Issues Paper 4
Research and Development: Low Emissions Energy Technologies

The issues discussed in this paper are based on topics raised at the Garnaut Climate Change Review Public Forum on 10 December 2007, other discussions with stakeholders, internal analysis, and commissioned reports.

The issues discussed in this paper do not represent the views of Professor Garnaut or the Review Secretariat, but instead seek to raise relevant questions and invite feedback from interested members of the community.

1 Introduction

1.1 The Garnaut Climate Change Review

The Garnaut Climate Change Review (hereafter 'the Review') is an independent review by Professor Ross Garnaut commissioned by Australia's Commonwealth, State and Territory Governments. The Review will examine the impacts of climate change on the Australian economy, and recommend medium to long-term policies and policy frameworks to improve the prospects for sustainable prosperity.

In carrying out this task, the Review will undertake consultation to encourage open and informed debates on key climate change issues. For more information on how to participate in the Review please visit: http://www.garnautreview.org.au

1.2 Purpose of this Issues Paper

On 10 December 2007, Professor Ross Garnaut hosted a public forum on *Research and Development: Low Emissions Energy Technologies*. This forum sought to explore how innovation happens, and the role of government and the market in the development of low emission energy technologies. In particular the forum focused on the rationale for the role of government, and sought to develop principles and appropriate policies for application to the innovation system in Australia. Presentations for this forum are available on the Review website: http://www.garnautreview.org.au .

Drawing on the outcomes of the forum, stakeholder discussions, internal analysis, and commissioned reports, this paper aims to raise and explore issues, and seeks input on the key innovation issues facing Australia's industries in the context of climate change.

1.3 Submissions Process

All submissions in response to this Issues Paper should be received by Friday 11 April 2008 via email at contactus@garnautreview.org.au with "**Submission to Issues Paper 4**" in the subject line. Hardcopy submissions should be sent to:

Submission to Issues Paper 4

Garnaut Climate Change Review Secretariat

Level 2, 1 Treasury Place

East Melbourne, Victoria 3002

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2 Context

New technologies will play a substantial role in both the mitigation of, and adaptation to, climate change. On the mitigation side, new technologies will be needed in energy production, new manufacturing techniques and the development of new product lines. On the adaptation side, new agricultural practices and construction techniques will aid in reducing the costs associated with climate change impacts.

Establishing a carbon price alone will be an incomplete approach to mitigating climate change; additional measures will be required. An emissions trading scheme will address the primary market failure of uncapped greenhouse gas emissions and will encourage some research and development (R&D) activity in lower-emissions technology. However, the existence of other market failures in the innovation system means that simply establishing a price on emissions will not generate optimal levels of investment in technological change.

The role of these complementary measures will be to remedy the market failures such that the cost of abatement is minimised in the long run[1]. Analysis by Stern (2006) estimated that global average costs of CO_2 abatement are expected to decline over time as new technologies develop and become more cost effective. After 2025 the cost of carbon abatement is much more uncertain, depending primarily on the rates of innovation and world oil and gas prices. It is possible, on a more buoyant scenario of innovation and successful policy (and tightening world markets for oil and gas prices), that the long-term costs of a transition to a low carbon system may become negative (Stern 2006; Papathanasiou and Anderson 2000).

Of particular importance to assisting Australia's transition to an emission-constrained future is the development of low-emissions technology for the energy sector. In 2005, emissions from energy-related sectors accounted for almost 70 per cent of total greenhouse gas emissions. Stationary energy alone accounted for 50 per cent of emissions and in the 15 years from 1990 to 2005 increased emissions by 42.6 per cent (AGO 2005). These contributions are much higher than for other developed countries

[1] The reverse is also true that technology policy can be a costly approach if used as a substitute for rather than a complement to an emissions trading scheme (Jaffe, Newell and Stavins 2003).

which have higher proportions of stationary energy coming from lower emissions sources of fuel.

The stationary energy sector is expected to provide the greatest and the earliest reductions in emissions through a dramatic technological transition. The decarbonisation of electricity supply through technological change will be central to a successful mitigation story. The development and commercialisation of new energy technologies could have the added effect of spurring technological progress in other sectors.

It is important to note that technology policy is seeking radical innovation in one of the least innovative sectors in the global economy. Globally, technological change in sectors like information technology and pharmaceuticals are characterised by high private investment rates of 10-20 per cent of turnover, while in the power generation sector, private sector investment has fallen sharply with the privatisation of energy industries to the point where it is under 0.4 per cent of turnover (Grubb 2004).

3 How innovation happens

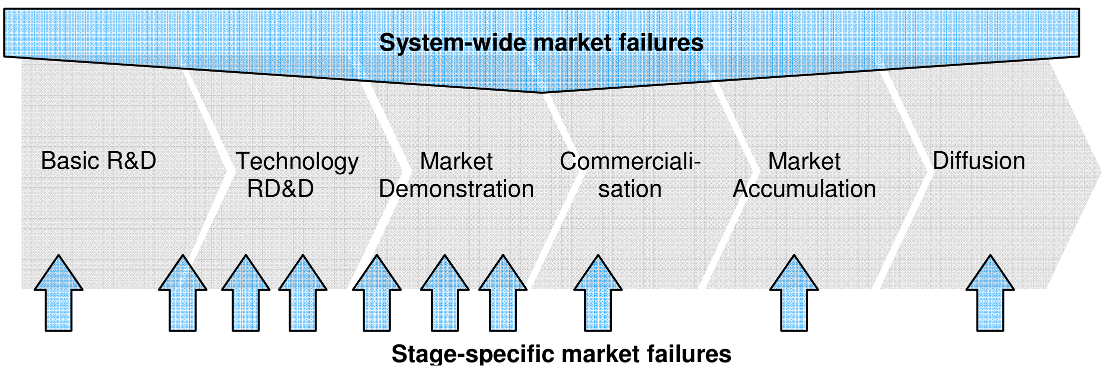
Establishing effective institutional arrangements that allocate scarce public resources to those areas of investment in R&D that generate the greatest societal benefit requires the identification market failures and barriers based on an accurate understanding of how innovation happens.

For many years, innovation was thought to occur by a simple linear progression along the innovation chain from R&D to commercialisation to diffusion. This view implied that the best way to increase the output of useful new technologies was to increase the input of new inventions by putting more resources into R&D, the so-called *technology* or *supply-push*. An alternative view was that the end-user demand for goods and services would stimulate inventive activity, so-called *market* or *demand-pull.*

More recent theoretical approaches and empirical research accept the roles of both technology-push and market-pull, but stress the importance of understanding the systems nature of innovation. Innovation systems theory depicts innovation as a more complex process of matching technical possibilities to market opportunities and stresses the flows of technology and information among people, networks and institutions. The innovation systems approach provides a much richer picture of the drivers of the rate and direction of innovation, and of the barriers that can prevent successful innovation.

Drawing on both perspectives, this paper discusses some of the important market failures and barriers that have become apparent to date, system-wide, and unique to particular stages of the innovation chain. System-wide failures are not confined to any group of actors but affect the entire innovation process, or the broad environment within which innovation occurs, thus requiring broad-based policies which attempt to introduce systemic change. Stage-specific market failures are much narrower and can often be addressed with targeted policies.

Figure 1 Three main stages in the innovation chain and illustrative market failures – system-wide and stage-specific



Source: Adapted from Grubb 2004

Questions for consideration

What is the role of an emissions trading scheme in driving innovation?

How large are the market failures in innovation?

Are there alternative frameworks that may be useful in the processes of policy analysis and development?

4 Market failures and barriers across the innovation system

4.1 Policy clarity, continuity and coherence

Industry has continually expressed the need for policy clarity, continuity and coherence in order to be able to formulate expectations about future markets. In Australia, industry has advocated for a single policy strategy that will determine the full scope of complementary policy measures, particularly in the early phases of an Australian emissions trading scheme (ABCG 2007).

High policy uncertainty can create the incentive to delay investment and raise investment thresholds in an already high risk environment (Blyth and Yang 2006). This is consistent with the analysis of innovation systems which suggests that it is important to create a long-term, stable and consistent strategic framework to promote a transition to a low carbon economy (Foxon et al. Forthcoming). Stern (2006) echoes these findings. Such a framework would aim to create a positive climate for investment across a diverse range of technologies.

Policy certainty and long-term investment signals can be "backed-up" by strengthened international policy action which enhances domestic policy credibility (Blyth and Yang 2006). Within the domestic strategic approach, key principles could include:

- **Perseverance with policy frameworks** – policy measures to support innovation should be stable over the long-term and be insulated from short term political changes. Research suggests that policy uncertainty and reversals in the early phases of a technology's development can 'sink' an innovation no matter what its long term promise might be.
- **Regulatory consistency** – measures should add to the functioning of innovation support as a strategic whole, by augmenting and not disrupting existing measures.
- **Continuity of policy measures** – measures should 'join up' across the stages of the innovation chain, so that a successfully performing technology can progress smoothly towards commercialisation, with a clear strategy in place for withdrawing support at that stage (Foxon et al., Forthcoming).

In providing greater investor certainty, the policy framework need not be rigid but rather, enable learning to occur in policy processes and program design. Just as it is not clear ahead of time which particular technology options will be successful, it may not be clear ahead of time which is the best mix of policy measures to apply. The ability to retain a degree of flexibility and adaptability within a clear long-term strategic framework is important.

Questions for consideration

How can Australian governments improve policy clarity, continuity and coherence for businesses for looking to invest in new energy technologies, or in other sectors with the potential to contribute to mitigation or adaptation?

How will this be improved with the implementation of an Australian emissions trading scheme? What areas of uncertainty might remain?

4.2 Risk management and diversification through a portfolio of technological options

Like in any investment strategy, it would be preferable to minimise diversifiable risk by taking a portfolio approach to investment in new technologies to transition Australia to a low emissions economy. There is a value associated with creating and keeping open 'options', which may be exercised in the future (Jaffe, Newell and Stavins 2003). The potential benefits of such hedging strategies could be very large, in terms of both emissions reductions and national industrial benefits.

Policies for promoting diversification in technological development need to consider the following issues:

- **Correlation of risks:** A strategy which seeks to maximise option value could account for how the risks of each project correlate with other investments in the portfolio and seek to minimise the diversifiable risk. Policy to encourage the development of a range of technologies however can be difficult to design without requiring government to select at least a range of 'winning' technologies.
- **Differentiation between technologies:** The policy framework to encourage the deployment of a range of options could differentiate between technologies or technology types and explicitly reward diversity through technology-specific quotas, or increased levels of price support for certain technologies[2]. The ideal policy would incentivise the market to pursue a range of technologies (some of which may be more speculative) without specifying arbitrary categories or technology types. a portfolio of technologies with highly correlated risks may be ultimately selected if agents are making investment decisions in isolation.
- **Balancing learning benefits:** Policies for creating option value should balance the maximisation of the positive externalities of a portfolio with the ability to allow learning benefits for particular technologies to accrue. There is a trade-off between the potential for increasing returns to scale and learning effects and the option value of maintaining work on a range of potentially competitive ideas. Premature lock-in or standardisation may result in the 'wrong' option becoming entrenched (Jaffe, Newell and Stavins 2003), whilst keeping options open indefinitely could mean that the potential advantages of increasing returns cannot be fully realised (Foxon et al. Forthcoming).
- **Technical failure:** Maintaining option value must also recognise that some technologies will fail, and equally others succeed and no longer require government support. Policy frameworks must therefore also proved a robust exit strategy. This requires predefined criteria that measure the success or failure of each technology and continual evaluation against these measures.

Questions for consideration

How can the Australian Governments avoid 'picking winners' while encouraging increased innovation? What is current best practice for technology neutral innovation policy?

How can the Australian Governments balance the need for diversity and option value with the increasing returns from uniformity and specialisation?

How can policy promote diversity without falling into the trap of needing to specify at a technical level what such diversity should include?

[2] A modified target based scheme may deliver the desired range of options. This was how the Non-Fossil Fuel Obligation (NFFO) in the UK operated until it was retired in 2000. Under the NFFO scheme generators qualified for government funded through competition within technology bands such as bands for wind or small hydro.

4.3 Technological lock-in

Some experts have posited that industrial countries have become locked-into fossil fuel-based energy systems through path dependent processes driven primarily by increasing returns to scale (Foxon et al. 2003). Lock-in arises through technological, organisational, social and institutional co-evolution, culminating in a techno-institutional environment which strongly favours entrenched incumbents.

Lock-in results in persistent market barriers where existing technologies benefit from incumbency advantages while new technologies face costly and inefficient barriers to entry. Barriers to entry are not by definition market failures, but in the context of climate change such barriers can reduce the important competitive pressures which stimulate and facilitate adjustment to an emissions constraint. This results in sub-optimal levels of research, development, demonstration and diffusion of carbon-saving technologies, even where environmental and economic advantages have been established.

In the energy sector, lock-in of existing technologies may arise from:

- **Regulatory certainty and established institutional arrangements:** Incumbent technologies benefit from the regulatory frameworks and institutions that have co-evolved with its development may implicitly favour investment that expands the scale and dominance of the current technological system.
- **Government support systems:** Some studies have found that at present, governments in Australia provide substantial financial support for the production and use of fossil fuels through direct payments, favourable tax treatment and other actions (Riedy 2007). These subsidies keep the cost of fossil fuel energy artificially low and contribute the entrenchment of current modes of energy generation, delivery and use.
- **Access to capital:** Investment capital tends to go to companies with collateral and a proven ability to service debt; these are likely to be the dominant design producers[3]. (See Section 5.5 for a discussion of capital market failures.)

All these advantages to the incumbent may have been instituted for reasons that were well considered at the time, but the enormity of the challenge of immediate emissions abatement may require that such states of lock-in be reviewed to ensure they are not inhibiting market innovation.

Questions for consideration

What are the barriers to entry that create uncompetitive incumbency advantages in the Australia?

What are the appropriate policies for minimising barriers to market entry without undermining the competitive advantage of established firms?

5 Market failures along the innovation chain

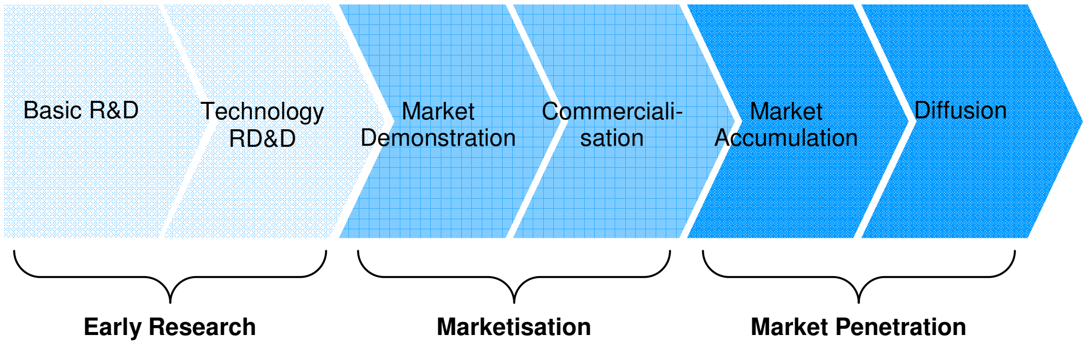
There are many variants to the innovation chain. Each part can be broken down into smaller subcomponents, but this does not necessarily capture the fundamental or meaningful differences between various steps[4]. The challenge is to select a model which is sufficiently comprehensive to capture key features of different stages of a complicated process, yet simple enough to allow a coherent framework for policy to develop. Grubb (2004) has identified six stages to energy technology innovation. From a finance and public policy perspective, it is useful to adopt Grubb's simplified paired groupings which

[3] Funding for potential radical or 'disruptive' innovations tends to come mainly from venture capital or government research programmes with much stricter lending conditions or higher costs.

[4] A multitude of steps and stages can also lead to the proliferation and fragmentation of government policy.

reduce the chain further to three components: early research, marketisation and market penetration.

Figure 2 Stage-specific market failures



Source: adapted from Grubb 2004

5.1 National public good research

Basic research—at the ideas end of the innovation chain—is commonly accepted as a *public good* in that it is non-rival and non-excludable. *Non-rival* in that once it has been created, its use by one agent does not reduce the amount or quality available for use by others. This makes it undesirable to ration access to it. *Non-excludable* as once supplied it is hard to deny access to other users, and hence its benefits cannot be captured by the entity that conducts the research. The result of basic research may have no immediate commercial application but is widely applicable and easily transferable. These features provide a strong rationale for government funding and support in the early stages of basic research.

Despite the desire to avoid 'picking winners', there is inevitably a good deal of discretionary judgement in decisions on allocation of public funding for public goods research and development. The important thing is that institutional arrangements for allocating funding apply appropriate expertise in a disciplined manner, and take appropriate account of Australia's comparative advantage. Systematic assessment of science and technology programs must be subject to routine, transparent and independent evaluation (PC 2007a). Measurement and methodological issues makes it difficult to provide rigorous quantification of the overall return on government contributions and thus effective performance evaluation and benchmarking are vital pre-requisites to the allocation of funding (PC 2007a).

Questions for consideration

What criteria, processes and institutional structures are most desirable for allocating funding to public good research?

What types of reforms are needed to ensure that public funding is allocated to the most appropriate and highest-value uses?

5.2 Early-mover disadvantage

The marketisation stage can be thought of to include multiple spillovers; the demonstration and commercialisation activities of one firm can result in externality benefits that accrue to other firms, other industries and even the community more broadly. The size of these spillovers is debated. Anderson and Willams (1993) found that when learning curves are steep, the positive externalities can amount to as much as 40-50 per cent of costs, depending on the prospective use of the technology. Other studies have presented historical evidence that suggest that much learning-by-doing is largely firm-specific and that spillovers into society thus could be quite small (Nordhaus 2004).

The variety of spillovers from innovative activity at the demonstration and commercialisation stages includes the following:

- **Knowledge spillovers:** The idea of knowledge spillovers has been long recognised in the economics literature (Arrow 1962). Knowledge spillovers can be large if application is visible; for example engineering patents are harder to enforce as learning takes place visibly in the marketplace unlike closed-door research undertaken by pharmaceuticals. Knowledge spillovers tend to be lesser when the sizes of step gains in ideas are large; breakthrough innovations are much harder to duplicate than simple incremental progress. Given that the marketisation of new energy technologies tends to be both visible and incremental in nature, knowledge spillovers are likely to be large.
- **Regulatory spillovers:** Early-movers may bear the costs of resolving legal or regulatory issues with government and other industries. Later movers would then benefit from regulatory clarity, reduced sovereign risk, and established contractual arrangements.
- **Skills spillovers:** Early-movers contribute to the future of all firms by bearing the up-front training costs to develop appropriate technical skills, including the development of engineering and wider technical capacity.
- **Support sector spillovers:** The commercialisation of new technologies by early-movers can spawn a host of supporting firms and industries. The development of such support industries requires some investment outside of the firms primary operations. Later movers are able to then enter the market and benefit from an established network of service providers.
- **Social acceptance spillovers:** Communities tend to be apprehensive of new technologies that are visually or acoustically intrusive, potentially dangerous or simply novel and misunderstood. An early-mover firm looking to commercialise such a technology will often bear the costs of communicating and informing stakeholders so as to attain acceptance for its particular technology. The construction of capital-intensive demonstration projects to increase societal confidence in the safety and effectiveness of a particular technology may also be required (ABCG 2007). This higher level of acceptance is then enjoyed at no cost by later movers in the industry touting similar technologies.

The cumulative effect of these spillovers can result in a very strong disincentive for any firm to be the early-mover in its particular industry. The first firm to act could bear all the costs of demonstration and taking their product to market, but share all the associated spillover benefits with firms that entered the market at a much later date. Where the spillovers are very large, product development may stall completely at the demonstration or commercialisation stages.

From a market failures perspective, the presence of historical learning curves in and of itself is neither a sufficient nor necessary rationale for government support. Learning or experience curves show empirically the reduction of unit costs of a technology with cumulative production[5]. Given that most of this learning is undertaken by early-movers, Stern (2006) appears to argue that the high upfront learning costs of deploying new technologies is a sufficient rationale for government intervention and that learning curves can be used to estimate the amount of deployment support needed to bring the cost of a new technology down to the level at which it is competitive with the existing technology under a carbon price. Unless there are substantial market failures (amenable to government correction) that prevent firms from appropriating the value from learning-by-doing, deployment support to facilitate or accelerate learning is more likely to increase the overall costs of mitigation rather than reduce it (PC 2007b). Theoretical and empirical

[5] For technologies in the early stages of development, unit costs fall by 10 to 20% with a doubling in cumulative installation (McDonald & Schrattenholzer 2001; Junginger et al. 2005).

evidence suggests that strong and effective competition policy which promotes market rivalry will be far more effective in stimulating technological performance.

Minimising spillovers and encouraging early-movers

While knowledge spillovers can be internalised through intellectual property rights and the enforcement of these rights through the use of patents, such solutions are inherently imperfect (Jaffe, Newell and Stavins, 2003; Fri 2003). Firstly, some knowledge is easier to patent and protect than others; highly specific solutions to very complex problems are less likely to be duplicated since the solutions cannot be easily generalised and adapted in other shapes or forms. Likewise some forms of knowledge are easier to reverse engineer resulting in higher likelihood of spillovers and lower chance of keeping it a corporate secret. Lastly, patent rights are not self-enforcing but rather require costly legal action (Martin and Scott 1998).

Where spillovers are large, deployment support may be warranted. So long as firms are able to secure some private returns, public policy can counter-balance the spillover problem by incentivising research in the private sector rather than performing it in public institutions (Jaffe, Newell and Stavins, 2003). However, Jaffe, Newell and Stavins (2003) also note that the deployment policy raises the question of whether government is the appropriate arbiter for determining which technologies should be supported, and whether or not government can manage the momentum which forms behind ill-advised or unsuccessful initiatives. Failure of some supported technologies should be expected and in this case it would be advisable for government to swiftly end those programs.

At the marketisation phase, it is possible avoid 'picking winners', making it more advantageous for government to explore more general mechanisms for assistance. Those proposed include:

- **Immediate and delayed tax write-offs:** For any development activity in climate change, including activities associated with demonstration and commercialisation, and infrastructure expenditure, firms get an immediate write-off. If the firms do not yet have any income against which this write-off can be made, they will be able to apply the write-off on future income instead (adjusted for the time value of money according to an appropriate indices such as a government bond rate). There may also be a possibility for firms to sell future tax credits to gain access to additional capital in the short term.
- **Accelerated tax deductions for depreciation:** Accelerated tax deductions are an appropriate incentive for capital-intensive demonstration and commercialisation activities and will help early-movers attract funds from investors looking to improve their tax position.
- **Matched funding:** Early-mover funding may be provided in the form of public funds matched at a percentage to every dollar of private investment.
- **Niche market creation:** Innovation studies have shown that new technologies tend to develop outside the dominant technological system with the support of niche markets or dedicated patrons. If suitable niche markets exist, these can act as 'incubation rooms' isolated from the pressure of competing with existing technologies in mainstream markets, where learning and knowledge spillovers take place with higher prices, price and performance improves, and new customer preferences form. Policies such as the renewables targets may establish niche markets for particular categories of goods which in turn accelerates learning.

Questions for consideration

What are the spillovers faced by firms at the marketisation phase and how large are these spillovers?

Are there significant spillovers at other stages?

Are patents adequate for internalising knowledge spillovers from new abatement or adaptation technologies?

What policy alternatives are available to increase the incentives for firms to undertake more demonstration or commercialisation activities?

What are the appropriate instruments available to government to reward early-movers for spillovers resulting from marketisation activities?

5.3 Coordination failures

Research collaboration can accelerate technological development by sharing risks, exchanging knowledge and resources, sharing learning investments and harmonising standards. The broad benefits from collaboration include:

- learning from technical and operation solutions and the failed approaches of others;
- sharing experience and expertise;
- decreasing risks through the pooling of investment and diversification;
- improving the reliability of tools and techniques;
- developing standards across market areas; and
- fostering technical expertise for regulatory and standard setting processes (Justus and Philibert, 2005).

In total, these benefits are felt by private collaborators and wider society. When the socially optimal level of innovative activity is not being undertaken because firms, in the pursuit of self-interest, choose to act alone rather than cooperate with other firms, there, by definition, exists a coordination failure. The causes for coordination failures at any stage of the innovation chain may include:

- **Product market rivalry:** The outcome of joint venture R&D is collaborating firms have access to the same technology in the competitive post-innovation market. In these cases, firms may consider that on balance, the accelerated development of the technology through a joint venture is not worth the fierce and constant competition that follows.
- **Information asymmetry:** Firms in competitive markets tend to be secretive of key ideas that could be a source of competitive advantage and as a result firms find it nearly impossible to know whether cooperation or coordination with another firm might result in mutually beneficial outcomes.
- **Transaction costs:** The legal and administrative costs of coordination could be so high as to outweigh the potential benefits. This is likely to be the case where complex contractual arrangements are required.

Whilst coordination failure is a market failure which warrants intervention, government may struggle to find effective policy solutions. Coordination and cooperation are activities that cannot be forcibly encouraged or instituted, but rather require shared values, belief in the uncertain benefits, and mutual trust. Government’s best and possibly only option is to provide forums to bring together market participants; Cooperative Research Centres are such an example. Intermediaries can also provide “coordination services” by acting as liaisons or net-workers who bring competitive firms together in mutually beneficial arrangements.

Questions for consideration

Does coordination improve research outcomes and thereby outcomes for society?

How large are the coordination failures in Australia?

How can government create more cohesive research environments and promote genuine cooperation between rival firms or organisations? Is this a role for government?

5.4 International public good research and coordination

Many of the market failures that have been discussed within the Australian context will also apply in the international innovation system. First, an optimal level of global investment in research, development and commercialisation of the new technologies requires public sector contributions, to correct for the public good character of basic research (see Section 5.1).

Second, there are likely to be spillovers and external benefits from private expenditure on development and commercialisation that flow beyond national borders and benefit those faced with similar circumstances internationally. These benefits suggest that where possible, governments should contribute to a pooled body of funding which is either used to undertake public good research directly, or to stimulate the total international innovation effort to socially optimal levels (see Section 5.2).

Third, coordinated international research has the potential to foster knowledge creation, share costs, share access to facilities and resources, and enhance domestic scientific capabilities through the exchange of information and experience (Justus and Philibert, 2005) (see Section 5.3). However, there is a tension in that while countries have a common interest in fostering the development of innovative technologies, they also have an interest in helping domestic enterprises to take the lead in international economic competition.

International innovation and technology transfer policies can have positive effects on the global mitigation effort by improving the terms of internationally binding agreements. Agreed commitments to investing in research, development and commercialisation by developed countries, and to facilitate transfer of technology to developing countries that accept emissions targets, could be a useful component of an international set of agreements to encourage acceptance of demanding emissions restriction targets in developing countries. Such international policies are complex and will evolve with time and negotiation.

Questions for consideration

In what areas would coordinated international public good research be warranted?

What are the appropriate institutional arrangements for shared public good research that will ensure the best outcomes at minimal administrative costs?

How can governments encourage the diffusion of technology internationally without diluting the incentives for innovation?

5.5 Capital market failures

Capital market failures may be present that limit an innovative firm's access to necessary capital. Technological innovation generally struggles to attract capital because the risks are larger and less easily understood than the risks of other available investments (Fri 2003). While all investment is characterised by uncertainty, the uncertainty associated with the returns to investment in innovation is often particularly large[6]. That being said,

[6] This applies to internal capital as much as it does to external capital as firms would rather allocate scarce capital to projects that advance the immediate interests of the firm, such as building market share or countering competitive threats (see research by Lempert 2002).

high risk premiums for capital investments with high technical risk are not in themselves a market failure since they are merely the efficient pricing of risk by the market.

The market may fail to allocate the optimal level of research and development expenditure due to the information asymmetry between innovators and investors. The prospect for success of given technology research investments is asymmetric because the developer of the technology is in a better position to assess its potential than outsiders. With information asymmetries, a firm attempting to raise capital to fund the marketisation of new technology will find potential investors sceptical about promised returns, and likely to demand a premium above and beyond the reasonable risk premium for technical risks.

These asymmetries are most pronounced at the demonstration phases as firms go through the cash flow "valley of death" (Murphy and Edwards 2003). Many technologies may not progress past the cash flow valley of death as firms may have to contend with the simultaneous challenges of:

- High capital costs for product development and demonstration activities; and
- A private capital market with very different values and demands compared to the public sector funding available at early stage research; few innovators are prepared for the significant shift away from technology focused public sector aims to the market focused objectives of private enterprise (Murphy and Edwards 2003).

Only those innovators that are able to provide credible (and 'bankable') signals to investors to indicate the viability of their technology are likely to obtain additional funding. Younger and smaller firms, which often develop breakthrough technologies outside of current mainstream solutions, are at a distinct disadvantage due to the lack-of existing private funds, limited available collateral, and the unproven ability to service debt. An established firm on the other hand is often in a much better position to communicate the potential of its technology.

Information asymmetries can also result in high transaction costs as investors seek to reduce the information gap. This is likely to raise the cost of capital further and limit the supply of funding to innovators with new technologies. In markets with previously low levels of innovative activity, these information asymmetry failures will be compounded by the high levels of risk aversion amongst investors, the lack of local funds management expertise to assess and manage risks, and the lack of funds management experience to accurately understand and price technical risks.

Questions for consideration

What are the weaknesses of capital markets in Australia?

What has been the experience of innovators in Australia in transitioning from public to private funding? How can government improve the transition process and reduce the capital shortfall for firms passing through the 'valley of death'?

Can government assist in reducing information asymmetries?

Submissions process

The Garnaut Review invites all interested parties to respond directly to the questions raised in this Issues Paper through written submissions.

All submissions should be received by Friday 11 April 2008 via email at contactus@garnautreview.org.au with "**Submission to Issues Paper 4**" in the subject line. Hardcopy submissions should be sent to:

Submission to Issues Paper 4

Garnaut Climate Change Review Secretariat

Level 2, 1 Treasury Place

East Melbourne, Victoria 3002

Submissions will be made available on the Review website unless specifically requested to be confidential. For more information on how to make a submission please visit the website at: http://www.garnautreview.org.au . If you have any queries, please contact the Secretariat via email at contactus@garnautreview.org.au.

References

ABCG (Australian Business and Climate Group) 2007, *Stepping up, Accelerating the deployment of low emission technology in Australia*, ABCG.

AGO (Australian Greenhouse Office) 2005, *National Greenhouse Gas Inventory 2005 – Accounting for the 108% target*, Australian Greenhouse Office, Canberra.

Arrow, K. 1962, *Economic welfare and the* allocation *of resources for innovation*, in Richard Nelson. ed., The Rate and Direction of Inventive Activity. Princeton, Princeton University Press.

Blyth, W. and Yang, M. 2006, *Impact of Climate Change Policy Uncertainty in Power Investment*, International Energy Agency Working Paper Series, IEA/OECD.

Foxon, T. J. 2003, *Inducing innovation for a low-carbon future: drivers, barriers and policies*, London: The Carbon Trust, available from http://www.thecarbontrust.co.uk/Publications/publicationdetail.htm?productid=CT-2003-07 (accessed 5 January 2008).

Foxon, T.J., Gross R., Heptonstall P., Pearson P., and Anderson D. Forthcoming, *Energy Technology Innovation: A Systems Perspective*, Report for the Garnaut Climate Change Review.

Fri R. W. 2003, *The Role of Knowledge: Technological Innovation in the Energy System*, The Energy Journal, vol 24, no 4.

Grubb, M. 2004, *Technology innovation and climate change policy: an overview of issues and options*, Keio Economic Studies. Vol.XLI. no.2. available from http://www.econ.cam.ac.uk/faculty/grubb/publications/J38.pdf (accessed 5 January 2008).

Jaffe, A., R. Newell and R. Stavins 2004, *A tale of two market failures*, RFF Discussion paper, available from http://www.rff.org/Documents/RFF-DP-04-38.pdf (accessed 5 January 2008).

Jaffe, A., R. Newell and R. Stavins 2001, *Technological Change and the Environment*, RFF Discussion Paper, available from http://www.rff.org/Documents/RFF-DP-00-47.pdf (accessed 5 January 2008).

Justus D. and Philibert C. 2005, *International energy technology collaboration and climate change mitigation*, Synthesis Report, IEA/OECD.

Murphy, L. M. and Edwards P. L. 2003, *Bridging the Valley of Death: Transitioning from Public to Private Sector Financing*, National Renewable Energy Laboratory, Colorado USA.

Nordhaus, W.D. 2004, *Economic modelling of climate change: Where have we gone? Where should we go?*, quoted in Montgomery, W.D. and Smith, A.E. 2005, Price, REFERENCES 111 Quantity, and Technology Strategies for Climate Change Policy, CRA International, Washington DC.

Papathanasiou, D. and Anderson, D. 2000, *Uncertainties in responding to climate change: on the economic value of technology policies for reducing costs and creating options*, Imperial College Centre for Energy Policy and Technology.

PC 2007a, *Public Support for Science and Innovation*, Research Report, Productivity Commission, Canberra.

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

Riedy C. 2007, *Energy and Transport Subsidies in Australia - 2007 Update*, For Greenpeace Australia Pacific, Institute for Sustainable Futures, University of Technology Sydney, Sydney.

Martin, S. and Scott, J. T. 1998, *Market failures and the Design of Innovation Policy*, available at: http://www.mgmt.purdue.edu/faculty/smartin/vita/csda4.pdf (accessed 5 January 2008).

Stern, N. 2006 *The Economic of Climate Change: The Stern Review*, Cambridge University Press.