 respectively on nuclear energy research each year (Commonwealth of Australia 2006) suggests that early research in nuclear generation is not a core priority area for Australia.

Australia's demonstrated strength in agricultural research is an example of an area of clear comparative advantage. In 2004–05, almost one-quarter (23.4 per cent) of all government expenditure on research and development could be attributed to plant production and plant primary products, and animal product and animal primary products.

## 16.3 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.

### 16.3.1 Spillovers from demonstration and commercialisation

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 the early mover, realising that it must ultimately compete with late movers who are able to carry out operations at low cost without having to bear the upfront investment. This is likely to result in an undersupply of early mover activities. For some new industries, multiple spillovers may cumulatively amount to a 'show-stopper' market failure resulting in no activity at all.

What may seem to be spillovers are not always real externalities, as there may be secondary mechanisms through which these spillovers are internalised. For example, 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.

There are five main types of spillovers that result from early mover activities which government must address to ensure an efficient level of demonstration and commercialisation activity.

- **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, such as through the patent system, this solution is inherently imperfect as not all knowledge lends itself to patent protection (Jaffe et al. 2003; 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 increased pool of skilled labour, up to some economic limits.

- **Regulatory and legal spillovers:** Early movers may bear the large upfront costs of working with government and other industries to develop new regulations and harmonised 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 then able to benefit from an established support sector without having had to bear the upfront costs.

- **Social acceptance spillovers:** Communities can be apprehensive of new technologies that are visually or acoustically intrusive, potentially dangerous, or simply novel and not yet fully understood. An early mover firm looking to commercialise such a technology will often bear the costs of capital-intensive 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 achieved is then enjoyed at no cost by later movers promoting similar technologies.

### 16.3.2 Are current policies for demonstration and commercialisation sufficient?

The Productivity Commission (2007b) has noted that the emphasis on innovation in Australia has moved towards demonstration and commercialisation projects: many recent low-emissions research and development policies have been targeted at the market uptake stages of the innovation chain (see Table 16.3). This could be because the scarcity of funding intensifies the pressure to focus resources 'downstream' on shorter-term, applied research aimed at the deployment of mature and commercial technologies.

**Table 16.3 Research and development programs in Australia targeting low-emissions technologies**

| Policy/fund name | Description | Funding |
|---|---|---|
| **Low Emissions Technology Demonstration Fund** | This fund supports the commercial demonstration of technologies that have the potential to deliver large-scale greenhouse gas emission reductions in the energy sector. | $410 million over 11 years from 2004–05 to 2014–15 |
| **Renewable Energy Development Initiative** | This initiative is a competitive merit-based dollar-for-dollar grants program supporting renewable energy innovation and commercialisation. | $100 million from 2004–05 to 2010–11 |
| **Solar Cities** | This program is designed to demonstrate how solar power, smart meters, energy efficiency and new approaches to electricity pricing can be combined. | $93.8 million over nine years from 2004–05 to 2007–08 |

**Table 16.3 Research and development programs in Australia targeting low-emissions technologies *(continued)***

| Policy/fund name | Description | Funding |
|---|---|---|
| **Energy Technology Innovation Strategy (Victorian Government)** | This funding aims to assist the commercialisation of coal drying, coal gasification and geosequestration technologies to reduce greenhouse gas emissions from brown coal electricity plants. This funding supports some Low Emissions Technology Demonstration Fund projects. | $182 million from 2008 |
| **Queensland Future Growth Fund** | This funding supports the deployment of low-emissions coal and renewable energy technologies. The fund will operate separately from the Queensland state budget. | $350 million |
| **Green Car Innovation Fund** | This fund aims to support the manufacturing of low-emissions vehicles in Australia. The fund will operate on a matched funding basis at a ratio of 1 to 3. | $500 million over five years from 2011–12 to 2016–17 |
| **National Low Emissions Coal Fund** | This 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 to 2. | $500 million over seven years from 2009–10 to 2014–15 |
| **Renewable Energy Fund** | This fund targets renewable energy demonstration projects with private sector funds matched at a ratio of 2 to 1. Funding will be 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 from 2008–09 to 2014–15 |
| **Energy Innovation Fund** | Investments are 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 from 2008–09 to 2012–13 |

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 16.3.1.

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.

### 16.3.3 A matched funding scheme to compensate early movers

The externality benefits from early-mover activities will vary widely on a case-by-case basis. Different projects in different contexts will generate different types of spillovers at a variety of levels. The prohibitively high administration and compliance costs of quantifying spillovers on a case-by-case basis means that such an approach will not be viable. In addition, some types of spillovers will be nearly impossible to measure short of complex and costly surveys.

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 16.4.

**Table 16.4 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 could be an alternative tax concession |
| **Niche market creation** | Technology target schemes | Policies such as the renewables targets may establish guaranteed niche markets for particular categories of goods |
| | Guaranteed revenue | Policies such as regulated feed-in 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 given criteria |
| | Income-contingent loans | Income-contingent loans compensate innovators for spillover by reducing their 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 |

The Review considers that of these many instruments, matched funding is the preferred option based on a range of criteria.[6]

- **Simple and targeted:** Matched funding can be simple and directly targeted in its design to specifically address the spillovers that arise as a result of activities that bring technologies for emissions reductions to market.
- **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. Unlike technology targets, government procurement programs, or other niche market–type instruments, matched funding does not need to target, and therefore inefficiently favour, particular industries or technology types.
- **Maintains risk exposure:** Some policy instruments (such as those that provide a guaranteed return on investment) may inappropriately insulate investors from known technical and commercial risks. 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. Government need not form a complete view of the potential benefits or risks associated with each project, thereby avoiding potential information asymmetry issues. Similarly, 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: unless there is real potential for the project to earn a return in the long run, the private investment would not be made.
- **Capped expenditure:** Matched funding can be designed so that the total expenditure does not exceed a given level of funding.
- **Transparency, impartiality and independence:** Matched funding is transparent to administer, and the amount of funding allocated is transparently accounted for in the budgetary process rather than being hidden in forgone revenue. The body or institution that administers a matched funding scheme can also operate at arm's length from government and thus be insulated from the political process.

The current Low Emissions Technology Demonstration Fund (see Table 16.3) is in essence a matched funding scheme but has been an imperfect mechanism for correcting early-mover spillovers. Although it seeks to stimulate the demonstration and commercialisation of low-emissions technologies, the Low Emissions Technology Demonstration Fund lacks technology neutrality by favouring emissions reductions from particular sectors at a particular scale, and may compromise independence by relying on ministerial approval for the final selection of projects.

### 16.3.4 Where would the funds for early mover support come from?

Apart from appropriations out of general government revenue, a matched funding scheme could be paid for from three other sources:

- **Auction revenue from the sale of emissions permits:** There is a strong policy rationale for a substantial percentage of permit revenue to be allocated towards matched funding of demonstration and commercialisation projects. In particular, these funds could potentially result in increased availability of low-emissions substitutes in the short term and a lower carbon price.
- **Reallocation from existing funds:** This would occur when, after review, existing programs were shown to be inefficient in compensating firms for the external benefits that they generated.
- **Industry levies:** Matched funding schemes for research and development 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 research, 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. In light of this, the Coal 21 Fund will raise an estimated $1 billion over the next decade from voluntary levies in the coal industry.[7] This could be extended.

### 16.3.5 Criteria for determining who qualifies for early mover support

The challenge with subsidies—whether through direct payments, tax system concessions or niche market support—is determining who qualifies, and what level of subsidy is appropriate. For any policy to target early-mover spillovers, an accurate and simple set of criteria is required based on 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 against the criteria, government needs to balance (1) the accuracy of the assessment process against (2) the complexity and associated transaction costs of the assessment process. The balance of considerations strongly favours simplicity and low transactions costs. The more complex the criteria, the more dependent the assessment process will be on the subjective judgments of the assessing panel and thus the less transparent it will be. Simple criteria would be more objective and contestable.

### Criterion 1: Will the technology contribute to lowering the cost of mitigation?

Applicants must demonstrate the relevance of their technology to the mitigation challenge. In most circumstances, this should be immediately apparent; all technologies that contribute to the delivery of existing goods and services at lower-emissions intensity would qualify. It does not matter whether emissions reductions are the primary aim of the new technology,[8] but it is important that the potential contribution to emissions reductions be material.

Choosing the appropriate cut-off level to select only those technologies that can be expected to make significant improvements will require specialist technical advice.

Not all technical problems will lend themselves to measurable and comparable metrics. For example, there is no straightforward way to compare technologies that contribute to building insulation, space heating or cooling, chemical refinement or production. In these circumstances, technical expertise will be required to assess whether there are reasonable prospects of a material contribution to emissions reduction.

### Criterion 2: Does the project qualify as an early-mover innovation?

Applicants will be required to demonstrate that the proposed project can be considered to be an early-mover innovation, at least in Australia. In short, projects that can be deemed to be pilot, demonstration or first commercial-scale projects should qualify, but 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 potential complications, the Review proposes that this question be answered by an independent panel of experts. The panel will make some technical judgments to determine whether a particular project is materially different from current available technology. For guidance the panel would have to provide a transparent account of its assessment in two stages:

- **Selection of an appropriate comparator:** 'Current available technology' can be objectively 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 then consider the particulars of the technology or suite of technologies being proposed and assess it against the comparator. In doing so it should examine the unique characteristics of the technology, the scale of the application, and the context within which the technology will be applied.

### Criterion 3: Are there expected spillovers associated with the project?

As previously discussed, attempting to quantify the size of different spillovers on a case-by-case basis is impractical due to the severe measurement issues. Instead, government will need to base it's assessment on a proxy measure of whether the spillovers in any particular case are material. The straightforward proxy is the assessment of whether or not a particular project, if successful, would be a genuine early mover.

Three types of project would qualify under the proposed matched funding scheme: pilot projects, demonstration projects and first commercial-scale projects.

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 objectively 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.

### What is an appropriate ratio for matched funding?

For a matched funding scheme, the difference between the private and social rates of return[9] may be a good proxy indicator for the estimated spillovers from demonstration and commercialisation activities in general. Table 16.5 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. Often the social rate of return is more than twice that of the private rate.

This comparison 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 16.5). Dollar-for-dollar matched funding is consistent with the evidence base.

**Table 16.5 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).

It might be suggested that the ratio of matched funds be varied based on various criteria, such as the level of expected emissions reduction. The Review would oppose this approach, which would reward investors on the basis of a particular technical characteristic of the project. This would undermine the aim of technology neutrality, and contravene the original intent of the funding scheme, which is to compensate early movers for spillover benefits.

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 some lags in the approval process. In this scenario, funds should be allowed to accumulate for use in future years.

On the other hand, it is also very 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 and return on funding from successful investments. The funding scheme should include measures that automatically reduce the rate of matching once the budgeted level of expenditure has been exceeded.

## 16.4 An overarching framework for innovative activities

For many sectors, the transition to a carbon-constrained economy will require much more than incremental efficiency improvements. 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).[10]

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) shares these views. 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). Industries in Australia have continually expressed the need for greater policy clarity, continuity and coherence so that they can formulate expectations about future markets (Australian Business and Climate Group 2007).

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 and accelerate Australia's technological transition to a low-carbon economy (Foxon et al. 2008). The most important overarching policies that will create investor confidence and overcome 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 A cooperative research centre is a company formed through a collaboration private sector organisations (both large and small enterprises), industry associations, universities, government research agencies such as the Commonwealth Scientific and Industrial Research Organisation, and other end users. There are currently 58 centres operating in six broad sectors.

3 For a survey and critical literature review of other types of potential missed economic benefits of publicly funded research, see Salter and Martin (2001).

4 The NHMRC is the single 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.

5 Note that these criteria are not the rationale for funding support, but rather the principles by which funding support may be allocated once the case for additional public good funding to correct for market failures has been clearly established.

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

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

8 Other aims could include improved efficiency in production, reduced waste or increased supply chain reliability.

9 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.

10 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

Australian Business and Climate Group 2007, *Stepping Up: Accelerating the deployment of low emission technology in Australia*, Australian Business and Climate Group, <www.businessandclimate.com/downloads/ABCG_Report_2007.pdf>.

ABS (Australian Bureau of Statistics) 2006, *Research and Experimental Development Australia, Government and Private Non-Profit Organisations*, *Australia, 2004–05*, cat. no. 8109.0, ABS, Canberra.

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

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

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.

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.

Energy Futures Forum 2006. *The Heat Is on: The future of energy in Australia: a Report*, CSIRO Corporate Centre.

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. 1995, 'R&D and productivity', in *Handbook of Industrial Innovation*, P. Stoneman (ed.), 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 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>, accessed 8 June 2008.

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.

Salter, A.J. & Martin, B.R. 2001, 'The economic benefits of publicly funded basic research: a critical review', *Research Policy* 30: 501–32.

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.