

**Investment in clean technologies as a public good: a
discussion paper prepared for the Clean Energy
Council**

Prepared by

Andrew Wait

University of Sydney

Executive summary

There is likely to be underinvestment in clean low-emission energy technologies relative to the socially-preferred level for three reasons:

1. Private (for-profit) firms engaged in this research are unlikely to capture the full benefit generated by their investment (there is a positive externality or spill-over from the investment).
2. Given the potential for free-riding, there is a possible second-mover advantage in the R&D market for clean technologies. If firms prefer to imitate rather than innovate, they will reduce or delay their investment to the detriment of society overall.
3. The price of carbon-intensive energy is too low as it does not reflect the full cost to society from these fuels. This makes the price of carbon-intensive (traditional) energy artificially low compared with alternative energy sources. This substantially reduces the incentive to invest in alternative clean technologies.

The government should use its policy instruments to address each market failure as directly as possible. Given there are several failures, it is likely that the best policy will use a multiple instruments. Specifically:

- The government could implement subsidies, grants, tax incentives or other incentive scheme to address the research and development (R&D) investment externalities (number 1 above). These schemes should aim to be the same relative size as the estimated externality and, as far as possible, they should be technology neutral.
- Policies designed to encourage firms to innovate and be market leaders, rather than imitators, needed to explicitly address the anticipated relative payoff from innovating compared with waiting for the new technology to be developed by someone else (market failure number 2). There are different options that could be explored all with their own advantages and disadvantages, such as R&D subsidies, tightening intellectual property rights or prizes for successful innovation. The key element of each of these policy instruments is that it needs to make being a market leader more attractive than being a follower.
- Policies that facilitate innovation in new clean technologies are unlikely to induce a sufficient reduction in emissions on their own. The price of carbon-intense energy is too low compared with alternative sources; without an increase in the relative price of carbon-intense energy there will be underinvestment in clean technologies. The government needs to commit to policies that change the relative price of traditional technologies compared with new low-emission sources (market failure 3).

Climate change is a global issue. This raises its own challenges. For example, if climate change is resolved, the benefits will be enjoyed by all countries, even if they did not participate in the solution. Moreover, the issues of underinvestment and free riding are

potentially accentuated when the firms involved are located in different countries. Innovation in Australia will not be sufficient to solve climate change; there needs to be substantial investment and public sector support for clean technologies in many countries. If committed to addressing climate change and supporting clean energy innovation, the Australian Government should pursue feasible policies that help boost international support for clean technology R&D.

1. Introduction

Given the potential global impact of climate change, significant modifications are needed to the way we produce and use energy; specifically, we will need to reduce our current reliance on carbon-intensive fuels and alternative sources need to be found. The development of new clean energy sources – like wind, solar, geothermal, ocean and other technologies – potentially play a significant role in reducing greenhouse emissions. Some of these technologies are already in use while others are currently high-cost alternatives compared with existing (carbon-intensive) technologies. Overall, however, these technologies are not yet in a position to replace traditional fuel sources on a large enough scale to reduce emissions by the levels required (see, for example Popp 2006).

Where the private sector does not produce the level of research and development (R&D) investment that would maximise the net benefit to society overall, there is a market failure and a potential role for government to encourage more investment. The R&D market for clean technologies has many of the characteristics of other research markets (reviewed in Section 2), but it has some potentially unique characteristics of its own, including the scale of the problem of climate change and the need for immediate action. Both of these factors suggest decisive and significant action is required. Specifically, if the science on climate change is correct and the private sector is not investing enough in R&D to address the problem, there is role for government to facilitate more investment in clean technologies and to ensure this investment occurs with an appropriate sense of urgency.

The paper has several goals. First, this paper reviews the characteristics of the clean technologies, in particular focusing on the possibility of market failures (Section 2). Our preliminary analysis suggests that there are several potential market failures. Second, we review some of the policy actions a government could take to address these issues; we also suggest several principles for any government intervention (Section 3). Finally, in Section 4 we note some of the implications arising from the international nature of both climate change and R&D investment in clean technologies. Section 5 concludes.

2. Innovation in clean technology: are there market failures?

There are several potential market failures in relation to clean energy technology R&D, including: R&D externalities; second-mover advantages from free riding; and the negative externality generated from the use of traditional energy sources. In this section we discuss the characteristics of the first two externalities. The important common element is that if there are additional benefits from investment in these new technologies that the investing firm does not fully capture, there is the potential for underinvestment.

Externalities

If a market is working well, all of the costs of production are borne by producers and all of the benefits of consumption accrue to the party that buys the good. When this is not the case – that is, when a third party outside of the market transaction receives a benefit or incurs a

cost – there is an externality. The problem that arises with an externality is that buyers and seller in the market do not take into account either the full extra benefit or cost of an additional item traded. The market outcome either ends up with: too much of a good or service when there is a cost to a third party (negative externality); or there is too little traded (which is the case with a positive externality).

A for-profit firm engages in R&D on the basis of the private returns they anticipate. But R&D can generate knowledge and new skills and techniques that can be also used by other firms. Moreover, the initial innovation can lead to further innovations. Given these additional benefits to other parties, a firm has too little incentive to invest.¹ It can be the case that firms do not undertake R&D projects that are not profitable for the firm but would generate net benefits to society overall, or that the investment undertaken by a firm is not as large as it would be if these external benefits were taken into account.²

When the investors are not able to appropriate all of the returns from their investment, there will be underinvestment in R&D relative to the socially-optimal level. In the context of clean technologies, the social benefit from these technologies will very likely be greater than the private benefit. The private return fails to fully account for the positive effect of reducing emissions and also the benefits enjoyed by third parties (other firms and consumers). In this case, there will be underinvestment in clean technologies.

The nature of second-mover advantage and free riding: leadership as a public good

The economics and business literature has often emphasized first-mover advantages, suggesting that it important to be the first into the market, the first to develop a product, the first to innovate.³ While this is undoubtedly true on occasion, sometimes it pays to be a follower, not a leader. There is growing theoretical and empirical evidence that second-movers and early imitators (rather than innovators) actually do better than market leaders.⁴

¹ Consider an example in which a firm has the potential to invest in an R&D project that will cost them $\$X$. They anticipate a return (in net present value terms) of $\$Y$. If $\$Y > \X , the firm will make the investment; if $\$X > \Y , the firm will not invest. Assume that the investment also has an external benefit of $\$Z$. If $\$X > \Y , but $\$Y + \$Z > \$X$, the investment does not proceed even though it would be beneficial to society as a whole, as the additional benefits outweigh the extra costs incurred.

² As detailed in Popp (2006), the private marginal return on R&D investment has been estimated from between 7 to 15 per cent, whereas social marginal returns have been estimates range from 30 to 50 percent.

³ First-mover advantages can arise in a wide range of situations. For example, being first might effectively allow the leader to commit to a capacity or to a quantity they are going to sell; observing this commitment the followers are resigned to take smaller market shares. In the case of a natural monopoly, the first mover manages to capture the entire market for themselves (see Bolton and Farrell 1990). First movers can sometimes establish a market standard or create a user network, giving the established firm market power and an advantage over in coming rivals.

⁴ Tellis and Golder (1996) reviewed the performance of pioneers and followers in a range of industries. They found that market pioneers had a failure rate of 47 per cent. Moreover, the average share of market leaders was

When there is a second-mover advantage, leadership is a public good because it is on the leader's investment that the other firms free ride.⁵ As a consequence, there will be a lack of development of new products or there could be socially-inefficient delay in bringing them to market. Moreover, it is important to note that it can be the case that all firms prefer to wait rather than lead, even though *collectively* all parties are better off with the new technology.⁶ This means that a second-mover advantage, if not addressed, could reduce the welfare of society.

A second-mover advantage could arise for different reasons. Consider, for example, two firms both contemplating investing in a new clean technology. For the sake of the illustration, assume that the investment involves an upfront cost of \$120m, but will generate production cost savings overtime valued at \$200m in net present terms. If a firm's investment – and the intellectual property generated – could be protected, each firm would be vying to make the investment as the project has a positive net return. On the other hand, if the intellectual property of the innovator be protected, the non-innovator will free ride on the market leader's new technology. In this case, the incentive to be the leader is dramatically reduced; the follower pays for none of the cost of developing the new technology, but gets to use it and share in the benefits. In our example, if the \$200m benefit from the new technology is shared equally between the two firms, the firm that developed the technology would make a loss of \$20m, whereas the imitator makes a profit of \$100m. Note, moreover, that the payoff difference need not be so extreme – for a second-mover advantage all that is required is that it is more profitable to be a follower than a leader. Consequently, the possibility of free riding can severely reduce investment in clean technologies, causing delays in their implementation.

The clean technology market has many of the characteristics that make a second-mover advantage possible. The development of new alternative technologies requires large upfront investments that are irreversible and sunk (in that once they have been made, they cannot be recovered). If successful, the new innovations often take the form of new skills or ideas, making it difficult to adequately protect the firm's intellectual property, particularly bearing in mind that many of these firms are located in different countries. Sometimes patents offer little protection if they can be worked around. With a second-mover advantage, the more easily others can free ride and copy a new technology and the larger the number of potential imitators, the less incentive any one firm has to invest.⁷ Moreover, uncertainty regarding the

10 per cent, which was one third the market share of earlier followers into the market. At the time of their study, Tellis and Golder found that pioneers were market leaders in only 11 per cent of all product categories.

⁵ See Bliss and Nalebuff (1984).

⁶ A second-mover advantage is a special case of an externality described in the subsection above. Whereas a positive externality implies that a firm will underinvest in R&D as they do not capture the full marginal return from their investment, a second-mover advantage suggests firms will potentially not invest at all, in the hope that someone else will be the innovator.

⁷ See Fudenberg and Tirole (1990), Section 4.5, for a discussion of second-mover advantages and the timing of investment. It can be the case that if imitation by the follower is very quick, even an innovation will a small

expected returns and the best choice of technology to pursue among the alternatives further enhances the option value of waiting, making a second-mover advantage more likely.

Summary

In summary, it is very likely that there are positive spill-overs (externalities) from investment in new clean technologies. It could also be that firms strategically delay making any investment in clean technology in the hope of free riding on the investment of others. There is also another critical factor – the price of carbon-intense energy sources are significantly under-priced relative to clean-energy alternatives, because so far old technologies have not had to incorporate fully the cost of their emissions on the environment. We address these issues in the next section.

3. Public policy and clean technologies

This section reviews some possible policy responses available to the government and outlines some key principles that should be considered. In essence: the government should attempt to address each market failure as directly as possible; and any intervention should alter the net return of investment by the estimated size of the externality at the socially preferred level of investment.⁸

Externalities

As noted above, there will be underinvestment in clean technologies if there are benefits from investment in clean technologies that are not captured by the innovating firm. The government can address this inefficiency by reducing the cost of investment, for example through a subsidy, or, alternatively, by increasing the anticipated potential return from these technologies. In either case, the decrease in cost or the increase in the benefit should be equal to the estimated size of the external benefit, calculated at the socially preferred (or optimal) level of investment.⁹

sunk cost will not be implement if the potential leader anticipates that post-invention competition will prevent them from generating sufficient returns to cover the investment cost.

⁸ For a review of climate-change related market failures and possible policy instruments see Duval (2008).

⁹ Returning to previous example, the private cost of the investment was $\$X$, the benefit to the firm was $\$Y$ and the external benefit was $\$Z$. To get the optimal level of investment, the government could either subsidise the cost of investment by $\$Z$, or increase the benefit by $\$Z$. In either case, the firm's incentives match those that would maximise society's net benefit. Specifically: with a subsidy of $\$Z$, the firm will invest if $(\$X - \$Z) < \$Y$; alternatively, if the government increases the return from the investment by Z , the firm will only invest if $\$X < \$Y + \$Z$. This is the same condition necessary to maximise total net benefits (get the optimal level of investment). Note, further, if the level of the externality changes with the level of investment, to give the socially optimal incentives to the firm the subsidy needs to be set a the estimated size of the externality at the optimal level of investment. If this is not the case, the firm will either have too much or too little incentive to invest, relative to the socially optimal investment level.

A typical intervention in response to a positive externality is a subsidy for R&D investment. Government could also provide seed capital for projects; this lowers the investment cost. Similarly, government loan guarantees lower the cost of financing projects by reducing creditors' exposure to risk. Another alternative is to provide some additional source or revenue for the successful innovator when they sell their output, such as an output subsidy.

Note, a significant part of the externality arising from clean-technology innovation could well relate to reducing harmful emissions. Consequently, what matters is the emission reduction achieved, rather than the type of technology adopted, per se. As a result, government support should be technology neutral. This is important for several reasons. First, if the government supports the development of a specific technology, it can prevent the development of an alternative technology, even if this alternative is lower cost and more effective.¹⁰ Given the level of uncertainty regarding alternative technologies, it is not possible for the government to be able to accurately predict the most cost-effective technology. As a result, support should be technology neutral and focus on the outcome (such as emissions reduced per dollar expenditure). Second, it is more than likely that many different technologies will have a role in providing the emission reduction required at the lowest possible cost. If the government has a specific target, minimising the cost of achieving this outcome requires the extra emission reduction from the last (government) dollar spent for each technology should be the same. If this is not the case, it is possible to increase the total reduction in emission for the same cost by reallocating resources to the technology with the higher additional reduction in emissions.¹¹ These arguments together suggest that government support for clean technologies should, ultimately, be technology neutral, and where there are technology specific programs, these programs should be integrated into an overall policy that is outcome focussed (regarding additional emission reductions for the lowest possible cost).¹²

Free riding and the second-mover advantage

When there is a second-mover advantage, causing an inefficient delay in innovation, the government needs to make the anticipated payoff from trying to be a leader greater than the payoff from being a follower, for at least a subset of firms. Once the relative payoffs have been adjusted enough so that at least some firms wish to innovate, the size of the subsidy depends on the optimal level of investment needed to maximise the expected return given the uncertain relationship between the level of investment and the probability of successful innovation.

¹⁰ See, for example, Kverndokh et al (2004).

¹¹ Importantly, this principle concerns the additional – or marginal – benefit generated. This is not the same as equating average emission reductions for expenditure between programs.

¹² Currently the Australian Government has several different programs, including grant funding measures such as the Renewable Energy Development Program, the Renewable Energy Target, the creation of the Australian Centre for Renewable Energy, the Solar Flagship Program, the creation of Australian Solar Institute and a geothermal drilling fund.

One typical policy to encourage research leadership is to use patents that prevent other firms using the innovator's intellectual property without permission (and payment). The patent system is designed in large part to prevent free riding, in so doing providing greater incentive to invest in new technologies. As noted, one problem with patents is that they do not always provide adequate protection for innovators. Second, once innovation has occurred, it is optimal that the new technology is used as widely as possible – by creating monopoly power for the holder, patents prevent this from happening. Consequently, the use of patents involves a trade off between encouraging firms to innovate (which requires guaranteeing high returns) with suboptimal use after invention (which limits the benefits from the new technology to society). Another alternative is to commit the government to making an up-front prize to reward the winning innovator. One advantage of providing a winner's prize is that there is no restriction on using the technology, as there is with a standard patent system. Still, it can be difficult to identify the party that should be awarded the prize, particularly when the intellectual property developed does not take the form of a tangible product.

Carbon-based pricing policies

With respect to climate change, a key market failure is the underpricing of carbon-based fuels. Many alternative energy sources are currently much more expensive than traditional technologies. In part, this is due to the price of carbon-intense energy not including the cost to the environment (from the build up of greenhouse emissions). If this externality was incorporated into the final price that consumers pay for carbon-based fuels, the relative price difference between traditional and clean technologies would be reduced. This would provide a significant incentive for investment in alternative technologies.

The increase in price for carbon-intense energy can be achieved in different ways (a production tax based on carbon emissions, a similar consumption tax, an emissions target with tradeable permits, etc), however, any successful scheme needs to increase the final price consumers pay for carbon-based energy, and that increase in price should reflect the external cost to the environment not already incorporated into the market price. If the price final consumers pay for carbon-emitting sources of energy are undone by rebates or other schemes the policy intervention will be ineffective.

Any policy to encourage investment in clean technologies is unlike to succeed without policies that increase the price of carbon-intensive energy sources. Popp (2006) argues that carbon-price policies achieve 95 per cent of total possible welfare gains of a policy that combines a carbon tax and R&D subsidies. On the other hand, a policy that implements an optimal R&D subsidy alone achieves only 11 per cent of the total benefit of the combined policy. The modelling of Acemoglu et al (2009) suggests failure to implement a carbon tax will mean that a more costly policy will be required redress the imbalance between the carbon-intense and alternative energy sectors in the future. They also argue that the best policy involves the use of a carbon tax and a R&D subsidy.¹³

¹³ Also see Bosetti (2009) and Pezzy et al (2008).

Another crucial advantage of price-based policies is that this form of intervention is technology neutral as it changes the relative price of carbon-based fuels for all alternative energy sources. This change in relative prices will foster investment in the lowest-cost alternatives without the need for government direction to specific technologies.

4. The global clean technology market

Reducing the impacts of climate change is a public good, because all countries in the world will benefit even if they have not contributed to the solution. It is the inability to exclude countries from the benefits of reducing climate change that makes finding a solution particularly difficult.

This adds another layer of difficulty to policies encouraging investment in clean technologies in the global market, as the externality and free rider problems also apply to governments and their support for clean technologies. For example, a government might be unwilling to support innovation if it anticipates that any successful innovation will be copied by other countries (or firms in other countries). An individual country might be better off not investing in clean technologies and, instead, adopting any successful innovations developed by others; as with firms, this can be true for all individual countries, even if all countries collectively would be better off with immediate innovation (or investment). If the government is committed to addressing climate change and supporting clean technologies, these difficulties need to be acknowledged.

The public sector solutions to the market failures described in Section 2 essentially involved the government correcting the externality (through a tax or a subsidy) and trying to commit to rewarding and protecting the returns to innovation. The solution to market failures at a global level are more difficult to address, because there is no credible authority that can implement a policy instrument across all the different countries involved.

The price of carbon emissions has been a difficult issue for the international community to address. But support for clean technology R&D is a relatively small issue in comparison, which might make some international cooperation possible. Moreover, given the difficulties involved in multilateral agreements, the Australian government might wish to pursue bilateral agreements or agreements with a subset of countries that are similar in their interests. Any such agreement is not an ideal solution, but it might help facilitate investment in some potentially important countries.

Clearly, this is not a simple issue to resolve, however, there are some speculative lessons from the literature on public goods. At times, communication between the parties involved can help coordinate contributions – or investments – in public goods. Part of the problem is the inability for any country to credibly commit to making a large investment in clean technology without renegeing on such a promise. The literature has shown that sometimes parties involved can make small sequential investments, with the threat that future contributions will not be forthcoming if one party does not fulfil its obligations. Another alternative is to strengthen international property rights, in an attempt to limit the

expropriation of returns by firms in other countries. There are two points worth mentioning here. First, as noted above, it is not clear patents provide enough of an incentive to invest in clean technologies. Second, as a small country like Australia is likely to be a net import of clean technology, stricter intellectual property rights might not be in the country's overall interest.

It is also worth noting that countries will have different benefits from investing in clean energy technologies. Australia is fortunate to be in the position of having relatively abundant natural resources. This is not the case for many countries, and they will have other incentives to invest in alternative sources of energy, such as energy independence or national security. If the Australian Government's position is that it is only the carbon risk that Australia faces, public policy should be designed to address on the market failures relating to climate change, and nothing else. This means that Australia will likely have a different public policy towards clean technologies than other countries, both in terms of the level of support and the structure of any program.¹⁴ Moreover, any international commitments by the Australian Government need to explicitly address only the climate-change market failures; these commitments should not be designed to ameliorate another country's energy-security concerns.

5. Concluding comments

Clean technologies have an important role to play in tackling climate change. But private sector investment in these technologies is likely to be below the socially-optimal level. Given this, the government could have a role in designing policies to address this market failure. Several principles need to be considered in designing any policies that attempt to correct this failure. First, any policy should attempt to address the market failures only, and to do so as directly as possible. Second, the policies should be technology neutral. The government is not in a position to anticipate the technologies that offer the most promise for reducing greenhouse emissions. Moreover, it is possible that active promotion of one technology can prevent the development of an alternative, more effective, technology. Third, government promotion of the development of clean technologies should be part of its overall climate change emissions policy. Explicitly, the price of energy must remain the cornerstone of any emissions-reduction policy as the price mechanism facilitates a reduction in the quantity demanded while at the same time encouraging investment in alternative energy sources. Furthermore, a policy that focuses on the development of new clean technologies without using policies that change the price of energy are unlikely to produce the level of reduction in emissions needed.

¹⁴ It is also worth noting that it is not necessary that all countries benefit the same amount from the provision of a public good, like reducing the impacts of climate change. There is a considerable literature in economics on methods of determining how much different parties should contribute to the cost of providing a public good, based on how much they will benefit.

References

- Acemoglu, D., P. Aghion, L. Bursztyn and D. Hemous (2009), 'The environment and directed technical change', *NBER Working Paper*, no. 15451.
- Bliss, C. and B. Nalebuff 1984, 'Dragon-Slaying and Ballroom Dancing: The Private supply of a Public Good', *Journal of Public Economics*, vol. 25, pp. 1-12
- Bolton, P. and J. Farrell (1990), 'Decentralization, Duplication and Delay', *Journal of Political Economy*, vol. 98, no. 4, pp. 803-26.
- Bosetti, V., C. Carraro, R. Duval, A. Sgobbi and M. Tavoni (2009), 'The Role of R&D and Technology Diffusion in Climate Change Mitigation: New Perspectives Using the Witch Model', *Fondazione Eni Enrico Mattei Working Papers*, Paper 274.
- Duval, R. (2008), 'A Taxonomy of Instruments to Reduce Greenhouse Gas Emissions and their Interaction', *OECD Economics Department Working Papers*, No. 636, OECD Publishing.
- Fudenberg, D. and J. Tirole 1991, *Game Theory*, MIT Press, Cambridge.
- Kverbdokh, S., K. Rosendahl, and T. Rutherford (2004), 'Climate Policies and Induced Technology Change: Which to Choose, the Carrot or the Stick', *Environmental and Resource Economics*, vol. 27, no. 1, pp. 21-41.
- Pezzy, J., F. Jotzo, and J. Quiggin, 'Fiddling While Carbon Burns: Why Climate Policy Needs Pervasive Emissions Pricing as Well as Technology Promotion', *Australian Journal of Agricultural and Resource Economics*, vol. 52, no. 1, pp. 97-110.
- Popp, D. (2006), Innovation and Climate Policy, *NBER Working Paper*, no. 15673.
- Tellis, G. and P. Golder 1996, 'First to market, first to fail? Real causes of enduring market leadership', *Sloan Management Review*, vol. 37, pp. 65-75.