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Advance Market Commitments for low-carbon development: an economic assessment

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FINAL REPORT
March 2009

vivideconomics

Executive Summary

What is the problem?

There is an urgent need to promote low-carbon investment in the developing world. Estimates suggest that more than $400 billion of low-carbon mitigation investment will be required per annum in the developing world by 2030. The vast majority of this investment will need to be undertaken by the private sector. At present, various endemic market failures such as an absence of carbon pricing, fossil fuel subsidies, a difficult investment climate and problems in accessing capital, mean that this level of investment will not take place without intervention.

Much of this low-carbon investment can promote economic growth and help alleviate poverty. Energy efficiency investment has the potential to reduce energy costs and hence directly contribute to economic growth. In other cases, the low-carbon alternative is cheaper than the fossil fuel alternative. In cases where the low-carbon alternative is more expensive than the alternative, development objectives/poverty alleviation may still be promoted through, for instance, reduced exposure to fossil fuel price volatility.

What are AMCs? Are they a good idea?

Advance Market Commitments (AMCs) are temporary interventions to make revenues from markets more lucrative and more certain in order to accelerate investment. The concept is not new. The definition of AMCs includes a wide number of well-established interventions, especially in the developed world, such as feed-in tariffs and renewables obligations. However, it also encompasses more innovative policies. AMCs are 'demand-pull' measures that can be contrasted with 'supply-push' measures e.g. capital grants. AMCs are already a powerful mechanism, but could be strengthened and used more widely to encourage low-carbon investment.

The AMC concept gained prominence in the public health sphere, where it was used to promote investment into vaccines for 'neglected' diseases which disproportionately affect people in the developing world. There is both theoretical

and empirical evidence that interventions which have the same objectives as used in the vaccine case, although not necessarily the same methods, can encourage low-carbon investment in the developing world.

AMCs are better suited to promote the deployment of existing technologies, or incremental R&D, than breakthrough, radical technologies. AMCs can be used to encourage investment either in innovation or in the deployment of existing technologies. They are more likely to be effective in the latter case. The challenge with using AMCs for innovation is that the market for a particular innovation is not always apparent. In addition, for innovations that remain a long way from market, the incentive created by a more lucrative, certain market may be quite weak, given the length of time that will elapse before the innovator can take advantage of the revised market conditions.

In the case of deploying existing technologies, or encouraging incremental R&D, AMCs are likely to be preferable to capital subsidies, and other interventions that aim to reduce the cost of supplying outputs, in a wide range of circumstances. In particular, AMCs are likely to be preferable to supply-push policies when:

— private sector firms have a clear advantage in managing the risks associated with the delivery of an output relative to the public sector;

— there is a particular aspect or component of output that is to be encouraged, as the support can be tailored to incentivise this aspect e.g. output rather than capacity;

— there is a diversity of products with different characteristics that might be appropriate to support and it is unclear which might be superior;

— there are relatively few market barriers in accessing capital and scaling up production (potentially because this market failure has already been addressed by other interventions).

AMCs should not be applied indiscriminately. Even in cases where AMCs are a potentially relevant solution, a number of important considerations need to be

assessed before adopting an AMC:

— **Can, and will, the supply-side of the market respond?** The greater, more certain, demand created by AMCs will only stimulate investment if suppliers in the market respond to the changed market conditions. If suppliers are not able to respond (e.g. because of constraints or bottlenecks in accessing inputs) or are unwilling to respond because of insufficiently robust competition, then there is a risk that the AMC will simply lead to higher prices and the creation of rents with little practical benefit. There is a need for consideration of the supply-side capacity along the entire value chain.

— **Is there a compelling market failure to justify intervention?** Often AMCs make markets more certain by setting minimum prices or quantities. In doing so, AMCs prevent the free interaction of supply and demand which, in theory, should lead to an efficient allocation of scarce resources. Disruptions to the market mechanism can potentially lead to perverse outcomes e.g. excessive investment in one technology when a more balanced spread of technologies may be desirable. To minimise these sorts of risks, a clear assessment of the market failures being corrected needs to be provided by the intervention.

— **Will the intervention be credible?** To commit capital, investors require a degree of certainty that the policy will not be reversed. A less ambitious, but credible, policy is more likely to promote investment than policies which are very ambitious (generous) but which, as a consequence, are perceived as unsustainable.

— **Is there a clearly defined exit strategy?** AMCs are intended to be temporary measures designed to improve permanently the economic viability of a technology. They are not ongoing subsidies. This requires that the barriers to widespread diffusion be permanently removed, for example, the cost of a technology can be brought down to a competitive level. There is good evidence to suggest this can be achieved. However, the AMC will need to be sufficiently ambitious to achieve these cost savings and a clear expectation

of how and where the cost savings will be realised should be undertaken beforehand. The budget will have to be commensurate with this ambition, factoring in uncertainty and the possibility of budget overruns.

How should AMCs be designed?

A wide number of interventions can be classed as AMCs. AMCs can be categorised along two dimensions. The first dimension is the market outcome about which certainty is provided e.g. a price AMC provides greater certainty by specifying a minimum price, a quantity AMC specifies the minimum quantity that the market will demand while a revenue AMC provides certainty that a minimum level of revenue will be available from the market. The second dimension is how this market outcome is achieved. There are three options here. The first is through the government introducing a subsidy to achieve the stated outcome e.g. to 'top-up' the market price to the specified minimum price. A second option is through the government forcing consumers to behave in a certain way e.g. forcing consumers to purchase a certain amount of a good or pay a certain price (such as a feed-in tariff). A third option is for the government to directly purchase the good for its own consumption. The table below shows these two dimensions and illustrates how some well known policies fit into the framework.

Table i A taxonomy of AMC types

		How is the certainty achieved?		
		Public sector subsidies	**Public sector mandates**	**Public sector purchases**
Which variable is made more certain?	**Price**	Vaccine AMC	Feed-in tariff	Feed-in tariff in state-owned electricity sector
	Quantity		Renewables obligation	Government procurement
	Revenue			Central bank open market operations

Source: Vivid Economics

When costs and demand are perfectly understood by the AMC administrator, different types of AMCs can all be designed to deliver the same benefits and market expansion. However, the distribution of costs between the different policies will differ. In many cases, this comes down to a straightforward trade-off between making existing consumers worse off (if they are forced to buy a certain amount of a good, or pay a certain price) and the public sector incurring a fiscal cost.

When costs and demand are uncertain, different AMCs are no longer equivalent: when cost uncertainty is acute, investors are likely to prefer quantity (or revenue) AMCs; but when demand uncertainty is more pervasive, investors are likely to prefer price AMCs. When the costs of a particular technology are very uncertain, investors may be reluctant to invest in a market where prices are fixed. By contrast, quantity and, to a lesser extent revenue, commitments insulate investors from a lot of cost risk. This is important in thinking about using AMCs to promote the deployment of immature technologies. The opposite is true when there is demand uncertainty, where profit variability is minimised by price AMCs. This may help to explain the popularity of feed-in tariffs for grid connected renewables (where demand uncertainty is generated by fluctuating oil/gas prices).

In all cases, removing risks from investors means that greater risk is placed on other market participants, i.e. either the public sector or existing consumers. The attraction of AMCs for investors is that the risks caused by unfavourable fluctuations in demand or costs do not have same profit impact that they otherwise would. These risks are instead transferred to either consumers, in the form of higher or, on occasion, more uncertain prices, or the public sector, in terms of an additional, uncertain fiscal cost.

AMCs can create rents. AMCs are intended to make markets more lucrative. This makes it very likely that they will generate some rents (i.e. cases where prices are greater than costs). Rents may arise either because the same price is applied to all suppliers in the market despite very different costs of production or because cost reductions over time are not matched by price reductions. This is a potential problem for all AMCs and it is particularly likely in cases where the administrator of the AMC has little information about costs. There are ways to reduce these rents, for example through administrative mechanisms, e.g. different support for different technologies, or competitive auctions. Although there are clear benefits associated with trying to remove rents, there are also risks. The appropriate trade-off between these benefits and risks will differ from case to case.

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1 Introduction

Estimates of the annual low-carbon investment requirement for mitigation in the developing world are huge: ranging from $265 billion per annum to $565 billion by 2030. The mid-point of these estimates is over $400 billion per annum. Between 2010 and 2020 estimates are slightly lower at between $60 billion and $300 billion (mid-point of $180 billion).[1]

This investment requirement is approximately 50 times greater than current low-carbon mitigation investment in the developing world from public and private sources.[2] A step-change in investment is required.

The required level of investment will not take place without significant policy intervention. There are a large number of market and policy failures that inhibit low-carbon investment in the developing world. These include:

- the absence of a carbon price in developing countries (nor a realistic prospect of its emergence)
- the prevalence of fossil fuel subsidies (nor any realistic prospect of their removal)
- a poor investment climate (e.g., administrative barriers, rule of law)
- under-investment in R&D
- policy uncertainty/credibility problems
- lack of information on the investment opportunities available in the developing world and the high costs of acquiring this information (imperfect information)

Much low-carbon investment in the developing world will promote development and poverty alleviation. There are currently 1.6 billion people

[1] World Bank (2009) '*World Development Report 2010: Development and Climate Change*' September.

[2] *Ibid.*

without access to electricity. In many cases, renewable energy production represents the lowest cost way of providing electricity access to these people.[3] It also offers the prospect of reduced exposure to fossil fuel price volatility.[4] Energy efficiency is both the lowest cost source of emissions reductions and offers the potential for significant cost savings and hence development benefits.[5]

Momentum is growing for tackling these challenges and realising the opportunities they present. The aspiration embedded within the Copenhagen Accord, with $100 billion per annum of capital to be transferred from developed to developing countries by 2020, provides hope that the challenge can be met. This $100 billion per annum will come from both public and private sources. The fast-track money of $10 billion per annum in the period 2012 offers hope that problems associated with achieving scale can be tackled in the short-term.

However, $100 billion per annum is lower than the mid-point estimate of the 2010-2020 investment requirements of $180 billion for mitigation alone and significantly lower than the $400 billion that might be required by 2030. This leads to two related questions:

— How can the public money be used to leverage significantly greater quantities of international private capital for investing in the developing world?

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[3] ESMAP (2007), Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies, Technical Paper 121/07, Energy Sector Management Assistance Program, World Bank.

[4] In countries with per capita income of less than $300 per annum, the World Bank has found that every $10 increase in the price of a barrel of oil is associated with a 1.5 per cent decrease in GDP. World Bank (2009) *Energizing Climate-Friendly Development: World Bank Group Progress on Renewable Energy and Energy in Fiscal 2008.*

[5] World Bank (2009) op. Cit.

— How can domestic private capital be unlocked to encourage within-country investment?

Advance Market Commitments (AMCs), policies which increase the size and certainty of markets, can play an important role in addressing both questions. This report provides an economic assessment of the role of AMCs. It addresses the following questions:

— What are AMCs?

— What is the economic rationale for AMCs? When are they most/least likely to be effective at promoting desirable investment?

— How do various types of AMCs differ? In what circumstances would one or the other type of AMC be preferred?

— Whether AMCs might create rents and, if so, whether and how efforts should be made to dissipate these rents?

The Appendix to this report considers the experience of existing/historic policies that share some of the properties of AMCs. A separate Vivid Economics report sets out two case studies/illustrations of how AMCs could be used to tackle specific investment challenges in the developing world.

2 What are AMCs?

2.1 A brief history of the AMC idea

The term Advance Market Commitments was first used to describe a specific public health policy. The aim of that policy was to support investment into the research and development/deployment of vaccines for diseases disproportionately prevalent in the developing world. This included diseases such as malaria, sleeping sickness, etc. These ideas were developed by Michael Kremer and the Center for Global Development in a number of publications.[6]

This analysis put forward two reasons for the lack of R&D investment in vaccines for so-called 'neglected diseases'.

— **First, the markets for 'neglected' diseases are insufficiently lucrative.** The costs of developing successful new vaccines range from several hundred million to over a billion dollars. Moreover, many vaccines are unsuccessful but this is only realised once much of the cost has been incurred, e.g. on clinical trials. These very high costs mean that R&D resources would be most profitably deployed on diseases afflicting affluent developed countries.

— **Second, investing to develop vaccines for developing world markets was too risky.** Specifically, firms were put off undertaking investment as they feared that any price that might be agreed prior to the investment being undertaken would be negotiated downwards thereafter. Most purchases of vaccines are undertaken by governments or international organisations who have a strong incentive to see lower prices for vaccines and often have dominant purchasing power,

[6] See, for instance, Kremer, M. and Glennerster, R. (2004) *'Strong Medicine: Cresting Incentives for Pharmaceutical Research on Neglected Diseases'* Center for Global Development (2005) *'Making Markets for Vaccines: Ideas to Action'*, July.

regulatory control and/or the power of public opinion to achieve these outcomes. Moreover, having made investments, pharmaceutical companies would be in a relatively weak bargaining position as they would have no other way to recover the costs already incurred. Recognising the weak bargaining position which could ensue, firms chose not to invest in the first place. In other words, there was a 'time-inconsistency' problem.

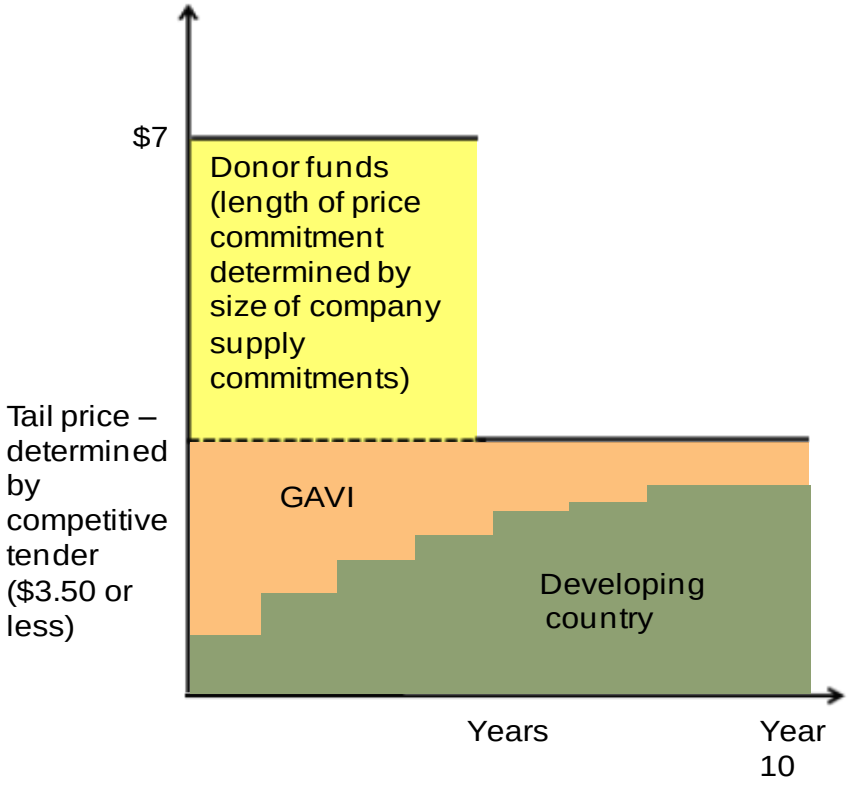
The response proposed was an Advance Market Commitment. This involved a legal commitment by donors to guarantee a certain price for the first x million doses of a vaccine for developing country markets meeting various technical considerations. The donor funds would be used as a 'top-up', or co-payment, to supplement the price that developing countries were prepared to pay for the vaccine. This was intended to ensure that the funds were only used where genuine demand for the vaccine had been demonstrated. Once the donor funds had been exhausted, firms were required to make a supply commitment at the lower, un-subsidised, price.

A pilot AMC for the pneumococcal vaccine was launched in 2009. Participating manufacturers are required to make a 10 year supply commitment to meet a proportion of the estimated demand for a pneumococcal vaccine of 200 million doses per annum. Around 80% of the total industry supply commitment will be at a price close to the marginal cost of vaccine production, (known as the 'tail-price' within the scheme). This tail price will be determined through a competitive tender but is not to exceed $3.50/dose. A combination of developing countries and GAVI[7] will undertake to fund this

[7] GAVI is a global health partnership representing stakeholders from both the public and private sectors including developing world and donor governments, private sector philanthropists, the financial community, developed and developing country vaccine manufacturers, research and technical institutes, civil society organisations and multilateral organisations like the World Health Organization (WHO), the United Nations Children's Fund (UNICEF) and the World Bank. Its goal is to increase access to immunisation in developing countries which it achieves through funding a variety of initiatives and programmes .

amount.[8] The remaining 20% of the industry's supply commitment will receive the higher price of $7/dose. The $7 price has been set in an attempt to make the overall revenues available to industry through the AMC sufficiently attractive to participate in the scheme through allowing quick recovery of a reasonable proportion of development costs. The difference between the tail price and the $7/dose price is met through donor commitments of USD 1.5 billion. The proportion of a firm's supply commitment which will receive the higher price will be a function of their overall supply commitment. Figure 1 below illustrates this graphically.

Figure 1 The pneumococcal AMC provides a price guarantee for a certain proportion of the supply commitments made by the successful tenderers



Source: Vivid Economics based on GAVI

[8] The precise split between GAVI and developing countries will vary from country to country depending, mainly, on the level of development in each country.

The intervention is expected to be highly cost effective. Modelling suggests that between 500,000 to 700,000 childhood deaths will be prevented during the period of the AMC itself and that as many as 7 million childhood deaths may be prevented by 2030.[9] The cost per disability adjusted life year (DALY – a standard measure of cost effectiveness of medical interventions) is expected to be between $33-$36.[10] This compares with a threshold value of $100/DALY used by the World Bank to define highly cost-effective medical interventions.[11]

Early indications are that the AMC will be successful. The policy has generated interest among pharmaceutical companies. Four companies have made firm commitments to supply vaccines in the first round of the tender process. The first supply agreements are expected to be signed in 2010.

2.2 Our AMC definition

We define AMCs as policy interventions that have two key characteristics. Although this definition is broad, it adopts the two properties of the vaccine AMC concept.

1. An intervention that increases the size of the market by directly creating demand

2. An intervention that makes market outcomes (e.g., prices) more certain

As well as including the vaccine AMC, this definition covers a wide range of policies, many of which are already used to promote low-carbon investment. For instance, feed-in tariffs involve setting a certain fixed price, above the prevailing market price, for electricity generated from renewable sources.

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[9] http://www.vaccineamc.org/pneu_amc.html

[10] Cernuschi, T. (2009) 'The Pneumococcal Advance Market Commitment: Innovative Finance to Help the Poor' *Global Forum Update on Research for Health, Volume 6: Innovating for the Health of All.*

[11] World Bank, (1993) Disease Control Priorities in Developing Countries.

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Renewable energy standards mandate that a certain proportion of electricity must be generated from renewables sources. The public sector may also undertake a procurement exercise to buy a certain number of a particular item. In all of these cases, the intervention makes the market larger (more lucrative) for those contemplating an investment and also provides greater certainty over a market outcome (prices, quantities). The definition also offers scope to include a range of innovative policies that are not (yet) in widespread use.

There are a number of other characteristics/features of an AMC:

— AMCs stimulate investment by making demand more lucrative rather than by making supply less costly, i.e. they are demand pull rather than supply push policies.
— AMCs are temporary interventions. They are focussed on removing a certain market barrier that is preventing investment, i.e. the higher financial costs of renewables versus conventional electricity generation. Once this barrier is removed, the AMC can be withdrawn.
— Although AMCs reduce the risks faced by private companies, this is achieved without the public sector providing capital or other financing support to companies .
— The benefits of the AMC can be applied to the market as a whole rather than to specific firms. This means they are non-discriminatory and do not distort competition. Firms that were more profitable due to greater efficiency before the introduction of an AMC continue to be more profitable after the intervention.[12]

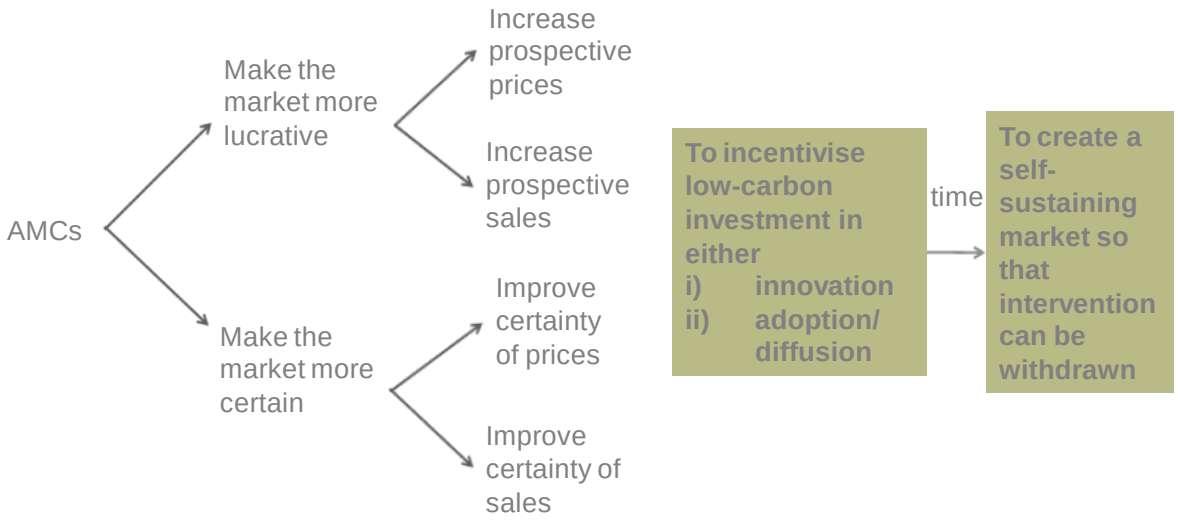
AMCs can be used to stimulate investment in either innovation (R&D) or deployment. The original conception of the AMC idea in the vaccine context

[12] If access to the AMC is restricted according to technological characteristics, i.e. certain types of renewable technologies, then the AMC will only be non-discriminatory between those firms that currently supply that technology. If no firms currently supply the technology but some are much closer to commercial deployment than others then, similarly, the effect of the policy will favour certain firms over others.

was to stimulate greater R&D effort. In many other cases, however, policies that fulfil the AMC definition are more focussed on promoting deployment of existing technologies. Indeed, the pilot pneumococcal AMC is best thought of as an intervention to promote the widespread diffusion of a vaccine that already existed.

Figure two below summarises our definition of AMCs.

Figure 2 AMCs are policies that make a market more lucrative and more certain



Source: Vivid Economics

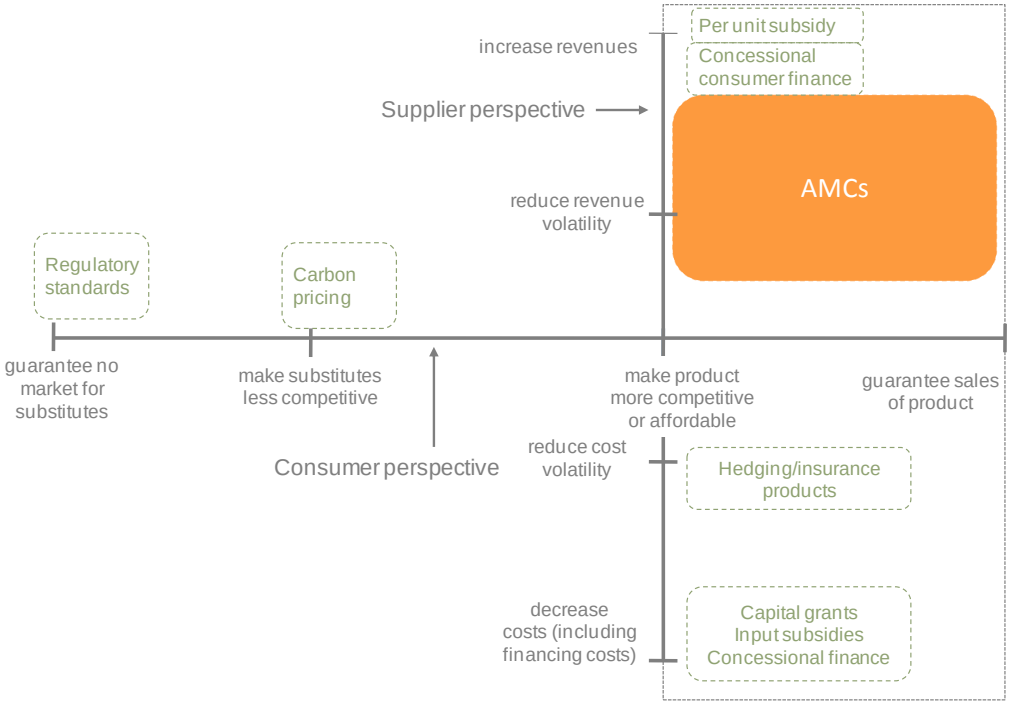
2.3 AMCs in the context of other policies

AMCs are just one of a suite of policies designed to stimulate markets for low carbon technologies. As such, they sit in a continuum of policies and measures with similar objectives and (for some) characteristics. Figure 3 summarises how measures may differ from each other both in the ways they shape demand and the support they provide to suppliers, represented by the two axes[13]. While policies such as carbon pricing and regulatory standards

[13] However, it is inevitably difficult to fully categorise and delineate these policies in only two

either ban the substitutes for low carbon products or increase their cost, AMCs and a range of other policies seek to make the low carbon products themselves more competitive or affordable.

Figure 3 AMCs are one component of the policy intervention toolkit



Source: Vivid Economics

AMCs focus on both increasing revenues and making them less volatile. This makes them distinct from per unit subsidies which increase revenues but may otherwise leave them volatile and uncertain. They are yet more distinct from measures which improve product competitiveness by reducing costs or risk of high costs, such as capital grants or publicly financed insurance products.

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dimensions; others may point to the distinction between regulatory vs. market-based instruments, or a high level of subsidisation vs. near commercial self-reliance, as key differences.

3 Are AMCs a good idea?

This section considers the merits of AMCs. It assesses whether they are a good idea, the contexts in which they may be a better or worse intervention and the factors which influence their success. To undertake this assessment, we combine the two defining characteristics of an AMC (that they increase market size and that they make markets more certain) with the two types of investment they seek to encourage: adoption and diffusion of existing technologies and innovation to develop new technologies. We examine the efficacy of AMCs in each of these four areas, as shown in table one below.

Table 1 The properties of AMCs can be matched against the types of investment they are trying to encourage

	Make the market more lucrative	Make the market more certain
Deployment	Section 3.1	Section 3.2
Innovation	Section 3.3	Section 3.4

Source: Vivid Economics

The assessment consists of two additional elements. First, we assess whether it is likely that, over time, AMCs can create a self-sustaining market and hence be withdrawn. This is covered in section 3.5. Second, we consider the efficacy of AMCs compared with other policies (notably investment subsidies) in section 3.6.

We conclude that, in the right circumstances, AMCs can play an important role in supporting low-carbon investment in developing countries. They can create self-sustaining markets and may often be more successful than alternative policies. However, it is crucial that AMCs are credible; they will need to be complemented with other policies; and they also need to be

carefully targeted to cases where there are clear market failures. We also find that AMCs are likely to be more powerful in supporting the deployment of existing technologies rather than stimulating innovation that leads to radical technological breakthroughs.

3.1 Does making the market more lucrative lead to greater investment in existing technologies?

There is straightforward theoretical backing, and overwhelming empirical evidence, that making a market more lucrative will encourage greater investment. From a theoretical perspective, investment theory states that if the market has higher revenues then it is more likely that a given investment will be profitable.[14] Evidence can be seen from a range of different cases, both in the developing and developed world. These include feed-in tariffs to support renewable electricity generation in Germany (where wind powered electricity generation increased from almost nil in 1990 to close to 25,000 MW by 2007), government procurement to encourage energy efficient products in Scandinavia (where the programme led to energy efficient lighting using high frequency electronic ballasts to become virtually standard practice over a five year period) and the experience of rural electrification programmes undertaken by the World Bank (where the success of the installation of solar home systems in India can be largely attributed to the growth in demand achieved through harnessing micro-finance institutions). More details of these policies, and their impact, are provided in the Appendix.

Previous policy interventions provide important lessons about the critical success factors for policies that seek to stimulate investment by making the market more lucrative an AMC. Box 1 below highlights some of the most important.[15] This is drawn from the examples discussed in the appendix.

[14] In other words the discounted cashflows from making the investment will exceed the costs of the investment yielding a positive net present value for the investment.

[15] These are lessons that could apply to any market expansion policy not just to those focussing

Box 1 Five factors for successful market expansion

1. **Don't ignore the supply side.** Creating additional market demand will only successfully lead to market growth if producers can, and will, respond to the stimulus. If they cannot, or will not, then the result will be higher prices and rents. Regarding ability, it is important to consider whether there are any constraints that prevent firms accessing the necessary raw materials, finance or appropriately skilled labour. Regarding willingness, healthy and effective competition between producers is important and may need to be carefully cultivated.

2. **Identify user needs and make sure these are met.** Rapid market expansion and quick policy withdrawal will be easier to achieve when customers experience immediate benefits from a technology. This helps to explain why market expansion policies for energy efficiency products (where users benefit from reduced energy bills) appear to have been more successful than market expansion policies for renewable energy production (where users perceive little/no immediate benefit to themselves). To ensure users benefit from a technology, careful research may be required to understand their requirements.

3. **Identify any opportunities to exploit niches.** Technology diffusion will be easier to achieve where there are market niches which allow a technology to become easily established with less or no competition from alternatives. For example the cost of PV cells fell due to their niche use for decades in satellites.

4. **Ensure information is disseminated.** Spreading information about the technology to users and other market players, e.g. through demonstration projects or marketing/publicity campaigns can significantly aid market expansion.

5. **Ensure that the policy is flexible.** Market expansion policies need to adapt flexibly to changes in circumstances or new evidence (while maintaining credibility).

Source: Vivid Economics and Kammen (2004)

on low-carbon development. In any one context, not all of these factors may be relevant.

3.2 Does increasing market certainty lead to greater investment in existing technologies?

Theory and empirical evidence both support the view that firms are more likely to invest if market outcomes can be made more certain.

The theoretical justification for the positive impact of greater certainty on promoting investment is provided by real option theory.[16] Conventional investment theory suggests that firms should make investments whenever the net present value (NPV) of an investment is positive, i.e. when the expected cash flows from the investment, suitably discounted[17], exceeds the cost of the investment. Real option theory shows that when there is uncertainty about how the future will turn out and when investment costs cannot be recovered once the investment is made, (i.e. the investment is sunk or 'irreversible') then the option to defer the investment and 'wait and see' is valuable. If an investment proceeds, then this valuable option is given up. Consequently investment should only proceed when the NPV is greater than the value of the option to wait and see. The greater the uncertainty over the future, the greater the value to wait and see and the less likely it is that investment proceeds.

Most empirical evidence concludes that greater uncertainty inhibits investment. Studies in a range of different contexts, including among Ghanaian manufacturing firms[18], rice milling firms in the Mekong Delta[19] and Dutch[20] and Italian[21] manufacturing firms all conclude that greater uncertainty

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[16] Dixit, A. & Pindyck, R. (1994) *'Investment under Uncertainty.'*

[17] Discounting reflects the fact that the prospect of £100 in the future is less valuable than the certainty of £100 today.

[18] Pattillo, C. (1998) Investment, Uncertainty and Irreversibility in Ghana, *IMF Staff Papers*, **45**:3, September.

[19] Ninh, L-K., Hermes, N. And Lanjouw, G. (2003) 'Irreversible Investment and Uncertainty: An Empirical Study of Rice Mills in the Mekong River Delta, Vietnam' *mimeo*, July.

[20] Koeste, M., van der Vlist, A., de Groot, M. (2006) 'The Impact of Perceived Expectations and

has a statistically significant depressing impact on firms' likelihood to invest.

Three aspects of these studies are particularly significant in the context of AMCs for low-carbon development.

— **Uncertainty may have a particularly depressing impact on investment in the developing world.** Real option theory explains why *irreversible* investments may be deferred when there is uncertainty. One of the key ways in which investments can be made less irreversible is through liquid second hand capital goods markets that offer the prospect of (at least partial) recovery of any investment made. However, in many developing world situations, such second hand markets are less well developed than in developed countries.[22]

— **Uncertainty may be particularly significant for renewable technologies.** It is plausible that many low-carbon investments have fewer alternative uses, e.g. wind turbines cannot easily be put into an alternative use if their intended use turns out to be unprofitable. This implies that they are more irreversible and investment is more likely to be deterred when there is a great deal of uncertainty about the future.

— **Demand side uncertainty may have a greater depressing impact on investment than other forms of uncertainty.** Studies which have compared the impact of different forms of uncertainty on firm investment behaviour tend to conclude that demand side uncertainty is more likely to hold back investment than, for instance, uncertainty

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Uncertainty on Firm Investment', *Small Business Economics*, 26: 365-376.

[21] Guiso, L. and Parigi, G. (1999) Investment and Demand Uncertainty, *Quarterly Journal of Economics*. **114**:1, pp185-227.

[22] Ninh, L-K., Hermes, N. and Lanjouw, G. (2003) op. Cit.

over input prices, stock prices, inflation or exchange rates.[23] AMCs are specifically focussed on reducing this form of uncertainty.

There are two important caveats about the efficacy of reducing uncertainty to promote investment.

First, it is necessary that the reduction in uncertainty is credible. Investment decisions take into consideration the cash flows over the lifetime of the asset. Uncertainty over these cash flows at any point may hold back an investment. Consequently, attempts to reduce uncertainty which are not perceived as credible (perhaps because they are also associated with an increase in market size which is not considered to be sustainable) will not necessarily induce the desired increase in investment.[24] This is particularly important for AMCs which imply policy commitments several years into the future. **Investment is likely to be more encouraged by a less ambitious but more credible policy than one which appears to be very lucrative but which is perceived to be (politically) unsustainable.**

Second, it is important to remove/reduce uncertainty only in those cases where there is a compelling market failure. Although fluctuating prices and quantities may deter investment, they also perform a useful function. They indicate consumer preferences and provide signals to companies to respond to these preferences. Economic theory shows how, under certain (restrictive) circumstances, this will result in the most efficient allocation of scarce resources. It follows that removing this fluctuation in prices/quantities can

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[23] Koeste, M., de Groot, M, Florax, R. (2006) 'The Impact of Uncertainty on Investment: a Meta Analysis' *Tinbergen Institute Discussion Paper*.

[24] As an example from a related area, Mexican trade liberalisation, which was expected to lead to a substantial increase in returns to capital and hence increase investment, was associated with a slump in investment. Ibarra (1995) finds that a substantial proportion of the fall in the investment can be attributed to the expectation that the policy would be reversed at a later date. Ibarra, L. (1995) 'Credibility of trade policy reform and investment: the Mexican experience' *Journal of Development Economics*, **47**:1.

have undesirable (unintended) consequences.[25] A public policy intervention to remove this uncertainty therefore needs to provide a compelling explanation as to why the investment is desirable and why it would not be forthcoming without the reduction in uncertainty. Although in many cases this will be straightforward, it should not be ignored. It is particularly important to address in situations where the AMC is targeted at a limited range of technologies.

3.3 Does making the market more lucrative increase private sector innovation investment?

There is plenty of evidence that larger market size leads to firms undertaking more innovation activity (private R&D expenditure). More lucrative markets incentivise firms to undertake innovation expenditure as they attempt to capture a larger share of the more lucrative market. A recent NBER study found that various policies which increase market size, (e.g. feed-in tariffs, renewable obligations) were associated with a statistically significant increase in patenting activity in renewable energy technologies in OECD countries.[26] Other research supports the conclusion that larger markets induce greater innovation.[27] This evidence would support the use of AMCs to encourage private sector innovation activity.

Others have stressed knowledge and technological opportunities as crucial

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[25] For instance, some economists have criticised the Fairtrade programme because the reduction in price uncertainty in this scheme has led to producers failing to diversify to a wider, more sustainable, range of products. See Zehner, D. (2002) 'An Economic Assessment of Fair Trade in Coffee' *Chazen Web Journal of International Business.* A full assessment of this topic also requires an assessment of the equity impact of the programme.

[26] Johnstone, N., Hascic,, I. and Popp, D. (2008) 'Renewable Energy Policies And Technological Innovation: Evidence Based On Patent Counts', *NBER Working Papers*, 13760, January.

[27] Popp, D. (2002) 'Induced Innovation and Energy Prices' *American Economic Review*, **92** (1), Schmookler, J. (1966) *Invention and Economic Growth*, Harvard University Press

determinants of the rate and direction of innovation.[28] This evidence suggests that the best policies to support private sector innovation are policies that increase the overall stock of knowledge such as government sponsored R&D, R&D tax credits, enhancing knowledge exchange and publicly funded demonstration projects. It would suggest that policies such as AMCs which increase market demand would be ineffective.

The consensus is that there is a role for both types of intervention to support private sector innovation. For instance, Mowery and Rosenberg[29] conclude that: *'Rather than viewing either the existence of a market demand or the existence of a technological opportunity as each representing a sufficient condition for innovation to occur ... both must exist simultaneously.'*

Increasing market size is likely to be effective at bringing forward incremental innovations where products are already close to market. It is possible to provide more insight as to when different types of policy are more likely to be effective. Policies which increase market size are typically more effective at stimulating incremental innovations and/or products that are already close to market. By contrast, supply-push policies are more effective at stimulating radical innovations that are a long way from market.[30] In these cases, demand-pull policies will be ineffective for two reasons. First, it may be unclear whether or not a market will exist for the innovation. Second, the long period of time between the initial discovery and bringing the innovation to market will dampen the power of any incentive created by increasing market size.

Incremental innovations to products close to market are central for low-

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[28] Klevorick, A., Levin, R., Nelson, R. & Winter, S. (1995) 'On the sources and significance of interindustry differences in technological opportunities', *Research Policy*, **24:2**

[29] Mowery, D. & Rosenberg, N. (1979) 'The influence of market demand upon innovation: a critical review of some recent empirical studies' *Research Policy*, **8**:2, 102-153.

[30] Johnstone et al (2008) *op. cit*, Popp, D. (2010) 'Innovation and Climate Policy', *NBER Working Paper Series No. 15673.*

carbon development. In 2003, the developed world accounted for around 84% of low-carbon innovations.[31] The bulk of climate friendly innovations will continue to be undertaken in the developed world for the foreseeable future. However, adaptive R&D is often necessary in developing countries to make the technologies fit local conditions.[32] Increases in market size through AMC interventions could encourage such adaptive R&D.

The focus of the AMC pilot on the pneumococcal vaccine is consistent with the view that market pull incentives are effective at stimulating deployment and/or incremental research and development. For a number of companies, little or no R&D activity to develop a qualifying vaccine was required. It was anticipated that two companies would license vaccines that were capable of protecting populations in developing countries (and industrialised countries) by 2010.

Policy credibility is crucial in encouraging innovation. The long lead times often associated with bringing (even incremental) innovations to market emphasise the need for policy credibility. If there is a realistic expectation that a policy to increase the size of the market will be reversed before the product reaches market then the policy will provide little incentive to increase innovation activity.[33]

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[31] Dechezleprêtre, A., Glachant, M., Hascic, I., Johnstone, N. Ménière, Y. (2009) '*Invention and transfer of climate change mitigation technologies on a global scale: A study drawing on patent data'* Working Paper, CERNA, Paris.

[32] Lanjouw and Mody (1996) 'Innovation and the Internation Diffusion of Environmentally Responsive Technology' *Research Policy*, **25**: 549-571.

[33] Nemet (2009) provides an interesting case study of innovation in the wind generation sector in California in the early 1980s. Prior to the introduction of a feed-in tariff regime there was a large spike in innovation activity (as measured by patent citations). Immediately after the policy was introduced, patent citations fell significantly. Although the explanation for this is not established for certain, one of the most compelling explanations is that the policy was perceived as unlikely to persist for a long period into the future. Given this, wind turbine firms focussed on

3.4 Does greater market certainty increase innovation investment?

There are strong theoretical grounds for thinking that greater market certainty will encourage innovation activity. Investment in R&D is a good example of an activity that is largely irreversible, i.e., it is not possible to recover the salaries of research personnel when they have been paid. As such, uncertainty will make firms more reluctant to commit to innovation investment for exactly the same reason that it makes them reluctant to commit to investing in conventional, tangible assets.

The available empirical evidence supports this assessment. Czarnitzki and Toole (2007)[34] find that German manufacturing firms, whose previous innovation activity has led to products with a high degree of revenue volatility, are significantly less likely to invest in further innovation activity than firms whose previous innovations have been subject to less revenue volatility. The authors note in the conclusion to their work that *'public policies intended to increase private R&D investment can achieve this objective by reducing the degree of uncertainty in the product market.'* They note that this conclusion supports the introduction of the vaccine AMC.

3.5 Summary assessment of AMC efficacy

Table two below summarises the evidence from the above four sub-sections on the efficacy of AMCs.

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deploying their existing technology as rapidly as possible and that this 'crowded-out' innovation activity. Nemet, G. (2009) Demand-pull, technology-push and government led incentives for non-incremental technical change, *Research Policy*, **38**, 700-709.

[34] Czarnitzki, D. and Toole, A. (2007) Business R&D and the Interplay of R&D Subsidies and Product Market Uncertainty, *Review of Industrial Organization*, **31**:3, November.

Table 2 AMCs are likely to be particularly effective at encouraging deployment of low-carbon technologies

	Make the market more lucrative	Make the market more certain
Deployment	✓✓ - plenty of evidence to support Series of factors are likely to determine the success of the policy. The most important is the extent to which the supply side of the market is able and willing to respond.	✓✓ - strong theoretical and empirical support Important for policy to be credible and for intervention to be targeted where there is a clear market failure
Innovation	✓- most likely to be successful at incentivising incremental innovations and innovations that are already close to market. Likely to be the most important type of innovation in a low-carbon development context	✓ - good theoretical reasons to believe important and available evidence is supportive more evidence is required

Source: Vivid Economics

3.6 AMCs in comparison to other policies

It is necessary to consider the attractiveness of AMCs relative to other policies. The previous sections considered whether AMCs are effective in encouraging investment and hence market expansion. However, it is possible that other policies could have similar impacts making it necessary to compare AMCs with other types of policies. The most prevalent alternative policy in the low-carbon development context is the provision of capital grants.

The key benefit of an AMC is that producers only benefit from the policy if the desired output is provided. A fixed higher price only needs to be paid if there is a product to purchase; a commitment to purchase a certain quantity of output is only meaningful if products are brought to market. AMCs place the risk that the desired output will not be delivered with firms. By contrast, capital grants, or other supply push measures, do not have this property: the

benefit of the policy is provided to producers in advance. The allocation of risk under AMCs is generally desirable (efficient) as firms will have a better ability to control whether or not an output is delivered than the public sector. It also provides the public sector with the opportunity to define what constitutes a desirable output in a way which is not possible with capital grants, e.g. the provision of electricity rather than the construction of capacity.

This benefit needs to be traded-off against the more onerous commitment it places on the public sector, which risks not being perceived as credible. The attractive allocation of risk under an AMC is a result of the public sector making a commitment to a future course of action. Furthermore, if the output being incentivised by the AMC is a flow of output over a number of years, e.g. supply of renewably generated electricity, then the duration of this future commitment may be both long and/or uncertain. Arrangements such as these can often be more complicated and costly to set up, e.g. to determine, in advance, what criteria the output needs to meet in order to qualify for the AMC support. They may also be unattractive to the public sector as it requires sacrificing future policy/funding discretion. The unattractiveness to the public sector may significantly limit the effectiveness of the AMC if firms perceive that this makes it likely that the AMC may be reneged upon in future.

There are also a number of other factors which will make AMCs relatively attractive in particular situations.

— **Firstly, AMCs will only be effective when there is the realistic prospect of an identifiable, liquid market for the output.** As discussed earlier, AMCs are less likely to work in stimulating radical innovations. This is because the market for these innovations is unclear or the revenues that might be obtained from such a market are too distant to influence behaviour significantly. Likewise, an AMC can only be withdrawn successfully if there is private market demand for the product to supplement/replace the temporary public sector stimulus. In cases where the market is either non-existent or too distant/risky to influence investment behaviour, policies other than

AMCs will need to be used to stimulate investment.

— **AMCs let the market (consumers) decide which products will benefit from the support.** For instance, the price support under the vaccine AMC only goes to those companies that produce vaccines demanded by developing countries. Likewise, a requirement to purchase a certain amount of a particular product does not determine which suppliers of that product benefit. Instead, this is left to consumers. By contrast, the allocation of support under capital grants will depend largely on the judgement of the public sector when allocating support. This desirable property of AMCs is particularly advantageous in markets where there are a wide range of competing designs that may benefit from support which may be the case when the market is reasonably immature. In markets where products are identical from the perspective of consumers (e.g. power markets) this is not relevant.

— **AMCs are best suited to cases where there are few supply-side constraints or other interventions are in place to tackle these problems.** As noted before, AMCs are only effective when the supply-side is able to respond to the stimulus provided. If these supply-side barriers are not addressed then the AMC will need to increase the profitability of investments very substantially before the investment will proceed. In these cases, it is likely to be more effective to correct the supply-side problem at source rather than use an AMC, in isolation, to incentivise the investment. In many cases the desirable response may be to both correct the capital market failure and provide an AMC.

Box two below summarises some of the main situations in which AMCs are likely to be a particularly effective policy at stimulating investment

Box 2 AMCs may be preferable over capital grants and other supply push policies in a number of common situations

1. When private sector firms have a clear advantage in managing the risks associated with the delivery of an output relative to the public sector.

2. When there is a particular aspect or component of output that it is desirable to see encouraged, e.g. output rather than capacity

3. When risks of public sector credibility in providing and maintaining the commitment are manageable.

4. When there is an identifiable market for a product that can, in principle, be sustained by private sector demand

5. When there are a diversity of different products with different characteristics that might qualify for support and it is unclear which might be superior.

6. When there are relatively few supply side barriers (potentially because this market failure has been addressed by other interventions).

Source: Vivid Economics

3.7 Can AMCs be successfully withdrawn?

An important component of the AMC definition is that it is a temporary intervention. AMCs are intended to stimulate the desired investment and allow a self-sustaining market to be created. It is therefore important to assess the evidence on the successful withdrawal of policies.

Two different cases can be distinguished.

— **Cases where the low-carbon alternative is already cost competitive with the status quo.** Barriers other than cost are preventing widespread diffusion. Many energy efficiency investments fall into

this category as well as some renewable generations in off-grid contexts

— **Cases where the incremental costs of the low-carbon technology are higher than the status quo.** This is often the case with grid-connected renewables.

In the case where the low-carbon alternative is already cost competitive, AMCs have the potential to rapidly develop the market and be withdrawn quickly. A number of examples in the case studies presented in the Appendix demonstrate this, e.g. the sub-CFL programme in the United States. The list of factors discussed in Box 1 will be important in ensuring this quick withdrawal.

In the case where the low-carbon alternative is higher cost, it is less likely that the AMC can be removed quickly. Many demand-pull policies to support renewable technologies in Europe (as an example) have been in place for over 10 years and look set to continue into the foreseeable future.[35]

Where low-carbon alternatives are currently higher cost, the withdrawal of the AMC will rely, to a significant extent, on the market expansion bringing down costs. This has important implications for AMC design: the AMC will need to be designed with sufficient ambition to have a material impact on costs.

The relationship between costs and output has been studied extensively. The relationship is often captured by the 'learning rate' concept: the percentage reduction in costs associated with a doubling of output. A commonplace starting point, from examining a range of different sectors, is that that a doubling of output is associated with a 20% reduction in costs.[36]

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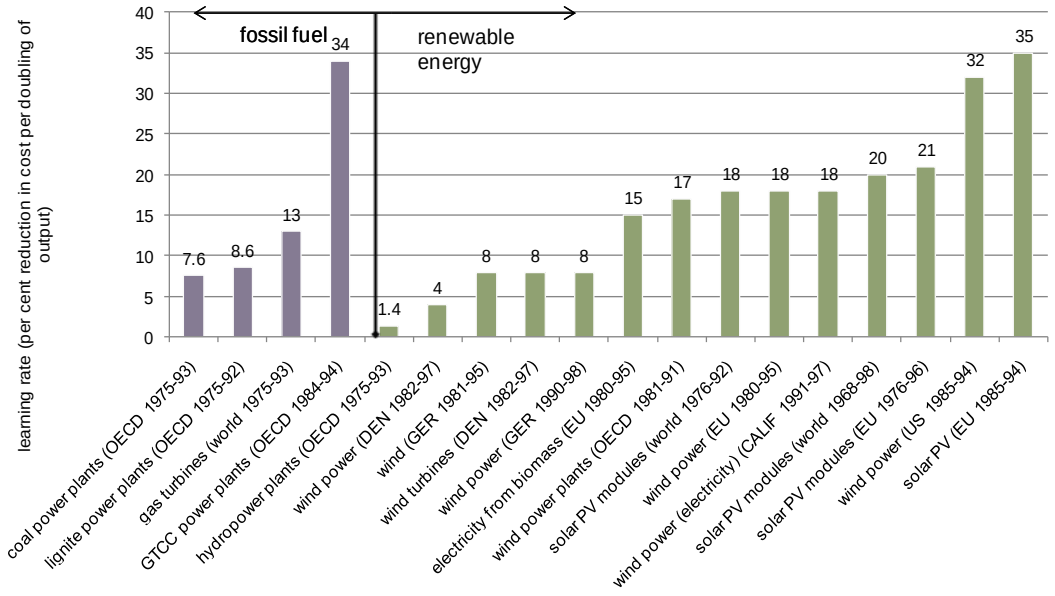
[35] Although in some cases the level of support provided has been reduced.

[36] Boston Consulting Group, (1970), Perspectives on experience, Boston Consulting Group, Boston, MA

Historically, renewable energy production has seen relatively high learning rates. This is shown in figure four below which summarises a cross-section of different estimates from a range of different studies. The figure also shows that renewable technologies have tended to have high learning rates reflecting the different maturities of the two types of technologies. It also shows considerable diversity between different renewable technologies. This is partly explained by the differential ability of technologies to take advantage of spillover effects from other industries, e.g. PV could take advantage of advances in the electronics and silicon sectors.

Figure 4 Learning rates for renewable technologies have typically been higher than for conventional technologies



Source: Kohler et al (2006) and Vivid Economics

Care needs to be taken in extrapolating historical learning rates into the future. Learning rates are useful in indicating the potential cost savings that might be achievable with scale. However, they suffer from a number of shortcomings. Most importantly, learning rates show correlation rather than causation, i.e. that greater deployment is associated with lower costs, not that greater deployment causes lower costs. It is possible that cost reductions lead

to greater deployment of a technology, rather than greater deployment leading to cost reductions. They also do not account for the possibility of hold-ups and break-throughs in innovation, which, by definition, do not follow a predictable pattern.[37]

For AMCs that seek to achieve significant cost savings, careful scrutiny of potential cost savings and monitoring of actual achievements are important. Simple extrapolation of historic learning rates could lead to significant error. In addition, careful monitoring will be required to detect whether or not the projected cost reductions materialise. In the event that they do not, policymakers will need to judge whether that failure is due to temporary, exogenous factors, which implies that the AMC should be maintained and potentially adapted, or whether it is due to technology(ies) being less attractive than initially thought, in which case the AMC should be withdrawn. Careful judgement will be required to delineate between these cases.

[37] Clarke, Weyant & Birky, (2006) 'On the sources of technological change: assessing the evidence', *Energy Economics*, **28**, 579-595. Other criticisms include that few studies have taken into account the effect of changes in input price, the price of substitute goods and economies of scale, unreliability induced by short time periods and a failure to separate out R&D impacts from deployment impacts.

4 An assessment of different AMC types

This section considers different types of AMCs. It assesses their different properties, advantages and disadvantages and provides insights into cases in which one sort of AMC might be preferred over another. It is split into four sub-sections:

— Section 4.1 provides a taxonomy for thinking about different sorts of AMC
— Section 4.2 discusses the advantages and disadvantages of these different AMC types in a situation in which there is certainty over market demand and costs
— Section 4.3 considers the merits of different AMC types in a situation in which there is uncertainty over market demand and costs.
— Section 4.4 discusses how the introduction of an explicit (public sector) budget constraint affects the key results and the implications for AMC design

4.1 An AMC taxonomy

There are two variables which can be used to define different AMC types.

— **The market variable over which the AMC reduces uncertainty.** Three different variables can be distinguished: prices, quantities and revenues

— **The way in which this market certainty is provided.** An AMC can promote demand by either making direct purchases to achieve the desired outcome, by mandating the private sector to deliver the desired outcome, or by providing incentives/subsidies to the private sector to induce the desired outcome.

Table three below shows how different permutations of these two variables result in a range of different AMC types.

Table 3 A taxonomy of different AMC types

		How is the certainty achieved?		
		Public sector subsidies	**Public sector mandates**	**Public sector purchases**
Which variable is made more certain?	**Price**	Vaccine AMC	Feed-in tariff	Feed-in tariff in state-owned electricity sector
	Quantity		Renewables obligation	Government procurement
	Revenue			Central bank open market operations

Source: Vivid Economics

The table demonstrates how a number of already well-established policies fulfil the AMC definition.

— The vaccine AMC is an example of how a price commitment can be achieved through public sector subsidy. In this case, the public sector commits to pay the difference between the price prevailing in the market (determined through an auction) and the guaranteed minimum price.

— A feed-in tariff is an example of a price commitment achieved through mandate: there is a legal requirement for a utility company to purchase all (qualifying) renewable energy at a given price. In turn, the presumption would be that the utility would defray these higher costs on electricity consumers.

— A feed-in tariff where the utility company is not operated on

commercial terms and cost increases are met from public funds would be an example of price commitment being achieved through public sector purchases.

— Renewables obligations, which mandate that a given quantity or percentage of electricity consumption must be generated from renewable sources, are an example of a quantity commitment being provided through the public sector mandating the private sector.

— Procurement could be used to provide a quantity commitment through public sector purchase: the government could commit to purchase a given number of units from the company supplying the most competitive tender.

— Alternatively, rather than committing to purchase a certain amount of quantity, the public sector could commit to spending a certain amount of money, i.e. provide a revenue commitment. Central bank open market operations, when the central bank commits to spending £x million on purchasing treasury bills could be considered a revenue AMC.

Innovative policies that fulfil the AMC definition can also be designed. By setting out these two variables for thinking about AMC design options, it is possible to devise alternative policies that would fulfil the AMC definition e.g..the public sector could commit to purchase a set number of units of a good which it would then sell at a rate which reflected willingness to pay to end consumers. This would be a quantity commitment achieved through public sector subsidy. [38]The analysis below focuses on the more familiar AMC policies, although the general conclusions would also apply to more exotic alternatives.

[38] As with other subsidy AMCs, careful design would be required to ensure that the AMC could be withdrawn and leave a sustainable market.

4.2 Choosing an AMC when costs and demand are known

We first analyse different types of AMCs under the assumption that market demand and costs are known. Although this is an artificial assumption (and is dropped in section 4.3) it helps to illustrate some of the key differences between different types of policy, before adding greater complexity.

In this setting, it is possible to calibrate all AMCs to deliver the same market expansion. This means that the benefits that might be realised from market expansion, e.g. reduced greenhouse gas emissions, poverty alleviation (through rural electrification) or a reduction in costs from scale expansion, could be achieved by any AMC policy. The balance between these different benefits will depend on the context in which the AMC is deployed.

The equivalence between different AMCs is illustrated in figure five below. The figure shows a situation in which the initial market equilibrium is given by the intersection of the demand curve $D_{\text{no intervention}}$ and supply curve S_1. The market quantity is Q_1 and the market price P_1. A policy objective is given to increase the market quantity from Q_1 to Q_2. The supply curve shows that producers will only be willing to increase supply to this level if the price rises from P_1 to P_2. This can be achieved in a number of different ways:

— The price P_2 could be mandated as is the case, for instance, with a feed-in tariff. This is shown by the green demand curve D price AMC which shows that when the price is P_2, consumers are forced to buy whatever is supplied. At prices higher than P_2, consumers are able to choose to buy as little or as much as they like.

— Alternatively, the quantity Q_2 could be mandated. This is shown by the purple demand curve $D_{\text{quantity mandate}}$. In this case, consumers are legally obliged to buy at least Q_2. They may, if they choose, buy more than Q_2.

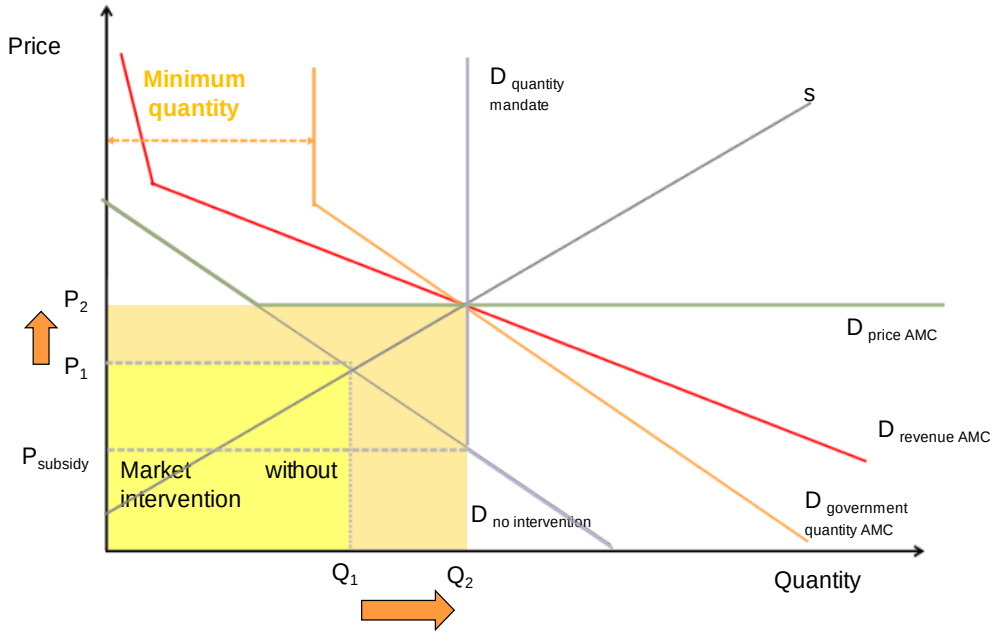
— The public sector could offer a subsidy. The demand curve $D_{\text{no intervention}}$

shows that consumers will only be willing to buy Q_2 if the price is $P_{subsidy}$. The government would then be required to pay the difference between the price suppliers require (P_2) and the price consumers are willing to pay ($P_{subsidy}$).

— The government could commit to buy a certain quantity of the good. This is shown by the orange demand curve, $D_{government\ quantity\ AMC}$. The minimum quantity commitment made by the public sector is marked on the figure. This is then added to the prior demand from consumers with the kink at the point where there is no demand from existing consumers but the government is still obliged to make its minimum purchase commitment.

— Finally, the government could commit to spend a certain amount of revenue in a market. This is shown by the red demand curve $D_{revenue\ AMC}$. This shows that at very high prices, the revenue commitment does not allow very much quantity to be bought, but at very low prices the revenue commitment can purchase a lot of output. This is then added to the existing consumer demand.

Figure 5 All AMCs can deliver the same market expansion



Source: Vivid Economics

While all AMCs can deliver the same benefits, the size and distribution of the costs in achieving these benefits can differ significantly. Different AMC types strike a different balance in the distribution of costs between existing consumers and the public sector.

Existing consumers

Existing consumers can be made worse off (at least in the short-term) by AMCs. This is most clearly the case for mandate AMCs: AMCs which fix prices by telling consumers that they must buy at that price (e.g. feed-in tariffs) or which force consumers to buy a certain quantity of output are, by definition, altering consumers' purchasing behaviour from what they would choose without the mandate. As consumers are forced to do something they would not otherwise, this is associated with a reduction in consumer welfare (erosion of consumer surplus).[39] Less obviously, but still importantly, existing consumers

[39] It may turn out that when 'forced' to purchase a certain amount or pay a certain price

can be made worse off by AMCs where the public sector uses its purchasing power to guarantee a certain market outcome. The additional demand created by the government causes prices to rise (from P_1 to P_2 in figure 4). The higher price means some consumers are no longer willing to purchase the good, i.e. they are 'crowded-out'.[40]

AMCs which achieve their objectives through subsidies make consumers better off. Existing consumers benefit from the lower price. The lower price also means that new consumers are willing/able to purchase the good which they were not before. This boosts consumer welfare.

Public sector

Mandate AMCs place no fiscal cost on the public sector. This makes them attractive to the public sector. However, they imply that the costs of market expansion are borne entirely by consumers which may not be tenable in some developing world contexts.

If the public sector incurs a fiscal cost, its magnitude is determined by market features. The following factors determine whether market expansion is achieved at lower fiscal cost by direct government purchase[41] (for its own consumption) versus subsidising consumers to achieve the expansion:

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consumer preferences change and this loss in consumer surplus is reversed. This is particularly likely in cases where the AMC is promoting a technology product that is facing non-cost barriers to implementation.

[40] This analysis applies in the case that the government purchases the product for its own consumption, perhaps most likely in the case of energy efficiency products. Cases where the government purchases the product and then supplies it to consumers at a reduced price (or for free) are, in effect, AMCs achieved through subsidy. The subsidy is equal to the difference between the price paid by the government and the price charged to final consumers.

[41] Government purchase of either a fixed quantity or at a fixed price or from committing a certain amount of revenue.

— **Demand responsiveness of consumers**. If consumers are not very responsive to changes in price then large price reductions will be required to induce market expansion. This will be expensive. It will often be cheaper for the government to make purchases directly.

— **Supply responsiveness of firms.** In cases where small increases in price will induce a significant supply response from producers then it will often be cheaper for the government to directly provide this signal through making its own purchase rather than indirectly subsidising consumers.

— **Market expansion ambition.** If the gap between the existing size of the market and the desired size of the market is large then existing consumers will require large subsidies to bridge the gap. It will typically be cheaper for the government to make direct purchases.

4.3 Choosing an AMC when costs and demand are uncertain

The choice of AMC becomes even more important when there is uncertainty about costs and/or demand. An AMC might be established with the expectation of delivering a certain market expansion (and accepting a certain distribution of costs between existing consumers and the public sector). However, if costs and demand vary from expectations, the market outcome will differ from expectations. How different the market ends up will depend on the type of AMC chosen.

When there is uncertainty over costs and demands, the variability of market outcomes becomes critical to determining the most desirable AMC. Investors will care not only about their expected profits on average, but also the variability of those profits if demands and costs differ from expectations. The public sector cares not only about expected spending, but the variability of those commitments. The same is also true for consumers.

Profit variability is the most important criterion for assessing different

AMCs. If profits are highly variable then investors may be deterred from committing capital. The benefits to be realised from AMCs (greenhouse gas emission reductions, poverty alleviation, cost savings) will not be delivered. At the same time, the variability of impacts on existing consumers and the public sector should not be ignored.

Cost uncertainty

When costs are uncertain, investors will prefer quantity and/or revenue AMCs. These help to reduce profit variability and hence make it more likely that the market expansion will be achieved. By contrast, price AMCs may actually lead to greater profit variability than when there is no AMC at all.

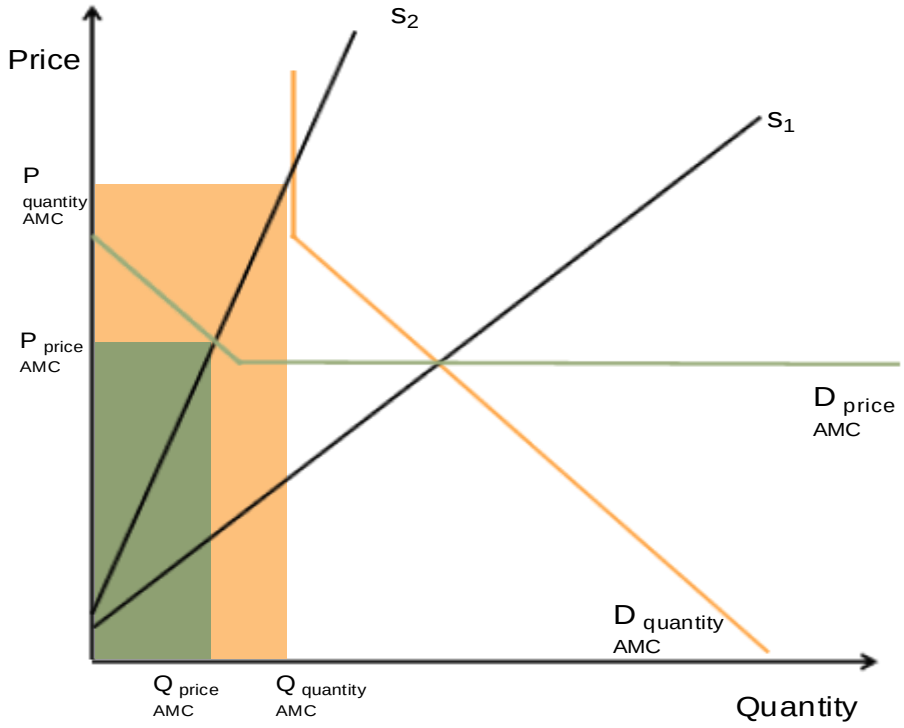
There is a strong intuitive rationale for this finding. If costs are uncertain, investors will be unwilling to commit to a fixed price contract. If costs end up being higher than the fixed price then either the firm will sell its output at a loss or not sell anything at all. By contrast, under a quantity commitment the output will still be purchased regardless[42] of the out-turn costs. Although less preferable from an investor perspective, revenue AMCs still ensure that some revenue/profit benefit is extracted from the AMC intervention than if costs are higher than expected.

Figure six illustrates this finding graphically. It shows a case in which there is a (government purchase) price and quantity AMC. The central expectation for costs is reflected in the supply curve, S_1. In this case both AMCs deliver the same market expansion and hence the same boost in profits. Higher than expected costs are shown by the supply curve shifting leftwards to S_2. Under a price AMC the price falls to $P_{price\ AMC}$ and the quantity to $Q_{price\ AMC}$. The revenues are shown by the green box. Under a quantity AMC, the market quantity remains higher at $Q_{quantity\ AMC}$ and this is associated with a price $P_{quantity\ AMC}$. Revenues are shown by the orange box. It is clear that revenues (and hence

[42] Section 4.4 discusses how a ceiling could be placed on the cost at which the quantity commitment would no longer bind.

profits) are higher under the quantity AMC than under the price AMC. Conversely, although not shown by rectangles in the diagram, if costs are lower than expected and the supply curve shifts to the right then revenues are greatest under the price AMC and lowest under the quantity AMC. In other words, when there is cost uncertainty, revenues (and hence profits) fluctuate much more significantly under a price AMC than they do under a quantity AMC.

Figure 6 When costs are uncertain, investors will prefer quantity AMCs to price AMCS



Source: Vivid Economics

The preference of investors for quantity/revenue AMCs under cost uncertainty is important for immature technologies. In these cases, perhaps because there is a need for residual R&D activity before the product can be brought to market, there is likely to be considerable cost uncertainty. For investors, quantity or revenue AMCs are likely to preferable to price AMCs.

Quantity AMCs transfer cost risk from investors to either consumers or the public sector. Investors prefer quantity/revenues AMCs when there is cost uncertainty as these interventions remove an element of that risk. Regardless of the cost, or perhaps up to a threshold, there will be a certain quantity of output purchased. This risk, however, does not disappear. Instead, the risk is passed either onto consumers (as higher prices) or the public sector (as greater fiscal cost). Robust competition between producers will help mitigate consumer/public sector exposure to this risk.

Demand uncertainty

When demand is uncertain, investors will prefer price AMCs. By committing a certain price for whatever (qualifying) quantities of supply, investors become significantly insulated from the impact of demand fluctuations. This finding is consistent with investor preferences for feed-in tariffs to support grid connected renewables.[43] Fluctuating oil and gas prices create significant demand uncertainty for grid connected renewable electricity. Feed-in tariffs help remove this demand volatility.

AMCs which mandate that consumers must purchase a certain quantity of output will also be popular with producers. This AMC removes this demand uncertainty by placing a legal requirement on consumers to buy a pre-defined quantity of output. There would still be competition between firms to meet this demand with those firms who produce output more favoured by consumers achieving larger market share from those who did not: it would only be in aggregate that the quantity mandate would have to be fulfilled.

Price AMCs transfer demand risk from investors to either consumers or the

[43] A recent survey of 60 investment professionals from Europe and North America found that feed-in tariffs were the favoured policy for supporting renewables. Bürer, M.J. and Wüstenhagen, R. (2009): 'Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international clean tech investors. *Energy Policy*, forthcoming.

public sector; the risk does not disappear. The demand risk is placed either with consumers or with the public sector.

4.4 Public sector budget constraints

AMCs which involve public sector spending will often incorporate a budget constraint. In cases where an AMC is being achieved through direct government spending or through subsidising consumers, the public sector is unlikely to be willing to accept an open-ended fiscal commitment. The pneumococcal vaccine AMC is an example of this: a price of $7/dose is supported until the $1.5 billion of donor funds is fully drawn down. Under a quantity AMC, the public sector could commit to purchase a given number of units as long as the price did not exceed a certain threshold.

Up until the point when the budget is exhausted, the properties of the AMC are unaffected. Price AMCs will still insulate investors from demand risk; quantity (and revenue) AMCs from cost risk.

Once the budget constraint binds, risks are passed back to investors. The attractiveness of AMCs to investors derives from the fact that changes in supply or demand do not feed through into changes in prices/quantities in the way that they would without the AMC. Instead, these risks are absorbed by consumers and/or the public sector. In the public sector's case, this is achieved by incurring a higher fiscal cost than previously anticipated. Hitting the public sector's budget constraint is equivalent to reaching its willingness or capacity to absorb these risks. At this point, investors once more absorb the risks.

Any public sector budget constraint should build in a buffer in excess of the expected spend. The transfer of risk from investors to the public sector is only achieved when the public sector spends more than initially anticipated in the event of unfavourable shifts in demand and supply. Consequently, for an AMC to genuinely transfer risk to the public sector, the public sector has to recognise that it may incur a higher fiscal cost than its central estimate when the AMC is designed, i.e. a buffer needs to be built into any budget constraint.

5 Dealing with rents

It is likely that AMCs will create rents (excess profits) for some producers. Part of the definition of an AMC is that it makes a market more lucrative. By making it more lucrative, i.e. increasing prices, some producers may end up making excessive returns.

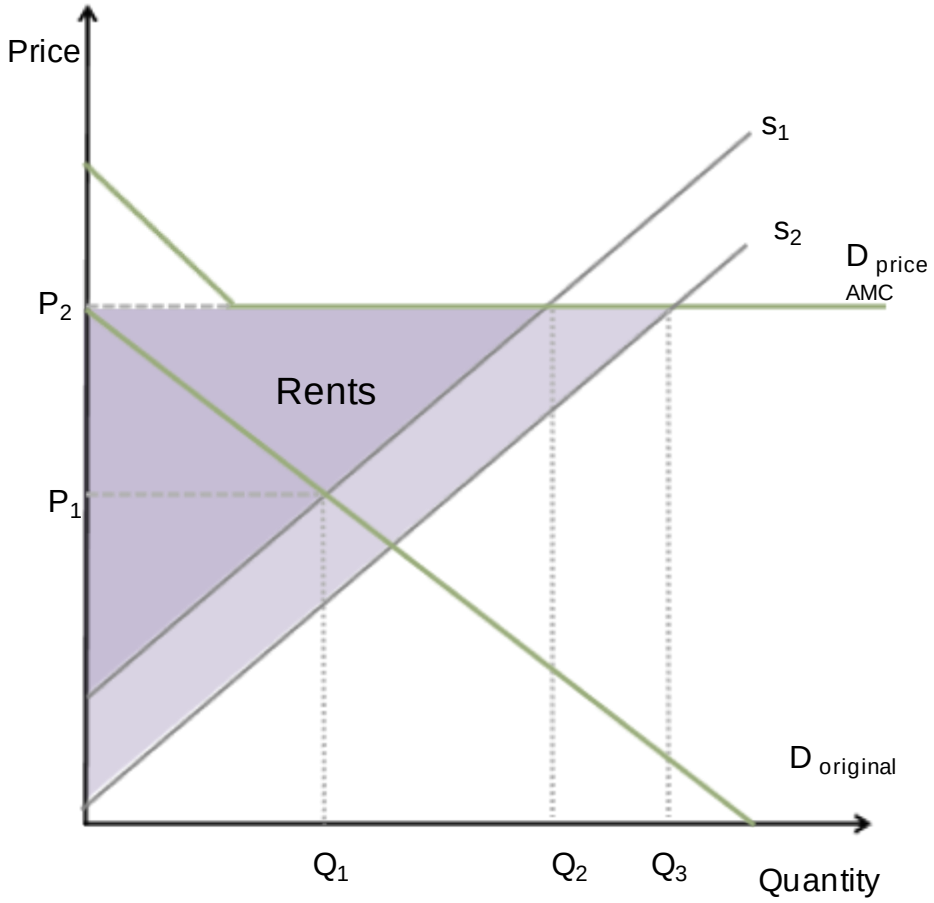
Rents can be created in one of two (inter-related) ways.

— The same price is applied to all units produced despite different costs of production

— The same price is maintained over time despite cost reductions from scale and learning-by -doing effects

These are illustrated graphically in figure seven below. The supply curve S_1 shows how much producers are willing to supply at a given price because, at that price, their costs of production are covered. Initially the market equilibrium is given by price P_1 and quantity Q_1. The figure shows the introduction of a price AMC. This expands the market from Q_1 to Q_2, as desired, but this is achieved by increasing the price from P_1 to P_2. The purple triangle shows the rents accruing to producers. These rents arise because only the very marginal producer requires the price P_2 in order to supply the market. All other producers would have been happy to supply at a lower price. The problem is exacerbated if, over time, costs of supply are reduced. This is shown by an outward shift of the supply curve. With lower costs but the same price, rents are further increased.

Figure 7 AMCs can create rents



Source: Vivid Economics

As all AMCs can have the same market expansion effect, they all have the same potential to create rents. Figure 6 uses an example of a price AMC for simplicity.

In principle, the same level of market expansion could be achieved with significantly less, or no, rent creation. Rather than setting the same price for all units produced, a different price could be set for each unit depending on its cost of production, i.e. the AMC could price discriminate. Likewise, as costs fell over time, prices could automatically track the reduction in cost.

Two broad categories of approach for removing rents are available:

— **Administrative mechanisms.** This involves the public sector making estimates of what the costs of supply are, and how they might change, and building these estimates into the design of the AMC. For instance, most feed-in tariff regimes have different tariffs for different technologies while a number of regimes have tariffs that decline over time (in relation to new connections) to take account of expected cost savings.

— **Competitive approaches.** Under this approach, support provided by the AMC is broken up into a series of smaller tranches and competition for each tranche of the support mechanism generated through an auction. In the case of a quantity AMC, for example, a commitment to purchase 1,000,000 units of output could be broken down into 10 sequential competitive auctions of 100,000 units. For each tranche, the competition would result in the winning bidder receiving a particular price, without this determining the price paid for the other 900,000 units. In the case of a revenue or price AMC, each round of the auction would specify the price that would be paid/revenue support that would be available and bidders would specify how much output they were willing to supply at that level of price/revenue support.

In many cases, it will be desirable to attempt to remove rents. By doing so, the same market expansion (and associated benefits) can be achieved but at considerably lower fiscal cost or cost to the consumer. The administrative cost associated with removing the rents will often be much lower than the rents saved.

However, there are also a number of risks associated with seeking to reduce rents. These need to be taken into account when weighing up the costs and benefits. Three of the key risks are the following.

— **Reduced dynamic incentives.** Always attempting to set prices to reflect existing costs may make it less likely that firms will reduce

costs, and/or otherwise improve their product, in the future. If firms are aware that any effort undertaken to reduce costs will be reflected in an immediate reduction in price, and no profit gain, then they will be less inclined to undertake the effort to reduce costs in the first place. In addition, firms may only undertake R&D activity when they are making significant profits due to problems they may experience raising external finance for R&D activity.[44]

— **Setting prices too low.** If an attempt is made to tailor the AMC support to the costs of individual suppliers then there is greater scope for introducing error, and providing a level of support that is too low to generate the market expansion desired. Although this problem should not be so acute when rents are removed through an auction mechanism (as companies should have a good idea of the level of support they require) there may still be a problem as companies suffer from 'optimism bias'. This risk is illustrated in the Non Fossil Fuel Obligation (NFFO) which was an auction based mechanism to provide subsidy support to on-grid renewables in the UK. Butler and Neuhoff (2004) report survey evidence that in one of the latter rounds of the auctions fewer than 50% of investors found that the support they had successfully bid was sufficient to allow projects to proceed profitably.

— **Setting prices too high.** Conversely, even though efforts are made to reduce rents, it could be the case that this is not successful and the administrative costs are incurred without any rent extraction. In the case of administrative methods, the public sector may not be able to get a reliable (forward-looking) estimate of costs. Under an auction based approach, efforts to remove rents may be unsuccessful if conditions in the market and/or the design of the auction lead to companies bidding for higher levels of support than they would if

[44] Hall (2002) finds a tendency among larger firms to finance R&D from retained earnings, Hall, B. (2002) 'The Financing of Research and Development', *Oxford Review of Economic Policy*, **18**, 35-51.

they faced more intensive competition.

The appropriate trade-off between risks and the benefits of reducing them will depend on the specific circumstances.

6 Appendix: Previous AMC-style interventions

This appendix considers a number of case studies of previous interventions that either meet the definition of an AMC or share some similarities with this definition. These case studies were primarily used to help identify some of the key factors that contribute to the success of AMC policies, particularly regarding whether making markets more lucrative will stimulate investment (as discussed in box 1 in section 3.1).

6.1 Energy efficient lighting in Sweden

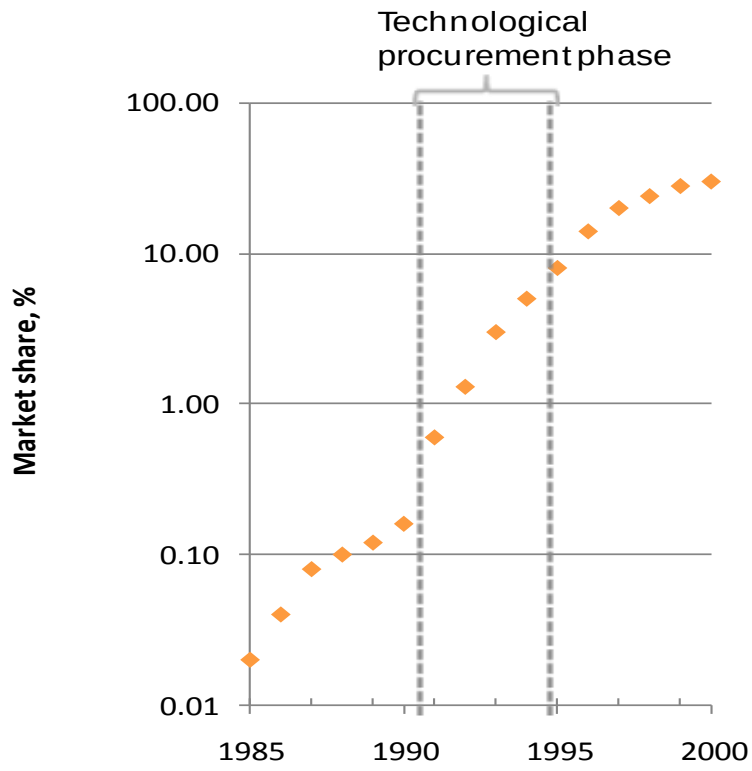
The Swedish Energy Agency facilitated a procurement that has led to the supported product becoming a market-leading component in energy efficient lighting. Between 1991 and 1992 the Swedish Energy Agency arranged for a group of public sector buyers, such as hospitals and sports centres, to commit to purchase 26,000 lights with high-frequency electronic ballasts (HF ballasts), with the option to purchase 26,000 more. Prior to 1992 total sales of high-frequency ballasts stood at just 5,000.

HF ballasts were a higher quality, but more expensive, product. A ballast controls the current in a light to ensure that excess current does not damage the light. An HF ballast does this in an energy-efficient way. It also has a longer life relative to other ballasts and produces a better light with less delay. However, HF ballasts were more expensive than traditional ballasts.

The programme was successful: sales went from around 5,000 in 1991 to over

600,000 in 1995[45]. By 2000 HF ballasts have become the dominant ballast in the market. This market growth is shown in figure eight below.

Figure 8 The quantity AMC for HF ballasts led to significant market growth



Source: Lund (2001)

Note: Data points estimated from figure in above paper.

The increased volumes of HF ballasts were associated with price falls. The

[45] IEA (2001) *'Developing markets for new energy technologies'*. Eds: Kliman, M., Schrattenholzer, L. and Lund, P

price of HF ballasts fell by 25% between 1992 and 1995[46]. It seems that the increase in demand enabled HF ballast suppliers to learn how to produce ballasts at a lower cost. Although this price decrease did not reduce the price of HF ballasts to the same level as for conventional ballasts, coupled with the superiority of the product, it helped make the product competitive.

The case study demonstrates the importance of information dissemination in supporting market expansion policies. Members of the buyer group were specifically chosen for their role as opinion leaders. The reputation building of HF ballasts was further supported by a concurrent demonstration program around the country. These initiatives helped to ensure that the higher quality of the product became widely recognised.

6.2 Heat pumps in Sweden and Finland

An AMC approach has been taken to accelerating the market for heat pumps in Sweden, while a more supply push has been taken in Finland. In 1990, the Swedish Energy Agency organised potential heat pump purchasers to design and offer a procurement tender for, at that time, a year's worth of heat pumps. In contrast, there was no such scheme to guarantee demand in Finland, where only some R&D funding and information dissemination was provided. Given the close cultural similarities and broadly similar customer needs, this comparison provides insights into the potential effectiveness of AMC policies.

The market has developed much more quickly in Sweden than in Finland. The scheme led to an established heat pump market in Sweden with market growth from 2,000 units in 1989 to 5,000 units in 1996[47]. The pace of diffusion of heat pumps in Finland has been nearly half the pace in Sweden and the effectiveness of the Finish policy in terms of electricity saved per policy euro is far lower than in the Swedish scheme, which has saved 2.5 times more energy

[46] IEA (2001) op. Cit.

[47] IEA (2001) op. Cit.

than the Finish scheme.[48]

Procurement was important in identifying user needs and overcoming misgivings about the technology. Heat pumps had a poor reputation in both countries due to low quality pumps in the mid 1980s. Also, few heat pumps existed that were suitable for small, single family houses despite this being the largest market for heat pumps. The Swedish Energy Agency, by facilitating consumers to develop a specification, ensured that new heat pumps would be suitable and provided the market with a basis on which to rebuild trust. This has helped the market grow much more quickly than in Sweden where there was less focus on user needs.

6.3 Energy efficient lighting in the US

The US Department of Energy (DoE) accelerated the introduction of appropriately sized energy-efficient light bulbs by co-ordinating private procurement. Prior to the 1998 initiative, energy-efficient light bulbs (also known as Compact Fluorescent Lamps, or CFLs) did not fit into standard light fittings. This was a major barrier to the widespread installation of energy-efficient lighting: smaller energy-efficient light bulbs, known as sub-CFL's, were needed. The innovation required to overcome this barrier was small but competition from traditional light bulbs meant that even the low level of innovation required was not motivated.

A procurement program, a quantity AMC, proved to be a highly appropriate form of intervention. The DoE co-ordinated private institutional buyers, such as housing developers, to devise a detailed specification for energy-efficient light bulbs. A tender was then offered where firms could bid on price to produce a quantity of light bulbs according to the specification. This provided the requisite demand to ensure that the small innovation costs were covered.

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[48] Lund, P. (2006) 'Market penetration rates of new energy technologies', *Energy Policy*, **34**, 3317-3326 and Lund, P. (2007) 'Effectiveness of policy measures in transforming the energy system' *Energy Policy*, 35, 627-639.

Targets were quickly achieved and the AMC was swiftly withdrawn. The DoE had a target of selling 1 million light bulbs. By 2000, 1.5 million light bulbs had been sold. Furthermore, since 1998, the price of energy-efficient light bulbs had fallen making them cost-competitive with traditional light bulbs. This enabled the DoE to withdraw its support, thus providing a credible end to the AMC. The depth of the market is illustrated by the fact that in the US in 2009 energy efficient light bulbs provided over 90% of the lighting needs in commercial and industrial buildings[49].

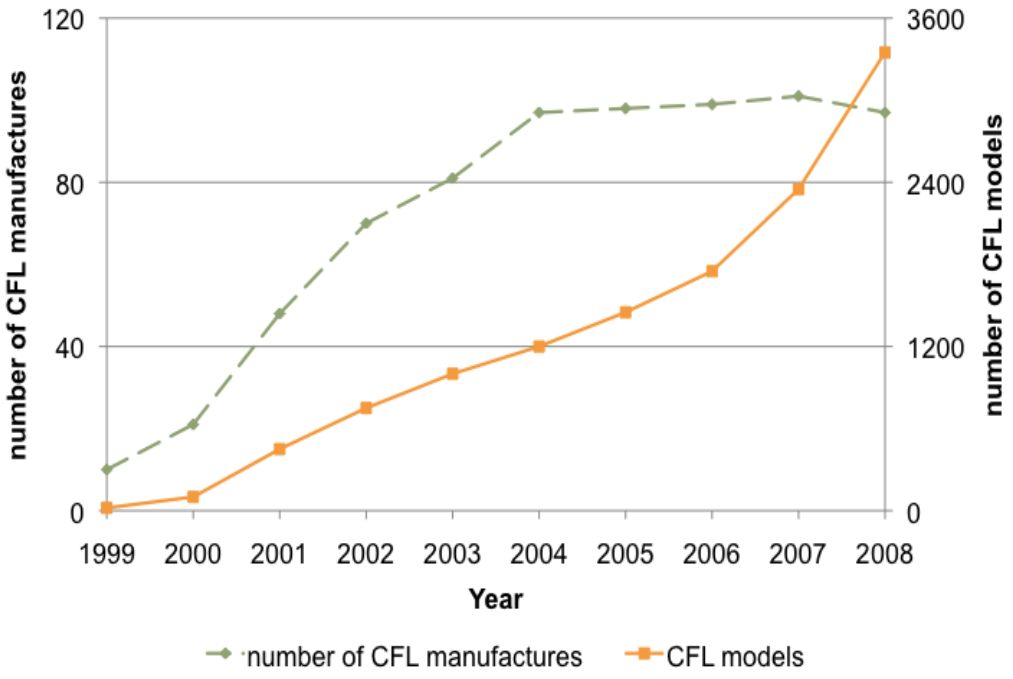
The DoE identified user needs and made sure that these were met. The development of the specification has been identified as a key factor in the programme's success. Developing the specification enabled customer preferences to be revealed prior to the risky venture of letting a market reveal customer preferences through sales. Thus the specification made the market more certain by discerning what type of product would be demanded.

The supply side was not ignored. The DoE went to a great deal of effort to encourage bids from a number of small manufacturers. The goal was to ensure that when the market for energy-efficient light bulbs matured it would be competitive. Such initial effort was costly and even exposed the DoE to accusations of anti-trust activity[50]. However the number of energy efficient light bulb manufacturers has increased dramatically since 1998, as figure nine illustrates. This has ensured a competitive market providing customers with a large range of choices at a low cost.

[49] US Department of Energy (2009) *'CFL market profile'*. US Department of Energy

[50] Pacific Northwest National Laboratory (2006) *'Compact Flourescent Lighting in America: Lessons Learned on the Way to Market'*. US Department of Energy

Figure 9 The sub-CFL programme increased the number of manufactures and CFL models dramatically



Source: Department of Energy (2009)

Scope remains for further market growth. Nearly 90% of residential buildings are yet to be lit by energy efficient light bulbs[51]. This suggests that the potential for energy efficient light bulbs has not been exhausted. Further measures may be required to accelerate the market for residential energy efficient light bulbs.

6.4 Feed-in tariffs in Germany

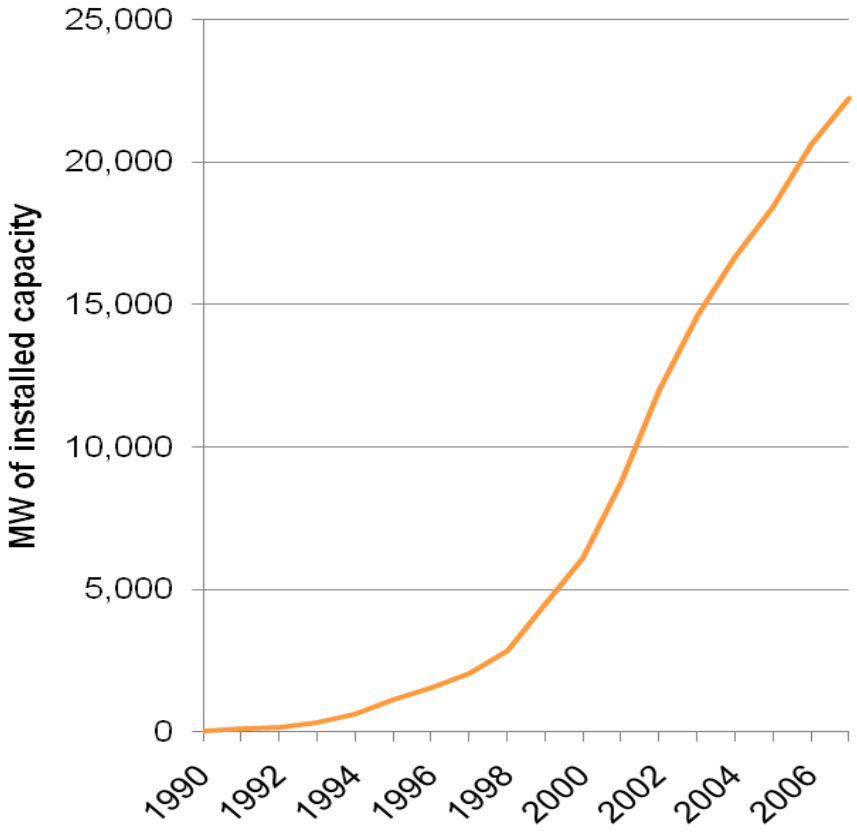
Price AMCs, in the form of feed-in tariffs, have supported renewable energy production in Germany since the early 1990s. The first policy was introduced in 1991 when public electricity suppliers were required to buy power supplied by renewable generators at 90% of the average price of electricity as charged to final consumers in the previous year. From 2002, a fixed tariff for wind energy was set. This tariff was 0.091€/kWh for the first 5 years of a renewable

[51] US Department of Energy (2009) op. Cit.

generator's operation and 0.0619€/kWh for the subsequent 15 years. To encourage early action the tariffs fell by 1.5% for every year after 2002 that capacity was installed. Renewables producers have been designated 'must-carry' facilities throughout the period.

The policy has been very effective in increasing market penetration. The quantity of renewables capacity in Germany has increased dramatically due to these measures, as illustrated by figure ten.

Figure 10 Feed-in tariffs in Germany have led to large increases in wind generating capacity



Source: Earthwatch

The price certainty of the German Feed in Tariff created a mature market where costs fell. However, operators rather than consumers captured these savings. The volume of wind turbines installed led to a lucrative market for

manufacturing wind turbines in Germany. Competition at this level in the supply chain led to innovation which reduced costs by up to 18% in real terms between 1994 and 2001[52]. The rate at which costs fell exceeded the rate at which the price paid allowing renewable energy suppliers to capture the difference as rent.

The Feed-in Tariff may have resulted in renewables being installed in sub-optimal locations. The German Feed-in Tariff made an allowance for the quality of the site. Wind turbines built on sites that failed to meet 150% of a reference yield received a higher payment for a longer period. So installation was incentivised in sub-optimal areas. This has contributed to estimates of a high economic cost for the activity: Lund estimates the cost to the taxpayer of around €60/MW.[53] Providing greater reward for installation at sub-optimal sites can be interpreted as a (second-best) solution to barriers on the supply-side, in this case planning restrictions.

6.5 The Photovoltaic Market Transformation Initiative

The Photo Voltaic Market Transformation Initiative (PVMTI) has achieved mixed success in transforming the solar PV market. The PVMTI was originally intended to follow in the footsteps of the EPA's 'pioneer advanced market commitment program'. It was motivated by the US EPA's 1991 Super-Efficient Refrigerator Program, where a prize of $30 million was offered to the first producer of a refrigerator that met the program's efficiency standards[54]. However, while designing the program it was realised that the dispersed nature of the developing world solar PV market would require a more tailored market pull approach than the prize offered by the EPA. As a result the PVMTI provides concessional finance to consumers, to provide the market pull, as well as concessional finance and technical support to firms. The PVMTI began in

[52] Butler and Neuhoff (2004) *'Comparison of Feed in Tariff, Quota and Auction Mechanisms to Support Wind Power Development'*. Cambridge Working Papers in Economics

[53] Lund (2006) op. Cit.

[54] IFC (2007) *'Selling solar: lessons from more than a decade of experience'* World Bank

1998 and will run until 2010. It is funded by the Global Environment Facility (GEF) and managed by the International Finance Corporation (IFC). The initiative operates in India, where it has been most successful, installing 97% of the 60,000 PV units supported by the program, and in Kenya and Morocco, where over 30% of the program's funding has been spent despite only delivering 3% of the program's PV capacity[55].

The PVMTI shares some characteristics with an AMC. The PVMTI makes the market more lucrative by increasing demand through the provision of cheap, hypothecated, credit. However, unlike an AMC the PVMTI does not make a firm commitment to a price or quantity.

The success of the PVMTI in India and its difficulties in Kenya and Morocco highlights the role that can be played by demand-pull measures. Much of the success in India has been attributed to the strong presence of micro-finance[56], which, when combined with the concessional finance from the initiative, catalysed demand for PV units. The absence of micro-finance in Kenya and Morocco meant that demand was constrained. A program with a stronger commitment to assisting demand may have had more success in markets such as Kenya and Morocco.

The PVMTI has focused on solving supply-side problems and this provides relevant lessons for AMCs. The relative failure of the project in Kenya until 2004 is partly explained by supply-side problems. These problems included a lack of technical proficiency leading to equipment that was not proficiently installed or successfully serviced as well as small enterprises not being able to process the level of bureaucracy that gaining access to IFC finance entailed. Recognising these problems, the PVMTI was restructured to provide more supply-side support. This approach has resulted in an increase in PV sales in Kenya. This illustrates that market growth is not just dependent on consumers and market-pull instruments but may also need complementary supply-side

[55] IFC (2007) op Cit.

[56] IFC (2007) op Cit.

measures.

6.6 Nepalese Biogas Support Program

A program supporting the installation and maintenance of biogas digesters in Nepal increased the size of the market. A biogas digester collects human and animal waste and allows it to naturally break down into a gas. This gas can be used for cooking, heating and lighting. The Nepalese Biogas Support Program (BSP) ran from 1992-2005 co-ordinating and subsidising the supply of biogas digester to poor, rural, Nepalese households. A subsidy of $100 was provided for each successful installation of a standardised biogas digester if it came with a guarantee and service commitment. The payment covered one third of the capital cost and reduced the payback time for an average household from 57 months to 39 months. The program has been successful, beating its installation target by 60,000 units and winning numerous awards, such as the Ashden Award in 2005.

Using traditional biomass for energy supply incurs a number of costs although these were not perceived as such by the Nepalese communities. Before the program 95% of rural energy demand came from traditional biomass, of which 95% was firewood[57]. This incurs a number of both private and public costs. Burning firewood results in local air pollution, especially when fires are lit inside dwellings. This leads to high levels of health problems, in particular respiratory illnesses. Also, the burden of collection primarily falls upon women, which, at up to three hours a day, limits their opportunities for education and other activities. Furthermore, as the resource is perceived as free, no effort is made to conserve it. This results in the over-exploitation of firewood. This means that the burden of collection increases as firewood becomes scarcer. In addition, soil erosion and deforestation occur, which reduces the quality of the land and contributes to climate change. Despite these costs, surveys revealed that firewood was perceived as having zero cost by the

[57] Dajgain, S. and Shakya, I. (2005) '*The Nepal Biogas Support Program: a successful model of public private partnership for rural household energy supply'*

majority of rural Nepalese.

Biogas digesters are a technology with considerable consumer benefits but for which there was little demand prior to the program. In contrast to traditional biomass, biogas burns with a clean flame, is produced close to the household and is sourced from a renewable supply of waste products. However a combination of the high capital cost of a biogas digester and a lack of knowledge about the benefits of biogas in comparison with firewood meant that there was little demand for biogas digesters.

The BSP reduced the price barrier, facilitated a strong demonstration effect and included measures to mitigate consumer concerns. While the BSP was not a 'true' AMC because it did not provide a credible commitment to the overall price received by or quantity demanded from a firm, it did increase the size of the market by lowering the effective price to consumers. The BSP also worked to overcome consumer concerns regarding the reliability of the technology by standardising the design of digesters and only offering subsidies to digesters installed with a guarantee and the promise of two services.

Niches were identified and exploited. During the design of the program it was recognised that a biogas digester is a particularly appropriate technology for fuel production in rural Nepal. This is because even poor households tend to have sufficient land holdings to accommodate the digester. Furthermore many households have at least one cow for religious reasons. These cows are often well looked after and so produce a large and steady stream of feedstock for a digester. Efforts were also made, through religious leaders, to suggest that the sanctity of the cows would be transferred to the gas. Appreciation of this cultural sensitivity led to a growing demand for digesters.

The policy was flexible, enabling support to be used as efficiently as possible. Payments were originally tailored so that larger digesters received the greatest subsidy. However, this resulted in small households purchasing digesters that they could not sufficiently utilise. This was realised and the payment structure was modified to incentivise households to purchase

appropriately sized digesters which has enabled funds to support the installation of more digesters.

However the supply side remains weak and only 32% of a potential 500,000 digesters have been installed. Only 8 firms can produce more than 500 biogas digesters a year against a current demand of ~30,000 units a year[58]. This is largely due to the lack of access to finance in Nepal. Once again, this demonstrates the importance of considering supply side capacity

6.7 South African pre-paid electricity metering

South Africa's state electricity company, ESKOM, enabled a novel technology to develop by using an AMC to mitigate the risks faced by consumers. In 1989 ESKOM embarked upon a plan to provide electrification for over 1 million previously disadvantaged households. Due to the social and economic issues, such as high levels of crime and the high credit-risk of these households, traditional credit based metering would have been difficult and expensive. Pre-paid metering circumvented these problems but the technology to enable pre-paid metering had yet to be matured. ESKOM made a commitment to purchase over 1 million electricity dispensers (ED) and also offered to pay a high price for early models[59]. These AMC type policies, when combined with ESKOM's strong role in coordinating the development of standards, led to a mature market for ED's, which are now in use all over the world.

ESKOM nurtured the supply-side with both a quantity and a price AMC. To develop suitable electricity dispensers required a considerable amount of research along a number of dimensions, ranging from the consumer interface to cryptography. It was realised that the diverse set of requirements would be best met by a number of competing private firms rather than through the

58 Dajgain, S. and Shakya, I. (2005) op. Cit.

59 Iliev, I., (2005) *'Resource-based Technology Innovation in South Africa: pre-paid metering technology – systemic innovation in the South African energy sector'*. Human Sciences Research Council, UK.

research of ESKOM. To gather a quorum of private firms ESKOM made generous commitments on both the quantity of units it would purchase, over 1 million, and the high prices it would pay for early ED models. Such commitments were credible given ESKOM's state-granted monopoly. They enabled firms to incur sunk costs during research and development with little risk that they would not be recovered. This meant that appropriate technology was brought to market within 3 years of the initiative starting[60].

ESKOM developed a strong vision of user needs and disseminated this information to ensure that the market was not locked-in to an inferior product. To ensure that different firm's ED's were fungible ESKOM developed a specification to which firms had to comply. This specification was iterated in partnership with private firms. ESKOM funded the testing of ED's against its specification, which ensured quality, established dialogue and reduced the costs of development for firms. By 1994 the specification developed to such an extent that it was formalised as a standard. At this point the market was mature enough to continue without support and ESKOM retreated from its market supporting role.

The unique environment of South Africa in the 1990's meant that a niche for electricity dispensers existed and was exploited. The laggard economic development of South Africa until the 1990's meant that a majority of households were not covered by a network, so there was no technological legacy to overcome[61]. Also, on the demand-side, ESKOM's monopoly on electricity distribution meant that it acted as a monopsonist purchaser of ED's. This meant that it had a leading role in nurturing the technology and that its purchase commitments were credible. On the supply-side, South Africa's developed military-industrial complex provided a particularly useful source of innovated ideas.

[60] Iliev, I. (2005) op. Cit.

[61] Iliev. I (2005) op. Cit.