Innovation in long term renewables options in the UK:

Overcoming barriers and 'systems failures'

Centre for Energy Policy and Technology
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Innovation in long term renewables options in the UK – overcoming barriers and 'systems failures'

ICEPT report for the DTI Renewable Innovation Review

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Executive summary

Context

DTI are currently undertaking a review of support for innovation of new and renewable energy technologies, to ensure that policies are well integrated and coherent, and are providing appropriate support to the full range of technologies. This paper feeds into the review, with a particular focus on the early stage technologies. ICEPT was asked by DTI to provide a 'think piece' on overcoming current barriers to the innovation of renewables options for the long term in the UK, drawing on the review of *'UK innovation systems for new and renewable energy'* undertaken by ICEPT and E4Tech in Spring 2003.

The innovation systems review identified five stages of technology development: basic and applied R&D; demonstration; pre-commercial; supported commercial and commercial. Technologies which may be regarded as options for the long-term are those currently at the first three stages of this innovation chain, and include:

- Wave and tidal stream
- Some types of PV
- Renewable hydrogen
- Fuel cells
- Micro CHP
- Biofuels and advanced biomass

Technologies which are at the 'supported commercial' stage, including onshore and offshore wind, biomass co-firing and combustion, medium-scale CHP and conventional PV, are the subject of a separate paper dealing with the prospects for meeting the 2010 target. However, because policy issues that affect each stage overlap to a considerable degree, some of our discussion is also relevant to these options.

Key issues

Though most innovations pass along a 'chain' whereby they progress from R&D to commercialisation, each stage is characterised by a complex web of actors, subject to a number of driving (and inhibiting) forces, and there are feedbacks and iterations between the stages. The review identified 'systems failures' in UK innovation systems which are currently preventing many renewables technologies successfully moving along the chain.

At a very general level, UK innovation systems appear to being failing at the intermediate stages – developing and commercialising technologies that are emerging from R&D. Unless these systems failures are addressed in the near term, the option of creating a UK capacity for these technologies to make a significant contribution to long-term carbon reduction may be curtailed. This report identifies potential policy measures to overcome these system failures and barriers, and assesses the feasibility and appropriateness of these policy measures.

Main findings

Creating, keeping open and closing off options (Section 3)

There is a value associated with creating and keeping open 'options' which may be exercised in the future, in analogy with financial and investment options.

- To create an 'option' for meeting long term targets, new technologies need to move beyond R&D into the pre-commercial or supported commercial stage.

- The cost of keeping early stage options open needs to be investigated, but should not be prohibitively high, as total volumes are still relatively small. Potential benefits could be very large, in terms of both emissions reductions and UK industrial benefits. ***Therefore, there is a strong case for policy support to keep early stage options open.***

Policy coherence, continuity and expectations (Section 4)

The benefits of a more strategic approach to policy development are investigated, which would aim to improve policy coherence, ensure continuity of policies over a longer time frame, and improve expectations of stability for technology developers and investors. Such a shared strategic vision for the transition to much higher levels of deployment of renewable energy technologies would:

- agree strategic goals for the medium term;
- set out transition paths or 'route maps' for how these might be achieved;
- agree support for the initial steps or 'learning experiments' along these paths.

The benefits of such an approach would be to:
- Build on existing policy steps by placing these within a more strategic framework.
- Provide positive expectations of future policies and markets.

It is recommended that the DTI explicitly and publicly adopts a strategic approach to securing medium and long-term options and develops a 'strategic vision' of renewables development and policy. Such an approach would follow on from the current Renewables Innovation Review and should be developed in collaboration with stakeholders, with industry having a leading role. It should avoid excessive revisiting of existing policy decisions, and have as a core objective to define a shared strategic vision for the development of renewable energy technology. This vision should involve agreeing strategic goals for the medium term, setting out transition paths or 'route maps' for how these might be achieved, and providing support for the initial steps along these paths, which would provide valuable learning experience.

Within the strategic approach, key priorities should be to ensure:
- ***Perseverance with policy frameworks*** – policy measures to support innovation should be stable over the long-term and be insulated from short term political changes.

Research suggests that policy uncertainty and reversals in the early phases of a technology's development can 'sink' an innovation no matter what its long term promise might be.

- ***Regulatory consistency*** – measures should add to the functioning of innovation support as a strategic whole, by augmenting and not disrupting existing measures.
- ***Continuity of policy measures*** – measures should 'join up' across the stages of the innovation chain, so that a successfully performing technology can progress smoothly towards commercialisation, with a clear strategy in place for withdrawing support at that stage.

Systems failures: problems, prospective solutions and policy issues (Section 5)

Specific 'system failures' that hinder the progress of renewables along the innovation chain are addressed. Addressing these requires new measures and new funds, but new money is not sufficient alone, implementation should take account of the strategic framework, and improve flows of influence and knowledge within the innovation system.

New measures are needed to address the gap between the demonstration and pre-commercial stage. Existing measures do not provide opportunities for small scale pre-commercial trials, so a new framework that creates a small niche market for technologies at this stage is needed. The report discusses different support mechanisms for achieving this:

- premium prices, through either an early stage tranche within the RO, a premium on top of the ROC price, or a fixed 'feed-in' tariff;
- a dedicated capital grants programme.

It is argued that neither a new pre-commercial band in the RO, nor a premium paid on top of the RO is likely to be the most appropriate mechanism to provide support at this stage. A fixed tariff reduces market/regulatory risk, complements the RO without causing disruption to it. However, no form of price support can address technology risk directly. A capital grants scheme would addresses technology risks directly.

Therefore overall, the simplest and most effective means to create a small niche market to allow early stage technologies move into pre-commercial trials would be to combine a capital grants programme with a fixed premium price scheme. The premium prices would be independent of the RO, whilst the grants programme would need to be of clear duration, and institutionally insulated from short term swings in funding. A reconfiguration of the RO would not be needed and impacts on ROC prices would be minimal.

Linked policies to address the move from pre- to supported-commercial development are also assessed. Existing grants for biomass and offshore wind are a good start, but funding is rather short term.

It is recommended that, in the transition from pre-commercial to supported commercial phase, the existing capital grants are replaced by a new scheme of grants that is funded

over a clear and longer term time period and is made available as a generic measure for all technologies moving from one stage to the next. This does not mean all technologies will require equal levels of support, but the measure should be seen as a stepping stone for innovation, not ad hoc support for specific options. This should be clearly linked to the measures proposed for the early pre-commercial stage.

Ways of addressing the risk/reward ratio for project developers and investors at this stage are discussed, either by support that mitigates some risk, as in the capital grants programme above, or increases the potential rewards.

It is recommended that policymakers improve long term risk/reward ratios by creating a framework for investments that encourages long term contracts. Potential rewards could be increased, for example, by extending the RO beyond 10% in 2010, for example by making the aspiration of 20% renewables by 2020 into a target under the Obligation. Where appropriate, eg in the case of offshore wind, larger returns could also be encouraged through licensing rules that encourage larger projects.

Exit strategies for withdrawing support from technologies which are successful in the supported commercialisation stage are also discussed.

If new measures to promote development of early stage options are to succeed then the timeframe for support, criteria by which it will be both provided and withdrawn, and the mechanism by which technologies will move out of innovation support measures need to be more clearly defined. Exit strategies at each stage need to be developed, and agreed in advance with stakeholders, in order to provide stability.

Institutional arrangements for achieving the above measures are discussed.

It is recommended that all new schemes should be embedded in a single institution, to ensure all schemes are integrated into a coherent whole that spans the pre-commercial stage.

Scale and sources of funding for new measures (Section 6)

The level of funding currently available at each stage of the innovation cycle is examined, and an indication of what an idealised system of support might look like is provided. The cost of a hypothetical scheme to provide a niche market for pre-commercial trials is estimated, based on wave and tidal stream technology costs. Finally, mechanisms by which new funds could be found are assessed.

- ***Assessment of the UK's current policy mix clearly indicates the funding 'gap' at the early pre-commercial stage***. No measures provide support at this point in the innovation cycle.
- Assessing the 'right' amount of support at each stage requires more empirical work, including an assessment of the success of policies in other countries. However, we

provide a view of the shape of an idealised curve that plots total spend against technology stage. Funding levels through RD&D and pre-commercial development are of a similar magnitude, but increase substantially at supported commercial stage. ***Costs per unit are high in the early stages, but installed capacity is very small, whilst much larger numbers of units need to be installed in the supported commercial stage.***

- This is borne out by rough costing of a pre-commercial programme for wave and tidal. Its costs, of around £50m, are similar to current funding for offshore wind capital grants and the Carbon Trust and DTI RD&D programmes.
- ***This case study also indicates that a combined programme of capital grants and a fixed premium 'mini-feed in tariff' could be the least cost means to provide a small niche market at the beginning of pre-commercial development.***
- The basis for support will change by stage: from full public grants for basic R&D to regulated transfers – such as the RO – that do not draw upon the public purse at all. At the intermediate stages a combined approach is needed.
- New funds can be raised in a number of ways. ***The new measures we advocate would not redirect RO revenues.***
- The ***potential for a capacity development charge*** hypothecated to the long-term development of the energy system is investigated.
- ***It is argued that 'minimising costs to the consumer'*** in energy market regulation should be interpreted to mean ***minimising the present worth of the long-run social costs likely to be faced by both today's and future consumers.*** This could help to create a more stable pricing policy that would be more conducive to innovative investments and the infrastructure investment required to support them, so helping to meet long-term environmental goals whilst maintaining energy market efficiency.

Contents

1. Introduction

DTI are currently undertaking a review of support for innovation of new and renewable energy technologies. The aim is to ensure that policies are well integrated and coherent, and are providing appropriate support to the full range of technologies, including, where needed, those that are currently at an early stage of development. This paper feeds into this review, with a particular focus on the early stage technologies. ICEPT was asked by DTI to provide a 'think piece' on overcoming current barriers to the innovation of renewables options for the long term in the UK, drawing on a review of UK innovation systems for new and renewable energy[1] (hereafter 'the innovation systems review') undertaken by ICEPT and E4Tech consulting in spring 2003. DTI specified that the report should address the following issues:

- Consider which are the key technologies for the creation of options for 2020 and 2050, i.e. all technologies except onshore and offshore wind.
- Identify the generic and specific barriers to renewables innovation which need to be addressed over this and the next Spending Review period in order to keep those options open, i.e. between now and 2008.
- Consider and make recommendations as to what government measures are required to address those barriers to innovation.

The innovation systems review described how, though most innovations pass along a 'chain' whereby they progress from R&D to commercialisation, each stage is characterised by a complex web of actors, subject to a number of driving (and inhibiting) forces, and there are feedbacks and iterations between the stages. The review identified 'systems failures' in UK innovation systems which are currently preventing many renewables technologies successfully moving along the chain towards commercialisation.

At a very general level, UK innovation systems appear to being failing at the intermediate stages – developing and commercialising technologies that are emerging from R&D. Unless these systems failures and associated barriers to innovation are addressed in the near term, the option of creating a UK capacity for these technologies to make a significant contribution to long-term carbon reduction may be curtailed. The purpose of this report is to clarify the nature and causes of these systems failures and barriers, to identify potential policy measures to overcome them, and to assess the feasibility and appropriateness of these policy measures, according to a number of key criteria.

The approach taken throughout this report is to start from problems identified in the innovation review, adding some further considerations that have emerged in subsequent discussions with DTI and others. A range of possible resolutions are explored, from which specific policy recommendations are made throughout the report.

[1] ICEPT & E4Tech, *The UK innovation systems for new and renewable energy*, Report for the DTI, June 2003, available at www.dti.gov.uk/energy

The report analyses UK innovation systems for renewables and the policy context, in terms of three broad levels of analysis:

- In Section 3, the rationale for intervention is considered in terms of the issues relating to creating, keeping and closing off low carbon options.
- Section 4 discusses high level or strategic issues to do with the way that policy is conceived, presented and delivered. It is argued that a more strategic approach to policy-making is needed to assist innovation system actors to develop clearer long term expectations, in order to encourage investment in new options. Recommendations for the formation of approaches to improving the strategic content and direction of policy are made.
- In Section 5, these strategic issues inform discussion of the more specific 'system failures', which are inhibiting UK innovation systems from creating the conditions for successful commercialisation of these technologies. These are considered in detail and a number of possible resolutions are analysed. The strengths and weaknesses of the range of measures are explained and recommendations for policy improvements are made.
- In Section 6, the current UK funding situation is considered and contrasted with an idealised pattern of support across the innovation chain, based on lessons from innovation theory and experience from other countries. This section also provides a rough estimate of the scale of funding that would be needed to support a new scheme of pre-commercial trials. Finally, the means by which new funds might be raised are discussed.

2. Innovation stages and key questions

2.1. Definition of stages of technology development

This paper looks at creating and keeping open renewables options for 2020 and 2050, and not specifically at technologies which are contenders for the 2010 targets. In the 'innovation systems review', we identified five stages of technology development: basic and applied R&D; demonstration; pre-commercial; supported commercial and commercial. Technologies which may be regarded as options for the long-term are those currently at the first three stages of this innovation chain, and include:

- Wave and tidal stream
- Some types of PV
- Renewable hydrogen
- Fuel cells
- Micro CHP
- Biofuels and advanced biomass

Technologies which are at the 'supported commercial' stage, include onshore and offshore wind, biomass co-firing and combustion, medium-scale CHP and conventional PV, though there remain significant barriers inhibiting adoption of some options in the UK. These are the subject of a separate paper dealing with the prospects for meeting the 2010 target. However, because policy issues that affect each stage overlap to a considerable degree, some of our discussion is also relevant to these options.

The stages of technology development are defined as follows:

- *Basic and applied R&D* includes both 'blue skies' science and engineering /application focused research. Primarily university research activities.
- *Demonstration* includes early prototypes, up to the point where full scale working devices are installed – but only in single units or small numbers, and still financed largely through R&D related grants. Mostly small spin outs or research subsidiaries.
- *Pre-commercial* captures a fairly broad stage of development, one where multiple units of previously demonstration-stage technologies are installed for the first time, and/or where the first few multiples of units move to much larger scale installation for the first time. Larger players begin to move in or spin outs must grow rapidly, so investment risks (and hence policy needs) are high at this stage.
- *Supported commercial* is the stage where, given generic renewables support measures such as the Renewables Obligation, technologies are rolled out in substantial numbers and by commercially oriented companies.
- *Commercial* technologies can compete unsupported, within the broad regulatory framework.

These stages represent a continuum, not rigid compartments. Whilst we provide below a brief discussion of the stage of development and prospects for each technology below, we do not analyse each technology individually. Instead, we focus on innovation system failures and barriers that affect all technologies at a particular stage. We illustrate these by example and also deal with some technology specific aspects.

2.2. Assessment of current maturity for technologies in the UK

The innovation systems review identified a number of issues inherent to each stage in the innovation process, which are summarised in Box 1. It also located individual technologies along the spectrum of maturity, with an indicative indication of their market penetration relative to potential, as shown by the S curve in Figure 1. We can see from this that some technologies are making good progress in terms of expanding markets as maturity increases, whereas others – such as biomass combustion – appear to be in trouble; market growth is not proceeding as rapidly as technology maturity would imply for a successful option. These options generally face particular barriers to adoption, and these are the subject of a separate study.

Box 1 – Issues at each stage of the innovation cycle

Basic and applied R&D technologies

Responsive mode funding allows personal interest and curiosity to proceed, but directed programmes and industry support also influence the direction of research. Technologies progress from this stage to demonstration in two major ways: via an existing supply chain in a related market (albeit one supported by policy, such as PV); or through the stimulus of a clear prospect of a (policy-supported) market, such as in marine technologies and hydrogen.

Demonstration stage technologies

At this stage, actors collaborate to launch demonstration projects, often supported by R&D funding from governments, and project funding from a wide range of sources. However, in many cases it is very difficult for technology and project developers at this stage to move from one to several demonstration projects. They are past the stage of R&D funding and are attempting to attract funding for novel projects, but at too early a stage for private sector interest or to benefit from market pull mechanisms.

Pre-commercial technologies

At this stage projects are still high risk. There is technical risk due to the relatively small number of proven systems. In many cases, the policy instruments specific to these technologies (e.g. capital grants) are new, and there is uncertainty about their longevity. Such instruments are necessary if the technology risks are to be financed. Issues that surround market and regulatory risks are common to the supported commercial options discussed below. In biomass systems specifically, there are also risks due to the complexity of supply chains. In addition to this, the large range of technologies and applications in biomass and to a certain extent in CHP, coupled with a lack of knowledge, leads to confusion for potential consumers and the financial community.

Supported commercial technologies

In these technologies, existing support mechanisms appear to be working, though it is too early to judge the efficacy of many reasonably new measures, such as the renewables obligation and fuel tax exemptions for biofuels. Innovation is characterised by learning-by-doing. A stable policy climate in the long term assists incremental development towards competitiveness with fossil fuels. There are market risks, such as future variation in the price of ROCs. These are considered manageable, provided the regulatory regime stays consistent, but additional long term signals would be beneficial.

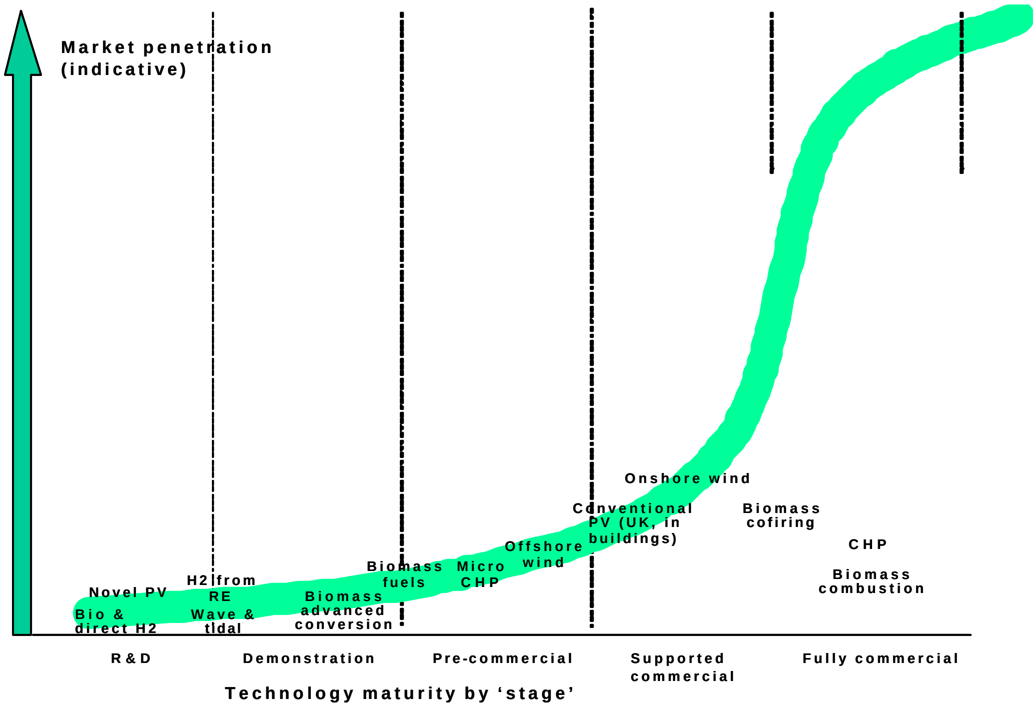


Figure 2.1. Technology maturity and market growth

2.3. The UK's role in renewables innovation systems

The innovation systems review identified a number of issues facing the UK, and raised questions relating to proposed ways of addressing these issues.

A key issue is the difficulty in moving technologies successfully along the innovation chain, since the innovation review indicated that this is happening at the moment for some emerging technologies. In addition, for more advanced options that have made good progress internationally, there is a notable absence of UK participants, despite historic UK participation in R&D activity – wind technologies provide a good example. It is therefore important to assess whether the UK's innovation system could be more effective in moving technologies from R&D to commercialisation.

This is not to suggest that the UK ought to be seeking to be active at every stage, for every technology; there will always be cases where comparative advantage lies elsewhere. However, it is reasonable to start from the assumption that UK firms have the potential to play an important role in at least *some* of the options currently emerging. The innovation review provides examples of technologies where the UK has done well with R&D activity and where UK companies appear well placed, and willing, to capitalise on UK funded R&D. This suggests that the problems faced by the UK innovation system are focussed around problems at some stages of the process, in particular helping demonstration technologies move into pre-commercial trials and pre-commercial options move into larger scale deployment.

The very nature of renewable technologies – infant or emerging technologies with social benefits that are dependent on policy support – suggests that policies play an important role in their success. In this respect they differ from many 'conventional' areas of innovative endeavour. A separate paper prepared by ICEPT indicates that other countries have (by luck or by judgement) put in place policies that have proved effective in both encouraging the development of new options and in fostering an active indigenous industry. So whilst all innovation systems are international in nature (to a greater or lesser extent depending on the technology and prospective markets), we take it as read that a more effective UK system is a desirable objective that policy is key to achieving. It is on this basis that this paper considers how the policies that bear upon early stage technologies could be improved.

2.4. Issues and questions raised by the innovation systems review

The subsequent sections of this report are informed by a number of key questions that emerged from the analysis undertaken in the innovation systems review.

Systems failures exist in moving technologies along the innovation chain

Technologies make progress along the innovation chain as a result of flows of funding, knowledge and influence between actors in the innovation system. On occasion, these systems can fail, and innovative products can get 'stuck'. At present, for some options, system failures or gaps appear to exist at two points:

a. Moving from demonstration to pre-commercialisation:

There are obstacles to companies seeking to move from the first one or two demonstration projects to more substantial (though still small scale) levels of deployment. The incentives offered by generic measures, such as the Renewables Obligation, cannot attract investment into technologies that are in their early stages of development, and so are high risk, high cost and confined to small niches. Potential remedies could involve support for niche markets, involvement of larger players and removal of R&D support for technologies not successfully progressing, raising questions:

- How should early niche markets best be supported?
- How should larger players be encouraged to commit effort and resources at the demonstration stage?
- When should technologies no longer attract R&D support?

b. Moving from pre-commercialisation to supported commercialisation

Several types of risk are hindering the large-scale deployment of pre-commercial technologies (such as offshore wind and biomass). Policies address these in part, but the rewards may be not yet strong enough to overcome the risks. Questions raised are:

- How could risk/reward ratios for project developers and investors be improved?
- How could regulation help to create much larger potential long term rewards?
- How could knowledge networking and sharing be improved for 'disruptive technologies'?
- How can change to institutional structures, which currently form barriers, be incentivised?

Expectations and knowledge about future markets are vital at all stages

Innovations in early stage technologies are predicated upon the expectation that there will be a supported market. Having unambiguous long term support, and a shared vision for the future, for each area of new and renewable energy, would have a self-reinforcing effect upon actors in the innovation systems for early stage technologies. Questions raised are:

- How can a durable policy environment be achieved, so that rewards from the full range of instruments are seen to be stable over a sufficiently long time-frame?
- How can a shared vision for the future of each technology area be developed between Government, industry and the research community?

The continuity of the regulatory framework is important

The need for a long term framework was emphasised by many parties and the longevity of the entire range of policies and regulations is important. Questions raised are:

- How can the regulatory framework be developed, so that it promotes the long-term view, whilst remaining flexible in terms of support for technologies at different stages of maturity?
- How can the stability of the support structures be maintained, whilst enabling technologies to move successfully along the innovation chain and out of support?

Technologies failing at the demonstration stage provide learning opportunities

- How can learning from unsuccessful attempts be used as a stimulus for further technology development?

In addition, the aims of this study raise further questions:

- What is required to 'keep an option open' for the long term?
- Is there a useful classification of barriers (including those already identified)?
- How can the case for policy support for innovation be made as convincing as possible?

3. Creating, keeping open and closing off options

Key issues

This section argues that there is a value associated with creating and keeping open 'options' which may be exercised in the future, by analogy with financial and investment options.

- ***To form an 'option' for meeting long term targets, new technologies need to move beyond R&D into the pre-commercial or supported commercial stage.***

- The cost of keeping early stage options open needs to be investigated, but should not be prohibitively high, as total volumes are still relatively small. Potential benefits could be very large, in terms of both emissions reductions and UK industrial benefits. ***Therefore, there is a strong case for policy support to keep early stage options open.***

In Sections 4 and 5, we discuss potential solutions to the strategic and specific failures and barriers that are inhibiting the further innovation of some of these technologies in the UK. Previously, in Section 2, we noted that many of the technologies that may be needed to form options for 2020 and 2050 are currently at the R&D or early demonstration stage. In this Section, we discuss in more detail what it means to 'create' and 'keep open' an option for the long term, and when it might be appropriate to 'close off' options. Though these issues are clarified by recent academic thinking in this area, this does not provide definitive answers, as these are essentially social and political questions.

It is useful to start by comparing a 'technological option' with the definition of an 'option' used in financial settings. Here, an 'option' is defined as something that is available to be enacted in the future, depending on the circumstances at the time. The more volatile and uncertain the future is perceived to be, the greater is the value of securing an option, i.e. the 'option value'. The option value is purchased by investment now to secure the availability of the option in the future.

As discussed in Box 2, U.S. economists Dixit and Pindyck (1995) have applied the analogy of financial options to firms' investment decisions. They make a clear distinction between an action that *creates* an option, i.e. makes it available for the future, and an action that *exercises* or *uses up* an option, i.e. takes advantage of the option at a particular moment in time. They argue that the incorporation of option valuation into investment decisions has a significant impact on the optimal timing of investments, compared to a traditional cost-benefit analysis. They note that an action that *creates* an option should be valued *more* than a cost-benefit analysis would indicate, whilst an action that *exercises* or *uses up* an option should be valued *less* then a simple cost-benefit analysis would suggest. This should make it easier for companies to persuade investors to fund actions, such as R&D, that create options, whilst increasing the difficulty of obtaining finance for actions, such as production and marketing, that exercise options.

Box 2. A simple calculation of option value

U.S. economists Dixit and Pindyck (1995) have applied option theory to firms' investment decisions. Here, we use one of their examples to illustrate how creating an option has an additional value, compared to a traditional cost-benefit analysis.

Suppose a firm has to make an decision of whether or not to invest $15 million in demonstrating the economic feasibility of a production plant. Before the investment is made, there are three estimates for the cost of moving to full production - low ($40 million), medium ($80 million) or high ($120 million), each judged to have equal probability of ?, and there is an expected revenue of $90 million from full production. Then, for full production,

expected profit = expected revenue – expected cost
= $90 - (? x $40 + ? x $80 + ? x $120) million
= $10 million.

As this is smaller than the initial investment of $15 million, conventional analysis would conclude that the initial investment should not be undertaken.

However, suppose that the initial investment in feasibility allows the firm to decide which of the three cost possibilities for full production is closest to reality. After learning about the cost, the firm may then make a decision whether to go ahead with the project or to drop it. In this case, the initial $15 million investment creates an *option* for proceeding. That this option has value may be shown as follows.

If the initial investment shows that the high cost scenario is likely, then production should not go ahead, and the operating profit will be zero. In the other two cases, full production will proceed, since, for the medium case, profit will be ($90 - $80) = $10 million, and for the low case, profit will be ($90 - $40) = $50 million.
Then, for full production,

expected profit = (profit for high cost case) + (profit for medium) + (profit for low)
= (? x $0) + (? x $10) + (? x $50) million
= $20 million.

The expected profit is now greater than the initial investment of $15 million, justifying the initial investment.

Thus, the option has value because the additional benefit that accrues if the option is undertaken is greater than the initial cost of the investment, given that we can choose not to exercise the option if further information tells us that it is not required.

Applying these ideas to the case of technology options, we can see the general point. Actions that create options, which we may later choose to exercise or not, have an additional value - the 'option value'- if the future is uncertain and decisions are wholly or largely irreversible. The additional cost of investing now to create or keep open the option may well be outweighed by the additional benefit that would accrue if the option is needed, given that we may choose not to exercise the option if further information tells us that it is not needed.

This option value is complemented, in the case of early stage technology development, by the positive benefits of learning, leading to cost reductions - 'moving down the learning curve' – that accrue if investment is made in experiments to gain experience.

We may then ask the question, what is required in order for a technology alternative to be an 'option' in the sense given above? Previously in energy policy, 'keeping an option open' has usually referred to a mature technology, such as nuclear power or deep mined coal, which is currently economically unattractive, but which would be lost if investment is not made to maintain current capability.

Here, we are referring to technologies in the earlier stages of development. In this case, there are typically long lead times and large amounts of investment needed for such technologies to advance to commercialisation. Thus, for such a technology to form an 'option' capable of making a significant contribution to renewable energy and carbon reduction targets in the medium term, around 2020, it is likely to need to at least move into the pre-commercial stage of large scale demonstration in the short term. The technology would then have the opportunity to demonstrate its technical and economic feasibility, and to find and develop niche markets for its commercialisation.

As further experience is gathered, it may become clear that, for some technologies, the UK does not need to maintain a capability at each point in the supply chain, but should instead concentrate at high value-added at key points in the chain.

To clarify this point, it is necessary to address the questions of 'An option to do what, for whom?'. There are two main dimensions relating to keeping low carbon options open for the UK: (1) the potential for reducing carbon emissions in the UK, and (2) the development of a UK low carbon industry, i.e. benefits to 'UK plc'. Depending on the relative priority to be given to these two dimensions, 'keeping options open' would imply focussing on developing capabilities at different stages of the innovation chain:

	Low priority to reducing UK emissions	**High priority to reducing UK emissions**
High priority to UK plc benefits	Focus on technology development capability	Focus on both technology development and deployment capability
Low priority to UK plc benefits	Rely on technology development in other countries	Focus on technology deployment capability

Table 3.1. Relative priority, in terms of keeping UK options open

As the government has committed itself to a long-term goal of reducing UK carbon emissions by 60%, the principal alternatives are in the right hand column, i.e. to focus both on technology development and deployment capability in the UK, or to focus only on technology deployment capability. It seems advisable that this question should be considered on a case-by-case basis for different technologies. For example, it may be desirable for the UK to develop a capability for offshore wind, wave and tidal technology development, as well as deployment, in view of the likely UK comparative advantage in these technologies; but for other technologies, including some types of fuel cells, the focus may be on deployment.

Given that there is an additional value to creating and keeping open options, we may then ask what level of investment would be appropriate to keep an option open. Attempts to calculate an 'optimal' value or timing of investment (Pindyck, 2002) quickly run into the complexity of the interactions between uncertainty and irreversibility in environmental and economic costs and benefits. However, it is clear that if investments are not made to support the progress of early stage technologies towards commercialisation, then the option value will be lost. In addition, it is highly likely that these technologies will find market applications if their costs can be reduced to a level at which they are competitive with existing alternatives, at first in niche markets and then more widely. As we shall see in Section 4, estimates of the order of magnitude of support that would be required in order to progress an early stage technology to the pre-commercial stage are comparable with the levels of support currently available at other stages in the chain. Hence, it appears that the cost of keeping options open is not prohibitively high, and the benefits are potentially very large. Thus, option theory suggests that there is a strong case for making the investments needed to keep these options open, though a more complete assessment of the costs and benefits, including the option value, would be needed in practice.

Of course, governments should not be expected to write 'blank cheques' for the support of technologies, for which there are large potential future profits. Thus, the case for keeping options open needs to be matched by criteria for 'closing off' options that, on the one hand, fail to make significant progress towards commercialisation given reasonable time and support, or that, on the other, are clearly capable of being financially self-sufficient. This means that policy support should have an 'exit strategy' for determining when support should be withdrawn, either because a technology has made sufficient progress that it is viable without further support, or because a technology has failed to make significant progress.

We return to this issue in Sections 4 and 5, in the context of specific measures to overcome systems failures and barriers.

4. Policy coherence, continuity and expectations

Key issues

This section argues for a more strategic approach to policy development, in order to improve policy coherence, ensure continuity of policies over a longer time frame, and improve expectations of stability for technology developers and investors. Policymakers should avoid ‘surprises’ that impact on investor confidence. The UK should develop a shared strategic vision to signal long term intentions for the transition to much higher levels of deployment of renewable energy technologies, which would:

- agree strategic goals for the medium term;
- set out transition paths or ‘route maps’ for how these might be achieved;
- agree support for the initial steps or ‘learning experiments’ along these paths.

The benefits of such an approach would be to:

- Build on existing policy steps by placing these within a more strategic framework.
- Provide positive expectations of future policies and markets.

Within the strategic approach, priorities should be to ensure:

- Perseverance of policy frameworks – policy measures to support innovation need to be stable over the long-term and be insulated from short term political changes.
- Regulatory consistency – measures should add to the functioning of innovation support as a strategic whole, by augmenting and not disrupting existing measures.
- Continuity of policy measures – measures should ‘join up’ across the stages of the innovation chain, so that a successfully performing technology can progress smoothly towards commercialisation.

4.1. The importance of a more strategic approach

In this Section, we address the questions raised by the innovation systems review:

- How can perseverance with the policy environment be achieved, so that rewards from the full range of instruments are seen to be stable over a sufficiently long time-frame?
- How can a shared vision for the future of each technology area be developed between Government, industry and the research community?
- How can the regulatory framework be developed, so that it promotes the long-term view, whilst remaining flexible in terms of support for technologies at different stages of maturity?

We argue that a more strategic approach is needed, in order to improve policy coherence, ensure continuity of policies over a longer time frame, and improve expectations of stability for technology developers and investors. Investor confidence is positively affected by long term signals from government, and negatively affected by regulatory changes that spring 'surprises' on investors.

The framework for UK energy policy has been evolving over recent years, as instruments have been introduced to deal with specific issues and rectify perceived problems. The 2003 Energy White Paper was important in setting overarching goals for UK energy policy – *reducing CO_2 emissions, energy security, competitive energy markets, relieving fuel poverty*. However, it did not provide a new set of detailed policies. Instead, it encouraged evaluation and improvement of a range of measures put in place over recent years. Clearly, it would not be appropriate to propose 'starting afresh', ignoring this considerable armoury of measures already in place. It is particularly important to avoid the perception that policymakers will frequently 'meddle' with policy, since this has been shown to undermine confidence and discourage investment. However, whilst many existing policies have considerable merit, and some were described in a recent ICEPT expert workshop as 'elegant and well conceived', there is also a perception that individual policies do not 'join up' very effectively.

Analysis from the academic literature on innovation systems suggests that there is a benefit to siting policy measures within a more strategic and systemic framework. A wide range of stakeholders in the UK energy industry also argue that greater coherence and continuity of policy making would improve expectations that the UK is seriously committed to a low carbon future, enable more effective planning by industry, and greatly assist in securing of the scale of investment needed to achieve such a future. As the innovation systems review makes clear, ***expectations of future policies and markets are absolutely central to the creation of successful innovation systems.***

Several countries have adopted long term targets and developed policies that offer considerable long term security to investors. One example that illustrates the desirability of a strategic approach is the 'Energy Transition' programme now being applied in the Netherlands (see box). This involves working with stakeholders to agree medium-term strategic goals (on a 20 year time frame), mapping out transition paths to achieving these goals, and providing the context for concrete steps forward and learning objectives in the short-term.

Such a strategic approach does not imply that the government should undertake detailed planning of energy futures, but rather play a facilitating and support role, in bringing stakeholders together and providing incentives at key stages, which use the power of markets to deliver innovation. This approach would mitigate some of the policy dilemmas which inevitably arise:

- the desire to avoid trying to 'pick winners', whilst providing focussed support that encourages 'winners' to emerge;
- the recognition that some technology 'failures' are inevitable in the early stages, and willingness to learn from these failures, whilst avoiding the perception that certain technologies can never succeed;

– the need for a stable regulatory environment, whilst avoiding ‘lock-in’ to particular measures or frameworks;
– the need for adequate funding and support measures, whilst ensuring that such measures have an ‘exit strategy’ to ensure that successful technologies move smoothly out of measures and that support is withdrawn from technologies which fail to make sufficient progress towards commercialisation.

Several other countries have achieved a high level of consensus between industry, policymakers and other stakeholders. There is a danger that attempting to define a more strategic approach in the UK risks being seen as more prevarication by policymakers – ‘yet another review’. Even worse, there is evidence that policy reviews themselves can give rise to negative expectations – the review of renewables deployment proposed in the White Paper for 2005/6 has actually discouraged some investors. Nevertheless, the benefits of combining a more integrated approach to policy with much more positive expectations on the part of the industry could be considerable. A variety of individual changes will affect expectations – extending the RO to provide greater confidence in ROC values post 2010, foe example with a 20% target in 2020 is one prominent example. But explicit adoption of a more strategic approach could help to ensure that this kind of change, and the recommendations made below secure a successful outcome – more investment, the emergence of a wider range of options and more rapid uptake of successful technologies.

We do not advocate direct transposing of the Dutch approach; there are important differences in industrial structure and culture. However, the UK could learn lessons. Such an approach should start from the strategic technology or system priority areas identified through the current DTI review process. For each such priority area, a public-private stakeholder team should work to define a long-term vision and medium-term strategic goals (for a 20 year time frame) for that area. Each team should be adequately resourced and tasked to report within a specified timescale, with a commitment given that the government will contribute positively to the process and act on the conclusions. The work of the DTI-supported, industry-led Innovation and Growth Teams for environmental technologies and low carbon vehicles provides a model of a similar process that can be adapted for this purpose.

We therefore recommend that the DTI explicitly and publicly adopts a strategic approach to securing medium and long-term options and develops a ‘strategic vision’ of renewables development and policy. Such an approach would follow on from the current Renewables Innovation Review and should be developed in collaboration with stakeholders, with industry having a leading role. It should avoid excessive revisiting of existing policy decisions, and have as a core objective to define a shared strategic vision for the development of renewable energy technology. This vision should involve agreeing strategic goals for the medium term, setting out transition paths or ‘route maps’ for how these might be achieved, and providing support for the initial steps along these paths, which would provide valuable learning experience.

Experience of 'Energy Transition' Programme in the Netherlands

Transition Management was adopted in the Netherlands, as part of the 4th Netherlands Environmental Policy Plan (NEPP), published in 2000. This Plan argued that there remains a set of persistent environmental problems to be addressed: climate change, biodiversity issues, depletion of resources, threats to human health, which require a systems approach to policy making, in order to stimulate *transitions* towards sustainable energy, transport, resource use and agriculture. Following the publication of the NEPP, transition management programmes have been initiated for these four areas by the Four Ministries responsible.

The 'Energy Transition' programme, being undertaken by the Ministry of Economic Affairs, requires the simultaneous meeting of social, economic and environmental goals, referred to as 'people', 'profit' and 'planet'. This requires long-term goals, combined with short term actions. Transition programmes are now being undertaken for four key elements:

- Biomass (in an international context)
- New Gas (including CHP in the short term and hydrogen in the long term)
- Sustainable industrial production (including efficient energy chains)
- Sustainable Rijnmond (the energy-intensive industries, centred around Rotterdam)

complemented by a Policy Renewal programme (for a more effective policy process).

Each transition programme takes a participatory approach, co-ordinated and facilitated by the Ministry. It involves stakeholders working in public-private project teams, led by industry. These set medium term strategic goals (for a 20 year time frame), define 'transition paths' and design concrete experiments to be undertaken. It is based on a 'learning by doing' approach - undertake experiments; design learning goals into experiments, feed back lessons into subsequent measures.

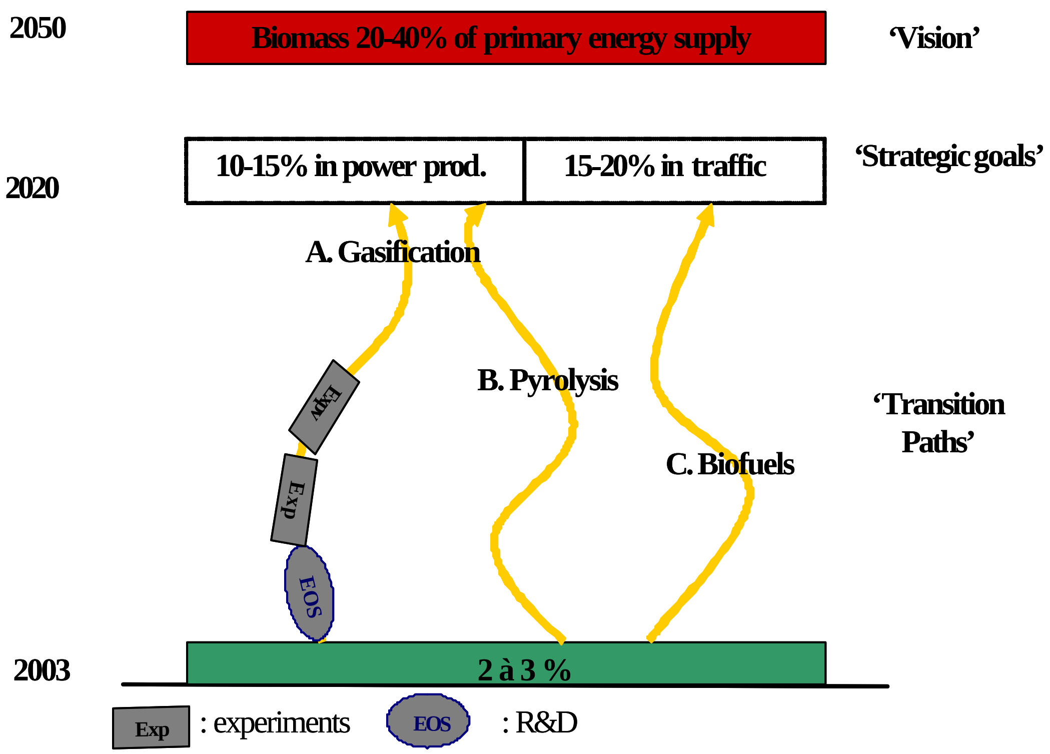
Policy Renewal

The policy renewal element of the programme aims to tear down barriers that obstruct an effective private-public partnership. Forging a clear commitment and consistent programme is seen as more important than financing developments. The key elements are

- *Commitment*: The Ministry of Economic Affairs must give clear priority to 'sustainability' as a guiding principle for socio-economic development.
- *Consistency*: Different departments must form one policy concerning future developments under the guidance of the Ministry of Economic Affairs.
- *Reliability*: Regulations, agreements and policies on which (long-term) plans are based must not be amended without notice.
- *Brokers*: The Ministry should broker the formation of coalitions between parties relevant to the transition.

This approach is being put into practice by allowing 'room for experiments'; enabling allocation of public funds for 'unique opportunities'; encouraging the setting up of 'service points', to ensure co-operation within the bureaucracy; and facilitating R&D in support of transition paths.

Transition Paths
For each transition programme, e.g. biomass, a vision for 2050 and strategic goals for 2020 are agreed. Potential transition paths to reach these goals from the current position are then formulated. Where additional R&D is required, this is being undertaken under the EOS programme. An initial set of experiments is now being agreed, so that the first set of experiments will be undertaken in 2004.



Transition Experiments
Transition experiments form the first steps along a transition path. They require the commitment of participants. A key feature is the formation of learning goals, such as

- What are the optimal circumstances for application of this technology?
- Will it meet with the approval of customers and stakeholders?
- What will be the appropriate institutional framework?

Targets of Transition Project by end of 2003
A number of targets have been set, so that the following will be achieved by end of 2003:

- Strategic goals formulated, shared by government, business partners and NGOs
- Clear and inspiring Transition Paths agreed
- 10 experiments prepared, ready to be started in 2004
- 'Room for experiments' created, by institutional change as necessary
- International links made
- Process know-how shared with others.

4.2. Coherence and continuity of policies

Within the context of a more strategic framework, it is important that the mix of policies provides coherence and continuity, with new measures augmenting and not disrupting existing measures. ***In particular, the policy mix should provide perseverance, i.e. that the range of measures is seen to be stable over a sufficiently long timeframe, in order to attract sustained investment.*** This point was emphasised in stakeholder interviews undertaken for the innovation systems review, and is reinforced by modelling work currently being undertaken by ICEPT as part of research for the Tyndall Centre for Climate Change. This modelling work shows that, under plausible assumptions, if policy support for non-carbon technologies is removed after too short a period of time, they fail to substitute for current carbon technologies. Conversely, relatively modest levels of support, maintained over a sufficient time scale, can stimulate learning and cost reductions, leading to significant levels of substitution (Anderson and Winne, 2003).

Continuity of policy measures across the innovation chain is also crucial. We discuss particular measures to overcome systems failures at particular points in Section 5, and what an idealised pattern of support across the stages of the chain may look like in Section 6. ***Here, we simply make the point that policy measures should effectively 'join up' across the different stages.*** An idealised picture is shown in Figure 4.1 (note that this is illustrative, it is not intended to advocate the specific instruments shown for any particular stage). A successfully performing technology would then be able to progress smoothly from the early stages to the final stage where it can compete without direct support (given, for example, a generally supportive environmental tax or trading scheme).

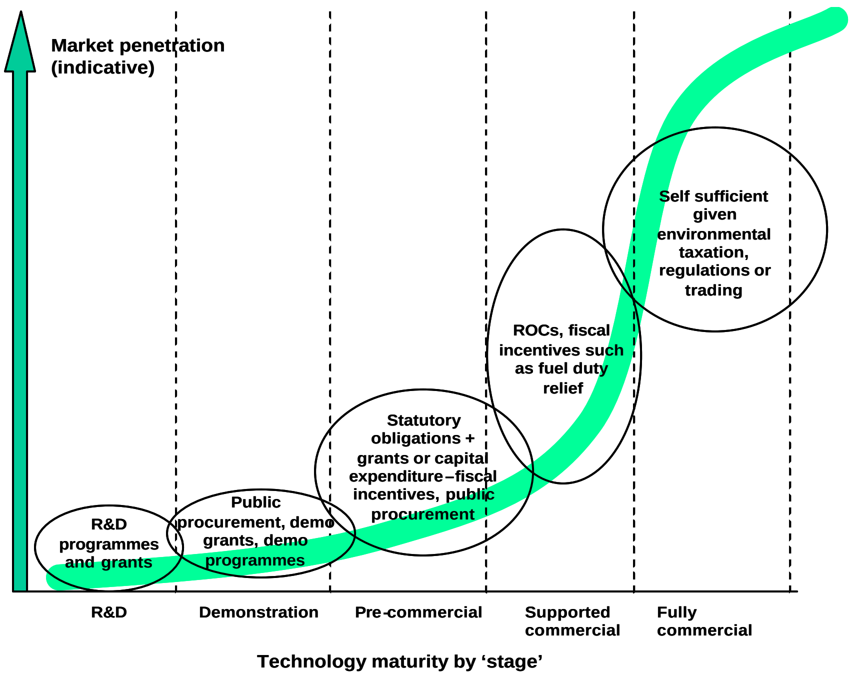


Figure 4.1. S curve of technological development and illustrative policy instruments

5. Systems failures: Problems, prospective solutions and policy issues

Key issues

This section addresses specific 'system failures' that hinder the progress of renewables along the innovation chain. Addressing these requires new measures and new funds, but new money is not sufficient alone, implementation should take account of the strategic aspects outlined in section 4, and improve flows of influence and knowledge within the innovation system.

- New measures are needed to address the gap between the demonstration and pre-commercial stage. Existing measures do not provide opportunities for small scale pre-commercial trials, so a new framework that creates a small niche market for technologies at this stage is needed. ***At the early pre-commercial stage, capital grants together with fixed premium tariffs would be most advantageous.***

- Linked policies are also needed to help technologies move from pre- to supported-commercial development. Existing grants for biomass and offshore wind are a good start, but funding is rather short term. ***A new programme of grants, available to all technologies that are close to competitiveness under the RO would be most advantageous.***

- Developers need clear expectations about the availability of support in the future, institutional arrangements must provide longevity. ***All measures should therefore be implemented by a new body, or added to the responsibilities of an existing body that has a clearly defined duration.***

- These changes would complement the RO, address early stage risks and assist new options to move into the RO. But a reconfiguration of the RO would not be needed and impacts on ROC prices would be minimal.

- Risky ventures will be more attractive to investors if rewards are high. Policymakers could improve long term risk-reward ratios by creating a framework for investments that encourages long term contracts. ***Extending the RO post 2010 would create larger potential rewards, for example, by making the a 20% aspiration for 2020 into a target under the RO. Where appropriate, for example in offshore wind, larger returns could also be encouraged through licensing larger projects.***

- So that developers have a clear view of the longer term and support is not sustained beyond the time at which it is needed, it is also important to develop exit strategies at all stages. Developing this requires stakeholder co-operation, to ensure that industry accepts and agrees to the changes.

5.1. Systems failures

The innovation systems review described how technologies make progress along the innovation chain, as a result of flows of funding, knowledge and influence between actors in the innovation system. There are two main drivers to progression of technologies along the innovation chain towards commercialisation: *technology push*, from R&D and early demonstration, and *market pull*, from expected consumer demand for products based on these technologies. These can be reinforced or inhibited by *feedbacks* between different stages and by the influence of *framework conditions*. Technologies currently at the early stages of development may need to progress to at least the pre-commercial stage and, in some cases to supported commercialisation, in order to be kept open as an option for the medium term. Equally, a technological 'option' is kept open, not just by it having reached a certain stage of development, but by it having a feasible path to commercialisation.

Historical analysis of the innovation process across a large number of industries shows that new technologies typically commercialise initially through small niche markets, in which experience is gained and cost reductions through learning can be made (see Utterback, 1994; Foxon, 2003). Market development is driven not just by price signals and expectation of profits, but also by the development of appropriate knowledge and skills bases, and the formation of institutional structures which support the emerging new technologies. These issues have been recognised in recent work by the International Energy Agency (IEA, 2003), which argues that policy initiatives designed to facilitate the adoption of cleaner energy technologies should combine three basic priorities: *investing in niche markets and technology learning*, *removing or reducing market barriers* and *facilitating market transformation*. The IEA recommendations, which echo many of the ideas put forward in this paper, are summarised in Box 4.

The innovation systems review identified two system failures or gaps - points at which UK renewables innovation systems are currently failing to move technologies along the chain. These are:

a. *Moving from demonstration to pre-commercialisation*:

There are obstacles to companies seeking to move from the first one or two demonstration projects to more substantial (though still small scale) levels of deployment. The incentives offered by generic measures, such as the Renewables Obligation, do not provide for investment in early stage technologies that are high risk, high cost and can only develop through small niches. Yet policy does not currently provide alternative measures by which such niches can emerge, allowing learning and experience to proceed.

b. *Moving from pre-commercialisation to supported commercialisation*

Several types of risk are hindering the large-scale deployment of pre-commercial technologies (such as offshore wind and biomass). Policies address these in part, but the rewards may not yet be strong enough to overcome the risks.

This Section describes potential solutions to each of these system failures, discussing the policy issues that surround each solution and what new institutional arrangements may be needed for policy delivery.

Box 4. Recommendations of IEA report on 'Creating Markets for Energy Technologies' (IEA, 2003)

Policy initiatives designed to facilitate the adoption of cleaner energy technologies should combine three basic priorities:

- Invest in niche markets and learning, in order to improve technology cost and performance;
- Remove or reduce barriers to market development that are based on instances of market failure;
- Use market transformation techniques that address stakeholders' concerns in adopting new technologies and help to overcome market inertia that can inhibit the take-up of new technologies.

Specific points, based on case studies for a number of technologies and countries, include:

- Deployment policy and programmes are critical for the rapid development of cleaner, more sustainable energy technologies and markets. While technology and market development is driven by the private sector, government has a key role to play in sending clear signals to the market about the public good outcomes it wishes to achieve.
- Programmes to assist in building new markets and transforming existing markets must engage stakeholders. Policy designers must understand the interests of those involved in the market concerned, and there must be clear and continuous two-way communication between policy designers and all stakeholders. This requires assignment of adequate priorities and resources for this function by governments wishing to develop successful deployment initiatives.
- Programmes must dare to set targets that take account of learning effects, i.e. go beyond what stakeholders consider is possible with present alternatives.
- The measures that make up a programme must be coherent and harmonised, both among themselves and with policies for industrial development, environmental control, taxation and other areas of government activity.
- Programmes should stimulate learning investments from private sources and contain procedures for phasing out government subsidies as technology improves and is adopted by the market.

The report concludes that it is the combined effect of technology potential and customer acceptance that makes an impact on markets and hence on energy systems. Developing a deeper understanding of both, including how they are influenced by government, is an essential ingredient of effective technology development and deployment policy.

5.2. Moving from demonstration to pre-commercial stage

5.2.1 Problems, prospective solutions and policy issues

UK innovation systems for renewables are failing to provide sufficient support for companies seeking to move from the first one or two demonstration projects to more substantial levels of deployment (though still small in scale relative to commercial stage deployment). One set of technologies for which this currently appears to be the case in the UK is wave and tidal. Because UK companies and research groups have been leading players in the early stages of development of wave and tidal stream technologies, and the UK has a large potential resource, improvements to the policy mix that help these technologies move into pre-commercial scale trials could help turn them into viable options for the long term. It would also help UK companies to develop a home market for these low carbon options technologies, which could have large export potential.

Wave and tidal are of particular interest at present, but the issues at stake apply more broadly. Historically, for other technologies, UK companies have left the market at this stage; whilst, in other countries, policies facilitated the development of successful new industries – most notably in the case of wind energy. This may have been an accident of history, but the evidence from the innovation system review suggests that that the problems currently facing wave and tidal are systemic rather than technology specific. Hence, it is likely that similar problems will also be faced by other technologies currently in the R&D and demonstration stages.

The innovation systems review identified three intersecting reasons for innovation systems failure at this stage:

- Financing available for first demonstration projects is insufficient to enable scaling up to the next stage. The incentive offered by near market measures such as the Renewables Obligation does not provide a sufficient level of support at a stage where returns are small, and risks and costs are large. Put another way – no small niche markets exist for pre-commercial trials, because existing renewables policies effectively 'miss' this stage.
- The skills needed for large-scale demonstration and early commercialisation may be different from the skills possessed by those involved in the R&D and first demonstration stages.
- There is a danger of perverse incentives that keep technologies at the R&D and first demonstration stages, as that is where public funding is available.

Policy action may target both the ways in which knowledge flow and influence affect the innovation system and the level and nature of funding available. System failures would not be overcome solely by additional funds. New funds (or some redirection of funding) are needed to provide for a small market niche that allows pre-commercial stage development. However, the way in which such measures are implemented is equally important – in particular, how they act to shape expectations and are complemented by other changes, such as institutional mechanisms.

5.2.2. Creating a niche market - new funding options

The main change that would help to overcome this failure would be to introduce new incentives for innovators and investors to experiment with larger scale deployment. Funds are needed for the early stage of pre-commercial development, and existing measures do not make provision for this. We provide an example of the scale of funding needed below (Section 6), but before doing this we provide an assessment of the means by which enhanced funding, that provides niche markets for early pre-commercial development, might be delivered.

There are two main mechanisms for delivering funds at this stage:

- ***Premium prices***: A special (high) premium level of price support could be made available for energy generated by such schemes. This could be delivered in three ways:

  1) A special band or tranche (capacity requirement) within the RO;
  2) A technology specific premium price over and above the ROC price;
  3) A fixed tariff 'mini feed in law' that supports a small amount of capacity[2].

- ***Dedicated capital grants***.

Enhanced ***international co-operation mechanisms*** and ***provision of 'soft' loans*** could play a complementary role.

These prospective solutions are each subject to a number of benefits and limitations, to which we now turn (see also summary table, below).

Premium prices

(1). *An early stage tranche within the RO*: This would have the benefit of providing dedicated support for options that cannot compete with more mature technologies. However, it has two types of problem – the first relates to the impact on the wider Obligation, the second to the nature of the support offered to developers:

- *It would disrupt the RO.* Dedicated tranches for early stage technologies would require additional mechanisms to be developed, since the existing RO arrangements are not amenable, in their current form, to providing such support. Changing this gives rise to political difficulties – since this would re-open the debate over 'banding' the Obligation, and would also partially undermine the stated objective of avoiding trying to 'pick winners'. More importantly to the renewables industry, changing the RO so soon after its introduction would give rise to a degree of regulatory uncertainty – a perception that the RO will be 'meddled with' frequently – which would impact upon ROC prices. This could have negative implications for investment in more

[2] Similar schemes are being offered for such technologies in some other countries, e.g. Portugal offers 20c/kWh for wave power, up to a total development of 20 MW, Ireland has a similar arrangement. There is experience in the UK too, there was a dedicated call for wave projects in Scotland under SRO3.

mature technologies eligible for RO support. Concern about regulatory rule-changing has already occurred in the case of the prospective change to co-firing rules.

- *Risks are not addressed*. All of the price risks associated with the ROCs (ROC market fluctuation, regulatory risk, electricity price fluctuations) would be unchanged. In addition, a band in the RO would have to provide a high level of support in order to assist developers overcome the technology risks associated with such early stage trials – this point is easiest to convey by comparison with capital grants; these directly support investment and hence some technology risk, whilst a band (and associated premium) are little use if a technology fails. For early stage technologies, this is particularly significant, since technology risks are particularly large, some failures are inevitable and can be useful by providing learning opportunities.

Overall, policy needs to consider the impact of a range of risks at this stage. It should provide support in a way that reduces the exposure of developers to some of the early stage risks, particularly those actually created by choice of policy instrument (such as ROC price risk). This solution does little to achieve this, and the level of support provided would therefore need to be higher (and more costly) than is the case for policy measures which can directly address an element of risk. This is not to suggest policymakers should seek to eliminate risk, nor that they need themselves to take a view on the level of risk in any specific project. However, policy choices do affect the 'risk framework' that developers face. We illustrate this further as we work through the remaining options below.

(2). *A premium on top of the ROC price*: Rather than provide a 'mini-obligation' or dedicated tranche of capacity, policies could be put in place that guarantee a premium on top of the ROC price to early stage technologies. Again, this would assist early stage options that cannot compete unaided in the ROC market. Unfortunately, this option shares most of the difficulties faced by a new pre-commercial band/tranche. It would reduce, but not eliminate, the impacts on other RO eligible technologies that we discuss in point 1) above. Again, the change could have a negative impact on expectations and perceptions of regulatory certainty since it would entail changes to the RO's 'rules'. Most important, from the perspective of the developer, risks are still not significantly changed. Whilst a premium rate would go some way to remove ROC price uncertainty for the early stage options, this risk would not be eliminated, since a proportion of price support would continue to depend upon the ROC market and electricity sales. Again, for the reasons discussed in point 1), this measure would not directly address technology risks.

(3). *A fixed tariff for early stage options*. This would provide premium price support that is entirely separate from the ROC market. It would take the form of a 'mini-feed in tariff'. This would provide a fixed price per kWh for specified types of renewables output, over a fixed timeframe, and for a given amount of capacity. It has two clear advantages:

- *Impacts on other RO eligible technologies would be minimal*, since there would be no introduction into the ROC market of a new category of technologies that receives special treatment, and hence no reason for ROC prices to change or become more uncertain. The scheme would be a complement to the RO, which would largely avoid the regulatory risk imposed by the perception of meddling with the RO. Indeed, it is possible to envisage such a scheme being run completely separately from the RO – a complementary programme that does not count towards to obligation target.

- *Early stage technology developers would be insulated entirely from ROC price risk*, and for this reason a fixed price scheme offers more advantages to developers than a dedicated tranche within the RO, or a premium payment on top of ROCs. As with all premium price schemes technology risks are not directly addressed.

The fixed tariff proposal could be the most cost effective of the three alternatives. This is because this proposal has the advantage of removing market and regulatory risks, we assess the impact of this by example in Section 6. However, no form of energy price support can directly address *technology* risks that are inherent to this stage, since even a secure price per kWh will not be beneficial if a project does not succeed. Because technology risks are high at this early stage, all three premium price cases would have to factor risks into the support offered. All would have to provide high enough levels of support per unit (kWh) to induce prospective developers to invest in the face of high technology risks.

For all these reasons, neither a new pre-commercial band in the RO, nor a premium paid on top of the RO seems likely to be the most appropriate mechanism to provide support at this stage. A fixed tariff reduces market/regulatory risk, complements the RO without causing disruption to it, and is the most advantageous price support mechanism to support early stage trials. However, no form of price support can address technology risk directly.

Capital grants

The above issues provide a good *prima facie* case for also targeting support towards capital expenditure. First, 'meddling' with the RO would not be required since a capital grant that provided for a small amount of early stage deployment would not require any changes to the RO.

Most important, capital grants change the *'risk framework'* faced by investors. Policymakers would not have to make detailed judgements about projects, since all projects meeting a given criteria would be eligible for grants (subject an appropriate total cap on spending). Some would fail, but to a degree that is desirable at this stage since it is part of the learning process. This is not to suggest that policymakers should micro-manage and make judgements on likely success or failure, nor that risks and rewards for those taking them should be eliminated. Developers must also be incentivised to take risks, improve technologies and succeed, so capital grants should never be the *only* form of support offered. They complement price support, particularly at the early stages, because the fact that *capital expenditure,* not just *energy price* is subsidised reduces the amount of early stage technology risk borne by developers – by supporting capital investment directly. Because these risks are directly addressed, a larger amount of investment can be supported at a more modest burden on consumers or taxpayers than if risks are covered solely through energy price. It can also be argued that, although the levels of support may need to be quite high on a per unit basis, because the installation levels at this stage are small, total costs (burdens) can remain modest.

Against all this, project failure may be essential to the learning process, but it could also give rise to political problems (tax payers backing losers). It is very important that the learning opportunities that individual failures offer at this stage are better understood – again, this is an issue that could be addressed through a more inclusive and strategic approach to policy development.

It is helpful that capital grants programmes already exist for some technologies, those for offshore wind offer support of around 10% of total costs. These could be extended to include earlier stage technologies, such as wave and tidal, if they provided a larger proportion of costs. It is important that support measures span the pre-commercial stage, providing a clear route through (and out of) this important step in technology development. However, the current capital grants depend upon direct state investment, with cash found every year or two through state spending rounds. A recurrent theme in this report is the importance of building positive expectations of future market support, in order to encourage innovation, but grants of this nature are subject to considerable political uncertainty. If Treasury priorities change, the grants are likely to be removed. This does not provide prospective innovators and investors with very much long term certainty; they cannot plan of the basis of capital grants being available in (for example) two or three years time, when they might expect their device to move out of the demonstration stage.

One way to tackle such uncertainty would be to create institutional arrangements and funding mechanisms that endure over time. Various alternative mechanisms are possible: a quasi-autonomous grant making body could be set up; funds could be channelled through long term government programmes (such as the DTI R&D programme); or existing bodies such as the Carbon Trust could be given additional responsibilities. Funds for such schemes might be raised through a 'capacity development charge', which we discuss in part 6. The second mechanism that would help overcome perceived short-termism would be to combine a capital grants programme with a premium price scheme of relatively long duration.

A capital grants scheme would be favourable for supporting early stage technologies, as it addresses technology risks directly. It could be complemented by a fixed tariff price support scheme, as discussed above.

Soft loans

A useful complement to the above would be to provide funding in the form of 'soft' loans, which are paid back as – or if – projects become successful. In this way, funds allocated to successful projects are recycled to the next generation of emerging alternatives.

International co-operation schemes

Another means to create a larger market for specific options would to develop a joint scheme that draws upon the incentives from several countries and combines them into a unified scheme. For example, the per kWh Portuguese and Irish support for wave power could be combined with a UK administered capital grants scheme. The benefits of such an approach would be to spread the burden of development over several countries and to combine the advantages of individual support schemes. In this example, the short term nature of UK capital grants would be partially offset by the greater certainty offered by the Portuguese and Irish schemes, whilst the provision of a measure of grant funding available would help ameliorate risk. Most of the issues that surround grants and premium prices remain relevant, and it would be beneficial if either new or existing institutions administered the funds, for reasons discussed above. However, this approach might also help to deliver the step to the deployment stage for a lower level of funding than otherwise, as the different schemes would effectively offer mutual leverage. However, the innovation systems review indicated that the SMEs active in the wave and tidal sector view EU R&D funding schemes with scepticism, largely because of the need for several partners and perceived bureaucracy. Any new scheme would need to adopt a 'one stop shop' and target specific projects, instead of forcing co-operation between developers.

Each of the options discussed above would be a major step forward if implemented with a clear strategy for support for technologies within, and in moving out of, the pre-commercial stage – which we consider in the next section.

Overall, the simplest and most effective means to create a small niche market to allow early stage technologies move into pre-commercial trials would be to combine a capital grants programme with a fixed premium price scheme. The premium prices would be independent of the RO, whilst the grants programme would need to be of clear duration, and institutionally insulated from short term swings in funding.

5.2.3. Removing R&D support after a cut off period

Improved incentives for larger scale deployment ought to encourage developers to move beyond the demonstration stage. However, in some cases, the nature of the support mechanisms available for RD&D, e.g. the grants available from the DTI's R&D programme, discourage this move forward. The reason for this is that companies undertaking development with support from DTI R&D programmes may find it easier to continue within an established mode of operation, working at a scale that they are familiar with, and within a secure policy environment. For this reason, it might prove helpful to indicate clearly that RD&D support will have a clear cut off date, beyond which further support will not be forthcoming. The strategic and consensus based approach described in Section 4 is important in this respect; companies need to understand the limitations on support available at a particular stage. More than this, it is important that developers and policy implementers develop an agreed programme of work that is clearly focused not just on successful development and demonstration, but also includes an agreed 'exit strategy' for support measures of this type.

5.2.4. Involving larger players

The involvement of larger players is likely to be desirable. The innovation systems review provided evidence that the absence of larger players may be associated with technologies that become 'stuck' at the RD&D stage. It is important to note that this is an issue for wave and tidal, and some biofuel technologies, but not for innovative PV, since here large companies such as BP, Siemens and Shell are already significant players. Small scale companies could be encouraged to seek support from more established concerns, and fora could be set up to facilitate this. However, the desirability of doing so is not necessarily clear. The PV sector experience suggests that acquisition of start ups will proceed if expectations about the technology are large, or if high value niche markets already exist. Moreover, there is little evidence to suggest that acquisitions of this nature are essential for the development of new industries. The experience of other countries suggests that there may also be scope for organic growth and development of firms – several Danish wind turbine manufacturers provide a case in point. As a result, it is important that policymakers are not overly prescriptive or interventionist. The most important policy actions are those that shape the incentives described above, such that larger scale deployment is encouraged, and perverse incentives phased out. Policy can also influence risk/reward ratios. One reason that larger players show little interest in demonstration stage technologies is that the scale of prospective rewards is modest compared to those in the markets typically occupied by established players in the energy industry. We discuss this issue in more detail below.

Overall, it appears difficult to envisage measures to explicitly encourage larger players to move into early pre-commercial development without embroiling policymakers in excessive and overly prescriptive micro-management. So, whilst the role of larger companies is an important consideration, it is one that should inform the way in which the substantive changes are taken forward, e.g. by involving larger energy companies in strategic policy development. Involving larger players is not particularly amenable to specific interventions, and so should not be pursued as an end in itself.

5.3. Moving from pre-commercial to supported commercial stage

5.3.1 Problems, prospective solution and policy issues

Supported commercial technologies are not the main subject of this report. However, the innovation systems review also identified systems failures that can impede the move from pre-commercial to supported commercialisation. Unless these failures are also addressed, the measures described above to improve the transition from demonstration to pre-commercialisation will be of little benefit - technologies might make progress into the pre-commercial stage, yet then become 'stuck' again a little further along the 'chain'. As discussed in Section 5.1, for a technology to be an 'option' requires it to have a feasible path to commercialisation. If prospective developers perceive that their technologies are unlikely to move effectively beyond the pre-commercial stage because of further policy-related systems failures, then investment could not be encouraged. Again, we can see that *expectations* of future potential play an important role in encouraging investment at the early stages of innovation. The gaps identified at the pre-commercial to supported-commercial stage are therefore discussed here, with reference to the importance of joining up measures that target this stage with those for early pre-commercial development considered above.

The innovation systems review indicated that numerous real and perceived risks are preventing pre-commercial technologies from large-scale deployment, as the rewards of large-scale deployment are not perceived to be strong enough to overcome these risks:

- The 'technology risk' inherent in the development to large-scale of any relatively new technology, as to whether it will achieve expected performance levels, efficiency improvements and cost reductions.
- The 'market risk' if the technology is being brought forward by a market-based instrument, such as ROCs, relating to the uncertainty of future levels of reward.
- The 'regulatory risk', since markets are created by policy mechanisms, which are subject to changes in policy priorities and changes in government.
- Additional 'systems risks' for those disruptive technologies, such as biomass, hydrogen and CHP, which require large changes to existing technological and/or institutional systems.

Regulatory risk and strategic policy
Some of these risks can be directly addressed by policy – we consider the options below. We argue throughout this report that the greater the confidence investors have in the stability and security of the policy environment, the better. We argued in Section 4 that a shared vision of the strategic development of both policies and technologies is one way to enhance expectations of regulatory certainty. Another way of putting this is that perceived regulatory risk can be reduced if industry and investors feel that they have some ownership of policy development, and feel confident that the rules will not be changed without consultation. Whilst this approach cannot remove regulatory risk altogether, it is likely to reduce it considerably, and this underpins the more detailed policy changes discussed below.

5.3.2. Sustained funding for moving from pre-commercial to supported commercial
The pre-commercial stage is rather broad – technologies that are entering this stage have markedly different levels of maturity and technological risk than those that are moving out of it. At the moment, the UK has measures in place to support two important technologies – offshore wind and biomass energy crops - that are in transition from pre-commercial to supported commercial development. These take the form of dedicated capital grants. There is some debate, at present, over whether the amounts of funding available are adequate for the purpose for which they are intended. We do not propose to comment on this issue since it is dealt with in other work. However, for the reasons discussed above, one of the main failings of these existing measures is their perceived short term and uncertain nature – the capital grants schemes appear rather ad hoc, introduced exclusively to support two specific technologies in the short term and with no clear arrangements to sustain this support. Instead of strategic policy developed in consultation with industry, there are only short term 'fixes' that appear to owe little to an objective assessment of technology needs. This has two aspects. Firstly, the grants are

dependent upon spending round competition in order to secure continued funding. Provision of capital grants for the second round of offshore wind sites is not certain, for example. Secondly, there is no commitment to maintaining similar arrangements for subsequent generations of technologies – such as wave and tidal devices in five years time.

It would help to provide confidence and security if the existing arrangements to provide capital grants for offshore wind and biomass were to be integrated with the arrangements proposed above for demonstration technologies moving into the pre-commercial stage. In all cases, the longevity and security of measures would be greatly enhanced if they were administered in such a way that funds are committed over longer term timeframes, and less dependent on the short term priorities of each spending round. So that it is clear that technologies cannot expect support under such arrangements indefinitely, a clear 'exit strategy' needs to be in place for determining how much support is needed, and for how long. Again, it is important that industry understands and accepts the timeframe for support, the criteria by which it will be supplied and, importantly, removed.

Capital grants or premium prices?

As we have seen for the early pre-commercial stage, it is possible to envisage support taking the form of both premium prices and/or capital grant. Again, each has a number of pros and cons, and the issues discussed above are equally relevant to technologies at a more advanced stage of development. Excessive 'meddling' with the RO needs to be avoided, and so measures should be sought that complement the RO rather than those that appear to undermine the principles upon which it was established.

For these reasons, it is reasonable to consider both an enhanced programme of capital grants and a new system of fixed tariff payments – either on top of ROCs or instead of them.

Capital grants have the advantage of building on existing arrangements and explicitly addressing a proportion of technology risk. Since technologies at this stage are better established, technology risks are rather lower than for the early pre-commercial options, and we would expect that the proportion of costs to be subsidised would be smaller. The exact amount of grant offered would have to differ by technology, since characteristics differ. However it is important that grants are provided as a generic stepping stone from one innovation stage to the next, rather than as ad hoc 'bail outs' of individual technologies. Thus, as one option moves on and eligibility is removed (as we would hope to see in due course for offshore wind), funding can be redirected to the next emerging option

A fixed premium price also has advantages – removal of the market risk associated with ROCs is the most significant. However, complete removal of all such risks for technologies entering the supported commercial stage would send a rather perverse signal. If the competitive pressures associated with the ROC market are desirable for technologies at the supported commercial stage, then complete removal of these pressures from options moving into this stage might encourage premature developments. The best approach would be to provide a route into unsupported competition within the ROC market whilst accepting that some additional support may be needed to provide a bridge into this stage, in particular, to reduce technology risks at the early stages.

For these reasons, whilst either a modest fixed premium on top of ROCs or a system of capital grants could support technologies moving into the supported commercial stage, the latter have several important benefits: they are already in place for offshore wind and biomass, they do not conflict with the stated purpose of the RO to introduce competitive pressures that could drive down costs, and they directly address technology risks.

We therefore recommend that, in the transition from pre-commercial to supported commercial phase, the existing capital grants are replaced by a new scheme of grants that is funded over a clear and longer term time period and is made available as a generic measure for all technologies moving from one stage to the next. This does not mean all technologies will require equal levels of support, but the measure should be seen as a stepping stone for innovation, not ad hoc support for specific options. This should be clearly linked to the measures proposed for the early pre-commercial stage.

A more coherent system for supporting the step from pre-commercial to supported commercial development would greatly enhance the prospects for successfully moving technologies into the latter stage. However, since the rewards available at the supported commercial stage are potentially larger than those at the pre-commercial stage, there is an additional dimension, to which we now turn.

5.3.3. Technological risk and the risk/reward ratio

Technological risk is obviously not something that policies can, nor should, seek to entirely remove. Preparedness to take on and, through technical development, address technological risk is essential for innovation to make progress. However, a major driver of willingness to invest in the face of technological risk is the level of expected reward. The greater the potential return on investment in a risky project, the more attractive investment to overcome technical problems becomes. What is sometimes called the 'risk/reward ratio' provides us with a measure of this. Even high risk ventures can stimulate substantial private sector investment provided that the prospective returns are high enough.

There are two main means by which policy incentives can improve risk/reward ratios for project developers and investors. Firstly, by providing additional, and more structured funds – e.g. larger capital grants, with longer term and strategic direction, discussed above. Alternatively, there may also be scope for regulation to provide for much larger potential long term rewards, so that the private sector is prepared to bear a larger proportion of early stage risk. In unrelated work, icept has held discussions with energy industry executives about their perception of renewables. The comparison was drawn between the licensing process for North Sea oil and the bidding and licensing process for offshore wind. To paraphrase the words of one commentator, 'offshore wind is risky, but it is tiny and offers utility rates of return - it is therefore of little interest to the oil industry'. Oil exploration goes ahead in risky areas, but makes sense because (when the market is right) rates of return are particularly high – sometimes 30% or more. The North Sea licenses offered large and long-term revenue streams. By contrast, the first round of offshore wind development offered returns that were modest, once risks were factored in (scarcely break-even according to one investment banker), and the overall scale of each development – both absolute size of investment and the flow of returns – is very small by energy industry standards.

This is a slightly simplistic comparison, of course, since the vagaries of the oil market add a significant degree of market risk – arguably larger than that of the ROC market – but also have a profound affect on short term risk/reward ratios, giving rise to the well documented boom-bust nature of oil industry investment. In addition, wind energy is by its very nature diffuse, and perhaps less amenable to the provision of a large revenue stream from each development than (highly energy dense) oil wells. The wider systems that the two energy sources feed into are profoundly different too, since one generates electricity and the other provides fuels and a host of other products. We don't want to stretch the analogy too far, or to draw to much analysis out of anecdotes. Nevertheless, is it possible to imagine regulation and licensing processes for technologies like offshore wind, and in future for wave and tidal stream energy, which make these sectors attractive to *risk takers* who specialise in technology intense investments in a hostile environment?

Larger projects provide higher potential returns. One means to do this is to make the prospective energy yield of a given license, which means the geographical area, much larger. The DTI's consultation document on the next round of offshore wind development explicitly addresses this – much larger developments are envisaged than were allowed in the first round. This is to be welcomed, and we suggest that DTI commission further work on what could be done to enhance the attractiveness of offshore developments in particular by enabling much larger individual schemes (or single license holders of multiple schemes).

Longer term investment. The other main means by which the risk/reward ratio at the supported commercial stage could be improved would be if developers were better able to secure long term contracts for ROC sales. At present a number of issues are currently impeding this, and these will be dealt with in other work. However, many commentators suggest that extending the RO target beyond 10% in 2010 and making the 20% aspirational target for 2020 into a firm obligation would be of considerable benefit here. It would help ensure that ROC prices hold up after 2010 and hence increase investor confidence. Whilst detailed assessment of all the issues that surround this change are outside the scope of this paper, we do endorse it, since this too would help build positive expectations and hence benefit early stage technologies.

It is recommended that policymakers improve long term risk/reward ratios by creating a framework for investments that encourages long term contracts. Potential rewards

could be increased by making aspiration of 20% renewables by 2020 into a target under the Renewables Obligation. Where appropriate, for example in the case of offshore wind, larger returns could also be encouraged through licensing rules that encourage larger projects.

5.4. Exit strategies in the supported commercial stage

In addition to action to address the barriers between pre-commercial and supported commercial development, it is important that provision is made for technologies currently in the supported stage to move out of it – that is progress to the fully commercial stage where renewables and innovation specific policies are no longer required to ensure deployment. Clearly it would not be desirable for technologies that no longer require support to continue to receive it, since this would place an unnecessary burden on consumers, and give developers a windfall gain. However, this concept of progression is also important to the development of technologies entering the pre-commercial stage, because it can help to create the 'space' for new technologies to progress. If it is clear to all actors that (for example) new onshore wind developments will not receive ROCs after a certain cut off date, then development of other emerging options will benefit. Developers can expect that if their technology proceeds successfully into the supported commercial stage it will not have to compete for ROC related investment with options that are already a lot more mature.

The expectations and perceived perseverance of the policy environment continue to be of great importance; rewards from the full range of instruments must be seen to be stable over a sufficiently long time-frame. However this does not imply that each and every technology will be able to benefit from each and every measure for ever. Just as the pre-commercial capital subsidies that we advocate above must be seen to be time limited from the point of view of a specific technology type, so should the support offered by the RO. If this can be achieved then one of the most important criticisms of the RO will be overcome – that because it does not impose any technology 'bands' it effectively picks only today's lowest cost options, and is therefore unlikely to be an effective means by which to help create a range of new options.

5.4.1 Prospective solutions and policy issues

Developing an 'exit strategy' for technologies that are currently eligible for ROCs will not be uncontroversial or straightforward. Changes of this nature have the potential to damage the credibility of the RO, since investors might perceive additional regulatory uncertainties – how can they be sure that investments made now will not become unprofitable because of some future change to the rules? This is one reason for the recommendations made in section 4. Changes of this nature will need to be agreed upon with stakeholders rather than being imposed, and timelines for revision of the RO's eligibility rules need to be long enough to ensure that current investments are not adversely effected. A shared vision of the development path of all technologies needs to be developed between policymakers, the industry and those responsible for its regulation.

Technologies that exit the supported commercial stage may well remain more costly than the 'traditional' options if these options are able to externalise their damage costs. The final link in the chain of support required for an effective innovation system for low carbon and secure energy systems is a regulatory environment that ensures that all options bear the full weight of any external costs that they might otherwise give rise to. Industry, investors, the regulator and policymakers need to develop a shared understanding of this relationship between innovation policy – based on options theory and an understanding of innovation systems – and environmental policies – that ensure that social and environmental costs are reflected in the regulatory and fiscal regime.

However this point appears to remain contentious, especially among economists involved in regulatory matters. It is therefore important to stress that environmental policies and innovation policies are separate but coupled groups of instruments: The former deal with negative externalities of energy use, the latter with the *both* positive externalities of innovation itself—by reducing costs and creating options--*and* the reduction of the negative externalities. Hence the wider regulatory environment needs to work with the policy drivers behind support for renewables innovation.

Detailed treatment of this issue is outside the scope of this report. However the three fundamental points that must be addressed are as follows: Developing an exit strategy that eventually takes the most successful options out of the RO is essential. A shared understanding of this must be developed with the industry and the means by, and timelines over, which it is to be done must not introduce uncertainty into the ROC market. Finally, it is crucially dependent on the development of a regulatory environment that will reward the 'external' benefits of renewables that emerge from innovation support measures.

If new measures to promote development of early stage options are to succeed then the timeframe for support, criteria by which it will be both provided and withdrawn, and the mechanism by which technologies will move out of innovation support measures need to be more clearly defined. Exit strategies at each stage need to be developed.

5.5. System risks

A final category of uncertainty that was identified in the innovation systems review that can affect investment in early stage technology relates to the need to develop new infrastructure. Wave and tidal technologies offer the potential of large resources in areas remote from existing electricity grids; hydrogen delivery requires new infrastructure; and the potential of CHP would be enhanced if the UK had more extensive district heating networks. At present, the development of new infrastructure is far from assured, indeed we do not yet know what will be needed with any certainty. As a result, investment in these options may be discouraged. Whilst new infrastructure is not needed in order for options to emerge, and it would be premature for investment to begin now, expectations about the long term prospects for its development are likely to be of increasing importance to future investment. A variety of approaches can assist in this case:

technology ‘route mapping’ – the development of scenarios for development of new options (including infrastructure); action to develop standards and assess regulatory drivers and barriers; and complementary RD&D activity – in hydrogen storage or managing decentralised generation for example. There is little point in encouraging the development of new generation and conversion technologies if the system change that must accompany them does not proceed.

5.6. Summary analysis of prospective policy instruments

In this Section, we have analysed and, where appropriate, recommended a number of potential policy measures to improve the innovation system for early stage new and renewable technologies in the UK, to help provide options for helping to meet policy targets for 2020 and 2050. We have stressed that, to form an option, a technology must not only move beyond R&D and early demonstration to the pre-commercial and supported commercial stages, but also have a feasible path through to commercialisation.

Here, we provide a summary of the policy measures, and assess them according to criteria based on the discussions in the earlier Sections.

Assessment criteria

In order to provide a clear view of the relative merits of a number of different approaches we have developed a *decision matrix* that summarises the issues, and helps to identify the most promising approaches. This requires a view of two factors – the criteria by which new policies can be assessed, and the full range of measures available to tackle each problem.

Defining assessment criteria
A number of policy changes in the form of new measures and mechanisms have been identified in this Section 5. All of these measures are subject to a variety of advantages and problems. We identified a number of important pros and cons, and we now use these to develop criteria against which new measures may be judged. These are:

- *Efficacy and cost effectiveness* – evidence of efficacy in promoting innovation, either in this country or elsewhere, and the relative cost effectiveness;
- *Longevity and continuity* – because expectations are an important determinant of investment, measures and mechanisms that will continue to exist for a clearly defined time period are to be preferred;
- *Regulatory certainty and consistency* – measures should add to the functioning of innovation support measures viewed as a strategic whole, augmenting not disrupting existing measures;
- *Avoidance of excessive burdens on taxpayers, consumers or industry* – measures should consider the scale of the prospective burden on taxpayers and/or consumers, and avoid particularly burdensome new regulations on specific industries;
- *Risk sharing* – where possible measures should directly address technology and other risks that discourage investment, either by ameliorating risk or by increasing potential rewards for risk takers;
- *Learning from failure* – given that some technologies in the early stages of innovation will naturally fail to proceed to commercialisation, measures needs to create a space that allows for some failures and encourages learning from unsuccessful technologies.

The above is not a definitive list of policy evaluation criteria *per se*; (a variety of policy evaluation methodologies already exist that are routinely used by departments and the Treasury). These criteria pertain solely to innovation system issues. They allow us to present a systematic overview of the merits of the policy measures identified above.

The key recommendations made above are as follows:

- Introduce new measures to support pre-commercial trials
- Build on existing measures to support the move from pre-commercial trials to supported commercial deployment
- Improve the coherence of all measures that affect the demonstration, pre-commercial and move to supported commercial stage

In all cases we advocate a more strategic approach, and attention to improving the flows of knowledge and influence in the innovation system, particularly by building confidence and expectations. This entails a clearer definition of exit strategies at all stages, attention to risk reward ratios, and attention to wider system issues. However, a number of more specific changes are discussed, these are:

New measures to support early pre-commercial trials:
1. Band the Renewables Obligation
2. Introduce a premium payment on top of ROCs for pre-commercial technologies
3. Introduce a fixed 'feed in' tariff for pre-commercial technologies
4. Introduce new grants for pre-commercial technologies, administered by a new body, or by extending the remit and funding available to existing bodies in this area
5. Soft loans for pre-commercial technologies
6. International collaboration to develop a joint scheme with other countries

New measures to support the move to supported commercial development:
1. Band the Renewables Obligation
2. Introduce a premium payment on top of ROCs for early supported commercial deployment
3. Introduce a fixed 'feed in' tariff for early supported commercial deployment
4. Extent the existing capital grants scheme to make it available to a wider range of technology, administered by a new body, or by extending the remit and funding available to existing bodies in this area

The advantages and disadvantages of each measure are summarised in Matrix 1, below, and evaluated systematically against our key criteria in Matrix 2.

Measure	*Main advantages*	*Main problems*
Banded RO (for both pre-commercial and early supported commercial development)	• Market based incentive, existing funding stream • Could be structured to offer long term signal	• Introduces uncertainty elsewhere in system due to RO 'meddling' • Undermines the principles on which the RO was founded • High prices due to technology risk
Premium payment on top of ROCs (pre - commercial trials)	• Provides additional funds	• Does not fully address regulatory risk • Does not directly address technology risk • No current funding stream
Premium payment on top of ROCs (early stage of supported commercial)	• Assists move into full competition in RO by reducing, but not removing, regulatory risk	• No current funding stream • Does not directly address technology risk
Fixed feed in tariff (pre-commercial trials)	• Removes regulatory risks associated with RO • Long term signal • Clear evidence of efficacy from other countries' experience • Complements RO but does not impact significantly on ROC prices or introduce uncertainty	• No current funding stream • Does not directly address technology risk
Fixed feed in tariff (early supported commercial)	• Long term signal • Clear evidence of efficacy from other countries' experience	• No current funding stream • Does not assist technologies with move into full RO competition – complete removal from RO market risk may not be desirable at this stage • May impact negatively on ROC prices and be perceived as 'meddling' with RO
Capital grants (scheme for both pre-commercial and early supported commercial)	• Reduces share of technology risks borne by developers • Allows for learning from failure • Complements RO but does not impact significantly on ROC prices or introduce uncertainty	• Politically determined each year, uncertain longevity, competition with other Treasury priorities could introduce political difficulties.
New institution to administer new capital grants Extend remit of existing bodies to administer new capital grants scheme	• Long term signal of intent • Advantages of capital grants, as above • Long term signal of intent • Advantages of capital grants, as above	• Additional bureaucracy and hence costs • Proliferation of bodies and undermining of existing institutions • Delayed implementation as time required to set up • Stretches competencies of existing bodies

Matrix 1. Advantages and problems of policy measures

Measure	*Cost effectiveness and efficacy*	*Risk sharing*	*Regulatory consistency*	*Avoidance of burdens*	*Longevity*	*Learning from failure*
Banded RO	?				✓	
Premium on top of ROCs (pre-commercial)	?		✓		✓	
Premium on top of ROCs (supported commercial)	✓	✓			✓	
Feed in tariff (pre-commercial)	✓	✓/?	✓	✓	✓	
Feed in tariff (supported commercial)	?	?			✓	
Extend capital grants	✓	✓	✓	?		✓
New institution making grants	✓	✓		?	✓	✓
Extend remit of existing institution to provide grants	✓	✓	✓/?	?	✓	✓

Matrix 2. Policy measures assessed against criteria

6. Scale and sources of funding for new measures

Key issues

This section considers the level of funding currently available at each stage of the innovation cycle, and provides an indication of what an idealised system of support might look like. It also estimates the cost of a hypothetical scheme to provide a niche market for pre-commercial trials, based on wave and tidal stream technology costs. Finally we assess the mechanisms by which new funds could be found.

- Assessment of the UK's current policy mix clearly indicates the funding 'gap' at the early pre-commercial stage. No measures provide support at this point in the innovation cycle.
- Assessing the 'right' amount of support at each stage requires more empirical work, including an assessment of the success of policies in other countries. However, we provide a view of the shape of an idealised curve that plots total spend against technology stage. Funding levels through RD&D and pre-commercial development are of a similar magnitude, but increase substantially at supported commercial stage. Costs per unit are high in the early stages, but installed capacity is very small, whilst much larger numbers of units need to be installed in the supported commercial stage.
- This is borne out by rough costing of a pre-commercial programme for wave and tidal. Its costs, of around £50m, are similar to current funding for offshore wind capital grants and the Carbon Trust and DTI RD&D programmes.
- This case study also indicates that a combined programme of capital grants and a fixed premium 'mini-feed in tariff' could be the least cost means to provide a small niche market at the beginning of pre-commercial development.
- The basis for support will change by stage: from full public grants for basic R&D to regulated transfers – such as the RO – that do not draw upon the public purse at all. At the intermediate stages a combined approach is needed.
- New funds can be raised in a number of ways. The new measures we advocate would not redirect RO revenues.
- The potential for a capacity development charge hypothecated to the long-term development of the energy system is investigated. It is argued that this would bring about a better reconciliation of aim of 'minimising costs to consumers' with the longer-term goals of UK energy policy, set out in the White Paper.

6.1. Present and idealised level of funding by stages

At the moment the UK's support at different stages of the innovation system for new and renewable energy is rather piecemeal. The picture is complex since a range of bodies and programmes provide support under a number of different headings, some of which overlap. We provide an illustration of the current situation in terms of both public subsidy and support that is provided through measures such as the RO that effectively redirect, or mandate, private sector investment (Figure 6.1).

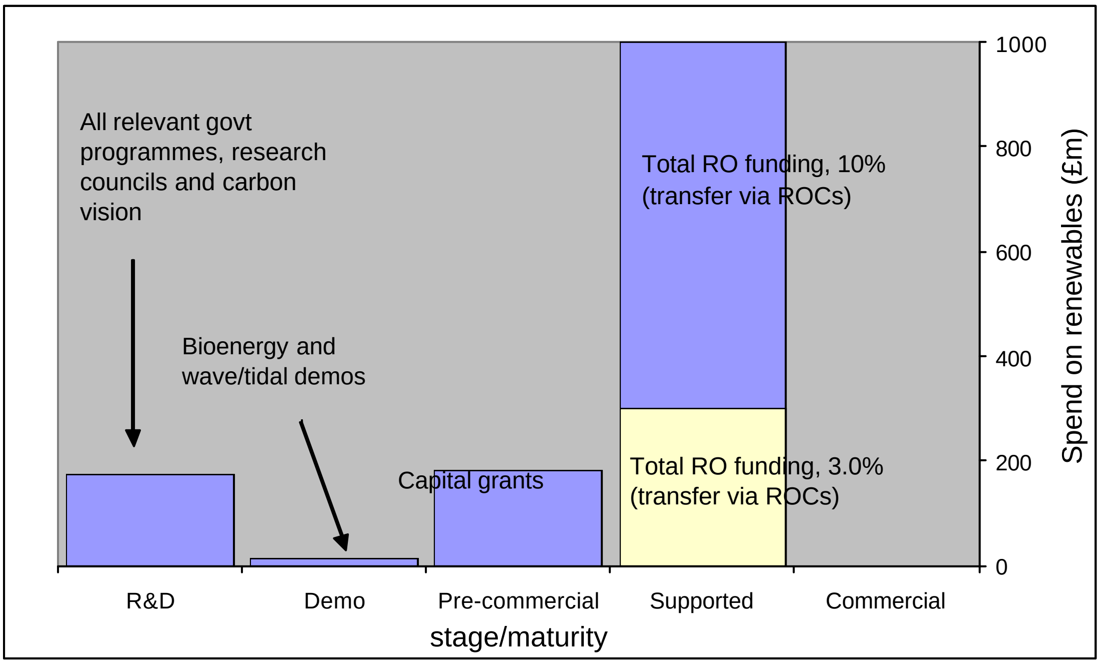


Figure 6.1. – Current support by stage of the UK NRE innovation system

Note that in all graphs showing current expenditure RO funding is representative of the additional revenue that accrues to renewables generation under the RO, it is not direct state spend. We assume generation of ~38 TWh for 10%, and ~12 TWh at 3%. In both cases the level of revenue depicted is based on the assumption that ROCs trade at 3 p/kWh. Note also that all graphs are indicative sketches rather than an accurate plotting of expenditures.

We argue above that the innovation system, and hence support for innovation needs to be seen as a continuum, and we represent this by means of a curve that fits existing arrangements (Figure 6.2).

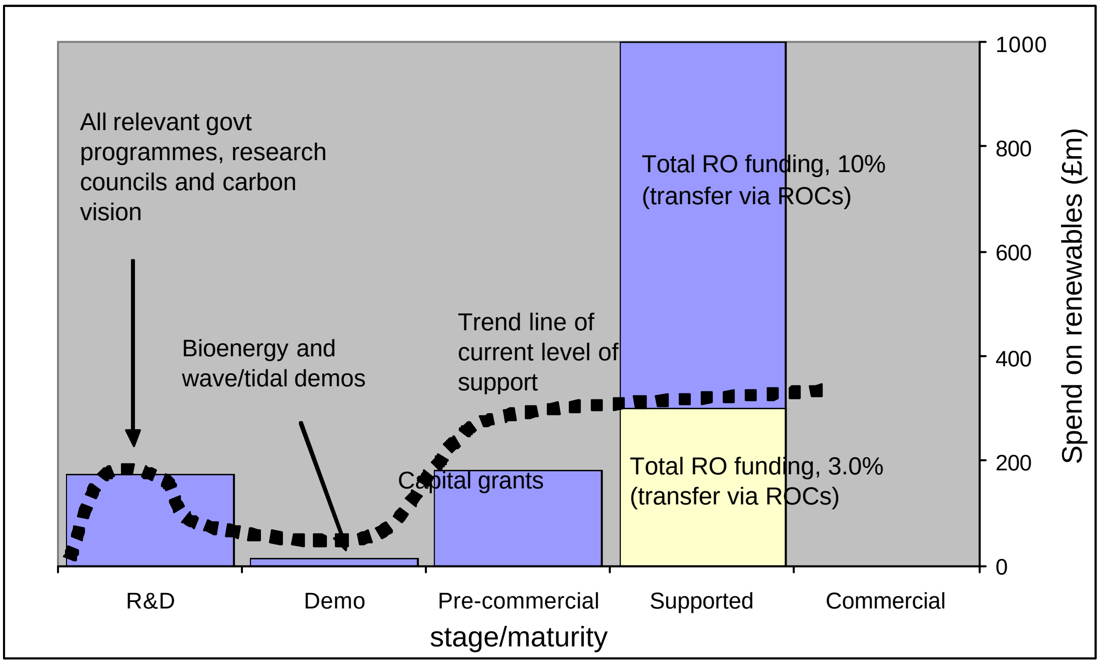


Figure 6.2. Curve of spending that spans the stages of the UK NRE innovation system (current spend is shown in curve – excludes spend if 10% target is reached)

Given enough empirical data – gathered from other countries and sectors, and analysed against some objective criteria that allows us to estimate when the costs of investment at each stage are outweighed by the benefits – it would be possible to define an idealised form for this curve. Obviously this is subject to a great many uncertainties and intangibles, so it would not be possible to define the curve with great accuracy. However, we can try to develop a rough indication of the scale of support that ought to be provided at each stage. The illustrations below (Figures 6.3 and 6.4) illustrate a closer to ideal pattern across the different types of support.

The reasoning behind this is as follows: R&D activity requires that a large range of options are supported directly. Costs per unit are very high indeed in some cases, but the number and size of units is usually very small. As we move through demonstration and pre-commercial development, the cost per unit declines, but the number and size of units increases. Finally, as we move into supported commercial development, we need to provide for a large amount of capacity, but with a very small amount of support on a per unit basis in comparison with the early stages. Note that as direct subsidy is reduced (shaded area), regulatory or tariff based support increases, before it too is phased out.

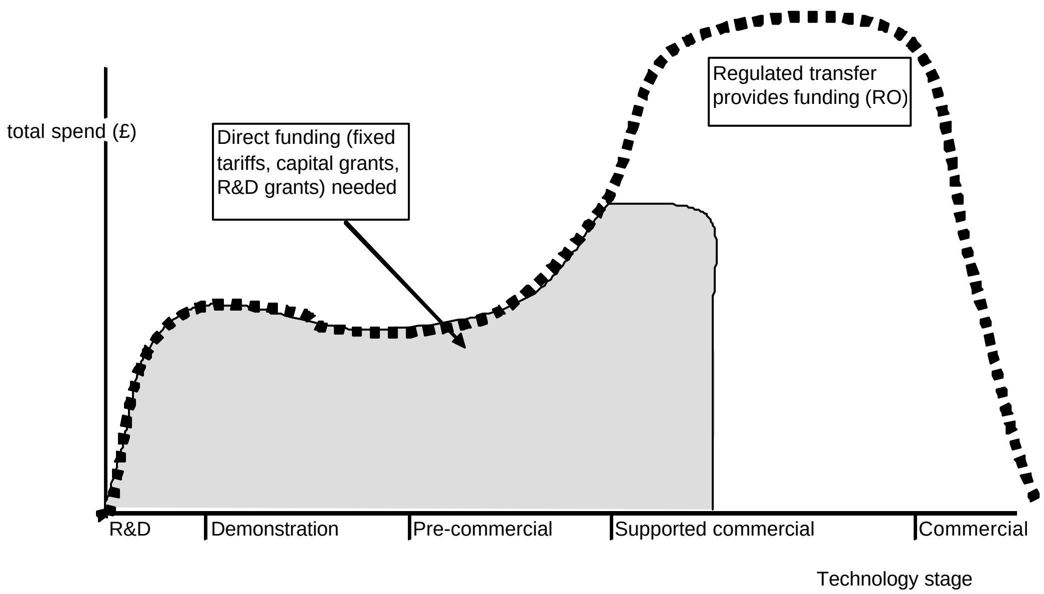


Figure 6.3. An idealised pattern of support

The above figure is only indicative, and is provided here to stimulate debate and to illustrate a concept; it is not based on detailed empirical evidence and is not intended to be prescriptive. However, analysis of spending in countries that have succeeded in developing new renewable options could allow for construction of a 'real' curve and this would allow comparative assessment of the UK position, and what has been typical in other countries.

We provide a concrete example of how much new funding might be needed below (section 6.2). In figure 6.4, this is superimposed over the current UK spend. We also reorient the position of the capital grants scheme in order to move us to a much more coherent arrangement. Our idealised trend line is shown in grey. This suggests that the changes advocated in this report would go some way to remediate the UK's current funding 'gap'. For the purpose of this illustration, we have left the trend line spend above that currently spent on R&D, demonstration and the pre-commercial scale, since UK R&D spend is low compared to most other OECD countries, and the UK currently spends very little on demonstration. In addition, the scheme that we describe and cost below would only deliver wave and tidal technologies – similar measures might be justified for other options. Detailed empirical work would be needed to establish whether the illustration reflects the scale of any actual gap.

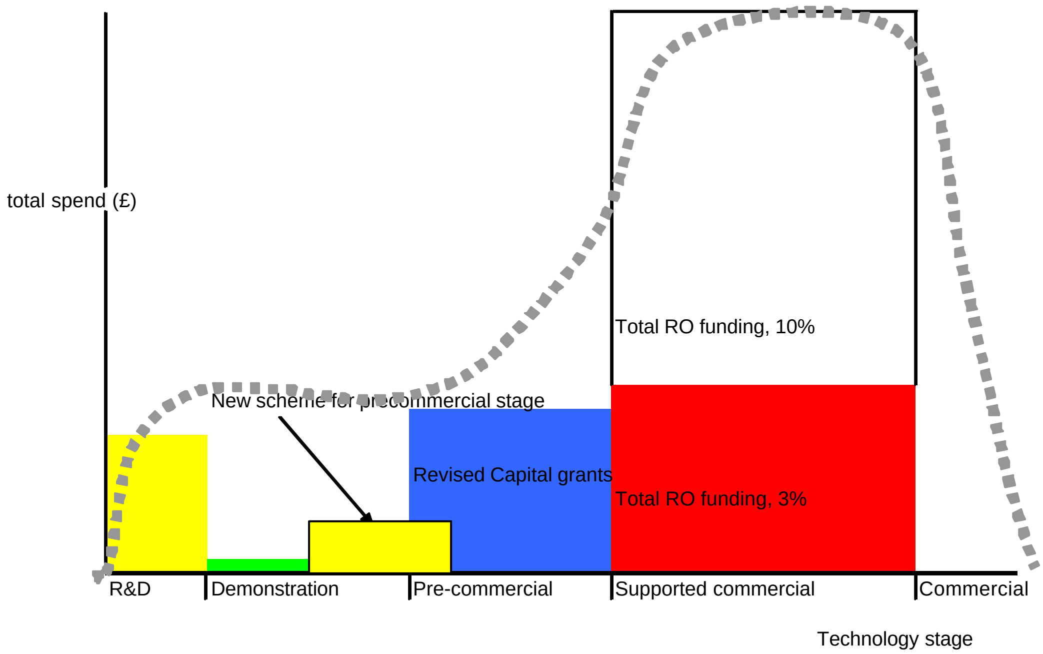


Figure 6.4. The UK spend adjusted to include a more integrated pre-commercial programme, with idealised trend line superimposed

6.2. Scale of funding needed at the pre-commercial stage

It is important to get a clearer picture of the scale of intervention that might be needed for technologies to enter the early pre-commercial stage. The precise needs of different technology options will differ, as their unit costs and characteristics (applications, small or large scale, electricity or fuels and so on) vary markedly. It is therefore helpful to consider a particular case of a type of technology that is currently at the demonstration stage and might be expected to move into pre-commercial deployment over the next few years. We provide below a worked example from the wave and tidal sector – one of the key UK options that is currently affected by the 'pre-commercial gap'

Whilst these estimates are very approximate, they indicate the order of magnitude required for intervention at this stage, for one round of development – around the £50 million mark. Timescales (would a 30 MW programme last for 1 year or 3?) and how many rounds of development would be required require greater elaboration. However, the comparison with the costs of existing programmes - £50m for the Carbon Trust, £19m pa for the DTI R&D programme and £100m for the offshore wind capital grants scheme – is interesting; 'plugging the gap' would require additional funds of a similar scale to those provided in existing capital funding schemes that target other parts of the innovation chain. We recommend that the DTI commission or undertake a more thorough study that attempts to ascertain projected costs more accurately, gathers evidence about the impact of different measures on project finance and runs sensitivity analysis on all of the variables dealt with here as assumptions.

Example of funding needed for wave and tidal pre-commercial scheme

What would it take to go from the first wave of demonstration schemes – a handful of installations – to the first round of pre-commercial trial? How much would this cost? And does the type of policies used affect total cost? Whilst it is not possible for this study to provide a detailed assessment of this issue, it is possible to provide some rough estimates that allow us to get a sense of the order of magnitude involved.

One case in point is the UK wave and tidal stream sector. There are 4 or 5 different designs of wave and tidal devices currently being prepared for demonstration activity, most with support from the DTI's New and Renewable Energy Programme. These demonstration projects are typically each around 1 – 2 MW in size, and modular. For successfully demonstrated devices to move to pre-commercial deployment, it is likely to require perhaps 30MW of plant to be installed, since this would allow small multiples of the units currently being developed to be deployed. A reasonable assumption is that 3 devices prove successful, and that early pre-commercial deployment of each would require arrays of 10 MW each. What then, would be needed in terms of financial support for such a level of deployment to be realised? Whilst detailed costs of each project are commercially confidential, most developers project costs in the early stages of 5 – 8 p/kWh, if we assume a 33% load factor, this would suggest that capital costs lie in the range £2000 - £3000/kW.

However, it is reasonable to assume that for the very first pre-commercial installations, costs will be rather higher, since considerable technological uncertainties exist, most projects would be bespoke, and unforeseen costs are probable at this stage. As a result, costs of around £4000/kW, or around 10 p/kWh, for these early multiple units is a reasonable assumption[3]. If we assume that long term ROC prices are just above the buyout price, say 3.5 p/kWh, and also assume that long run wholesale electricity prices are 2.5 p/kWh, then support from the RO on top of electricity sales results in payments of around 6 p/kWh for renewables developers. Hence, there is a shortfall to be made up through either capital subsidies or premium prices. The table below provides an indication of the level of support needed, for both capital subsidy and two forms of premium price support if different policy measures give rise to a variation in the finance risk of a project. All costs are net of electricity sales and ROCs, since this is the level of support if no special measures were implemented.

The table considers three alternative funding mechanisms, based upon a number of assumptions about financing risks.

Alternative A takes the form of a premium price on top of ROCs, such that developers receive the market rate for ROCs, sell electricity output, but also qualify for an additional 'early stage options' payment. This is the highest risk option for developers, since they must bear the costs of risks inherent to both ROC market fluctuations and those

[3] We assume a cost of capital of 7% to 8% and that costs are amortised over 15 years.

associated with an early stage technology. This is reflected in the highest discount rate on project finance – in this case we assume 8%.

Alternative B takes the form of a fixed premium mini-feed-in (see 5.2.2) tariff, for all of the developer's output. This would remove the market risk associated with ROC and electricity market fluctuations. In this example reduced regulatory risk allows developers to secure a slightly lower discount rate – 7.5%. However, since there is no direct support of capital expenditure, exposure to technology risk is unchanged.

Alternative C takes the form of a capital grant together with a mini-feed-in tariff (as defined above). The capital grant is sufficient to bring energy costs down to close to the level required to compete with more established options in the ROC market and it underwrites a proportion of technology risk[4]. We also assume that rather than competing in the ROC market, early stage options receive a mini-feed in tariff. This is equal to the support available through the ROC market (here 6 p/kWh), but without the market risks. So this arrangement also ameliorates ROC price risk. With both forms of risk reduced, this case is lowest risk, and hence able to secure lowest discount rate – 7.0 %.

Alternative	Installed capacity (MW)	Costs/kW	Capital subsidy	Project costs for private financing	Total payment needed per MWh	Subsidy per kWh above nominal ROC price*	Net cost of support**
A	30	£4,000	£0	£120,000,000	£10.96	£4.96	£54,300,000
B	30	£4,000	£0	£120,000,000	£10.27	£4.27	£49,920,000
C	30	£4,000	£1,500	£75,000,000	£5.99	£0.00	£45,000,000

The difference in the cost of each support scheme reflects the assumptions made about financing of technology and regulatory risk. One investment banker that we spoke to suggested that capital subsidy of the order of 1/3 of a risky project would be likely to reduce the effective lending rate for a project by around ½% and we used this as an increment in the worked example above. But this remains a highly uncertain assumption. Moreover, in all cases costs are sensitive not just to discount rates, but also to load factors and amortisation periods, as well as capital cost – which in this example is itself hypothetical. This is just an illustrative example. We would like to stress that costs could increase by around 30% given more conservative discount rates. However we also believe that the capital cost estimate is cautious – costs could well turn out to be lower. Overall, it appears sensible to conclude two things:

- That the *order of magnitude* cost indicated above is broadly correct. On our assumptions costs are around £50m per round of development, but a range of perhaps up to £75m would seem sensible given all the assumption and uncertainty.
- Second, that policies that directly address both main forms of risk (ROC market and technology) actually reduce the burden on consumers or tax payers – by up to 20% in our example.

[4] Note that the impact on risk finance assumes that grants are bankable, this may not be the case if policy rules preclude it.

6.3. Sources of funds

The preceding analysis has identified significant funding gaps in the post R&D and pre-commercial phases of innovation; indeed separate studies have shown that the R&D phase itself is significantly underfunded. Whilst we do not argue that increased funding is the only thing that is needed, there is a need to consider possible sources of funds. As indicated above, the funding required should not be prohibitive

In the end, public funding must come from the consumers, industry or the general public, whether it is raised through particular levies or taxes, or through general taxation. A full discussion of these issues is beyond the scope of this report, but we consider here some of the possible sources of funds. There are at least four main alternatives:

1) Hypothecated levies
   - Climate Change Levy (on use of energy by business)
   - New charge (e.g. capacity development charge on peak generation)
2) Regulated transfers
   - Renewables Obligation revenues
   - Amendment to Obligation
3) Consumers
   - Green tariffs
4) General taxation

(1) Hypothecated levies

The hypothecation of revenues from a related levy, thereby transferring funds from 'bad' activities to 'good' activities, is becoming recognised as a way of achieving social benefits, whilst minimising adverse economic impacts. This principle has been applied in the context of the Climate Change Levy (CCL), levied on the use of energy by business and public services. In this case, the majority of the revenue was used to reduce employers' national insurance contributions, with the remaining funds, around £50 million for three years, hypothecated to low carbon innovation and energy efficiency promotion by the Carbon Trust. Further hypothecation of CCL revenues remains a potential source of funding for the capital grants schemes proposed above.

A second possible source of funds would be a levy aimed directly at the energy industry, which would be completely recycled to fund low carbon innovation and associated network development. Such a levy, referred to as a hypothecated capacity development charge would, in effect, represent a mandated transfer of resources from existing energy sources to the long-term development of the energy system (see Box 4).

(2) Regulated transfers

In principle, it would be possible to use some or all of the revenues raised by the Renewables Obligation, from the penalties levied on those suppliers who fail to meet the obligation in any year, as a direct source of funding for low carbon innovation. However, the current mechanism, whereby revenues are recycled to those suppliers who have met their obligation, is an integral part of the incentive structure associated with the RO, and a key factor influencing the market price of ROCs. ***Hence, we would not advocate tampering with this mechanism.***

(3) Green tariffs

Other countries, such as the Netherlands, have strongly promoted 'green tariffs', whereby consumers purchase electricity from suppliers, who either source directly from existing renewable sources or commit to spending an equivalent amount on the development of new renewable sources. In the UK, take up of green tariffs has so far been slow. The variety of types of such tariffs and, in some cases, the lack of transparency in terms of their relation to renewable sources may account for this, in part. A stronger message of government support for such tariffs and a clearer commitment to transparency between government and industry may then encourage a faster take up, leading to a more significant source of funds for low carbon innovation.

(4) General taxation

The long-term, public good benefits of low carbon energy sources could be used to justify a higher share of receipts from general taxation, though, in the light of increased pressures on the next government spending review, other commitments will almost certainly receive higher political priority.

Box 4. A hypothecated 'capacity development charge'

The current regulatory environment for electricity is heavily concerned with the short-run marginal costs and the minimisation of prices to today's consumers. The merit of this approach has been that it has led to cost efficiency and, at the same time, has introduced far more transparency in costs. It has also been an excellent vehicle for the full commercial application of well proven innovations, the outstanding example being the combined cycle gas turbine plant in the 1990s, which rested on massive infrastructure investments and R&D over the preceding decades. That is to say, it has been and remains ideal for technologies on the right hand side of the axis in figure 1—the final stage of the innovation cycle.

However, the approach is not forward looking. What we need is a regulatory arrangement which retains the unassailable merits of the policies that have evolved over the past decade, while recognising the importance of supporting technologies in the earlier phases of development. The ROCs are a step in this direction, but as discussed at length above do not reach back far enough into the innovation cycle—and have also left us with concerns as to the adequacy of the grid infrastructure to enable future innovations to take root.

A capacity development charge hypothecated to the long-term development of the energy system would bring about a better reconciliation of the short-term goals of the current arrangements with the longer-term goals of energy policy, as outlined in the Energy White Paper. There are several advantages:

1) There would be no call on Treasury resources, and the financial onus would be transferred to the industry and its consumers.
2) Possibly, no major reform of regulatory policy would be needed, only a requirement that Ofgem accepts that the long-run goals of capacity development, both of the grid, and of new technologies for electricity generation, are part of its remit. In short, it requires that the term 'minimising costs to consumers' is interpreted to mean minimising the present worth of the *social* costs likely to be faced by both today's and future consumers.
3) It could generate resources on the scale required. For example, a £5-10/kW charge on peak demand would generate roughly £250-500 million per year, sufficient to support a major programme of innovation and infrastructure development.

Related to this:

4) It would have appreciable leverage, and it would be a stable source of revenues. Experience with a range of national and international programmes suggests that carefully targeted public funds can leverage significant private funds.
5) The responsibilities would be devolved to those most familiar with the industry.

The *modus operandi* of such a policy evidently requires more analysis. One of our recommendations is for a study of this and other options for solving the financing problem we have outlined.

6.4. Summary analysis of funding source options

There are a number of potential sources of funds:

1. Direct subsidy from public expenditure.
2. New hypothecated levy.
3. Expand the contribution from the CCL.
4. Fund through the RO, but redirect/target funding to dedicated tranches/bands.

The advantages and problems of these, discussed in Section 6.2, are summarised in Matrix 6.1.

Source of funds	**Main advantages**	**Main problems**
Direct subsidy as per offshore wind and biomass grants	• Maintains existing arrangements and extends to new areas. Therefore simple, with no new institutions.	• Burdens increase if requires additional funds. • Potentially uncertain and short term. • Cross subsidy issues (falls on all taxpayers regardless of energy usage)
New hypothecated levy on energy	• Long term signal of intent, secure funding stream, 'polluters pay'	• Increases burden on consumers • Might require primary legislation • Who would administer?
Expand the contribution from the CCL	• Maintains existing arrangements for redirecting funds • Long term signal of intent, secure funding stream, 'polluters pay'	• Where to find the additional resource? • Other CCL funded activities could suffer
RO funds targeted to dedicated tranches	• Long term signal of intent, • Existing funding stream so no new burdens	• Would introduce uncertainty into RO arrangements and impact ROC price • Would undermine the principles upon which the RO was established

Matrix 6.1. Advantages and problems of funding source options

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