Phase 2: Exploring the relationship between environmental regulation and competitiveness

A research report completed for the Department for Environment, Food and Rural Affairs by SQW Consulting

August 2007

Phase 2: Exploring the relationshiop between environmental regulation and competitiveness

Final Report to the Department for Environment Food and Rural Affairs

August 2007

Suggested citation for this report:

White, G. and Parashar, U (2007) *Phase 2: Exploring the relationship between environmental regulation and competitiveness: A report to the Department for Environment, Food and Rural Affairs.* SQW Consulting. Defra, London.

SQWconsulting

3rd Floor
Corinthian House
279 Tottenham Court Road
London
W1T 7RJ

Contact:	Urvashi Parashar	Tel: 020 7307 7140	email: uparashar@sqw.co.uk

Approved by:	Geoff White Director	Date:	August 2007

TABLE OF CONTENTS

Executive Summary i

Review purpose i
Methods i
Analytical foundations ii
Aspects of regulatory form that prompt innovation and productivity v
Differential regulatory impacts between large firms and SMEs ix
The importance of context x
Regulatory design principles xi

1 Introducing the study purpose and method 1

Background to the study 1
Study objectives 2
Study method 2
The structure of the report 7

2 Laying the foundations: Key concepts and distinctions 13

Key concepts and distinctions 13
Competitiveness and innovation 13
Regulation and its defining characteristics 16
The context in which regulation is designed and implemented 19
The relationship between regulation and innovation/diffusion 20
Propositions to be tested 23

3 Reviewing the case studies: An overview 25

Key features of the six case studies 25
Findings from the case studies 26

4 Assessing the influence of regulatory form on innovation and competitiveness 38

Introduction 38
Technology diffusion – moving to the frontier 38
Technological innovation – moving the frontier 45
Other factors affecting diffusion and innovation 57
Other economic drivers 61
Concluding observations 62

5 Conclusions and policy design principles 65

Conclusions 65
Policy design principles 73

References 76

Executive Summary

Review purpose

1. SQW was commissioned in October 2006 to carry out a study to "gather and analyse evidence on the impact of the design of environmental regulation on competitiveness". Specifically, it was to consider:

   - the productivity impacts of different regulatory designs and to identify what forms of regulation were most likely to stimulate innovation;
   - the impact of the design and implementation of regulation on SMEs as compared to larger businesses;
   - the importance of context (i.e. business sectors and/or environmental policy areas) in determining positive economic as well as environmental outcomes from regulation.

Methods

2. There were three components to the review method:

   - The literature review of 2006 was up-dated with a specific focus on the treatment of innovation as a response to regulation and on the experience with case studies in order to inform the selection and conduct of the case studies for the review.
   - Two stakeholder workshops were held during the course of the study. The first was designed to inform the conclusions of the literature review and the proposed selection and conduct of the case studies. The second workshop was to provide a sounding board for the preliminary findings from, and policy implications of, the case studies.
   - A range of case studies was carried out reflecting experience in different sectors, technologies and countries with a variety of regulatory forms (Table 1).

Table 1: Case studies

- SO_2 and NO_x regime in the UK and in the USA and other EU countries to provide cross country comparisons of instrument choice and its impact on innovation.
- Extended Producer Responsibility (EPR) and the UK Packaging Waste Regulations to provide evidence on the links between regulation and innovation.
- Nitrates Directive to provide a comparison with other EU countries where the Directive has been fully implemented.
- IPPC to be reviewed for its effect on competitiveness and innovation with particular regard to the food and drink sector.
- Energy Labelling with particular reference to the EU Energy Labelling scheme to provide a cross-border comparison of regulatory design and its effect on competitiveness.
- Renewable Obligation (RO) regulation in the UK compared with the Renewable Energy Feed in Tariff (REFIT) regime in countries such as Germany and Denmark to assess the relative impact on the development of renewable technologies.
- The case studies were in a variable state of readiness for the purposes of the review – some needed little extra work (although still requiring consultations with stakeholders) whilst others required new work.

Analytical foundations

3. The following concepts were central in setting the study's analytical foundations.

- **Competitiveness**: The fundaments of competitiveness are in the efficiency with which resources are allocated and used at micro levels (i.e. within sectors, businesses and other organisations) and it is at this level that the consequences of regulation are most appropriately investigated. The productivity framework adopted by HMT/DTI specifies there to be four drivers of productivity (i.e. investment, enterprise, skills and competition) in addition to innovation. Regulation may have an effect on all five but our terms of reference required us to focus on innovation.

- **Regulatory form:** This refers to the way regulations are designed, the manner of their introduction and implementation and the way in which they are mixed with other regulations and interventions. The components of regulatory form that are important in influencing its effects on innovation and productivity are not confined to the choice of instrument (Table 2).

Table 2: Components of regulatory form

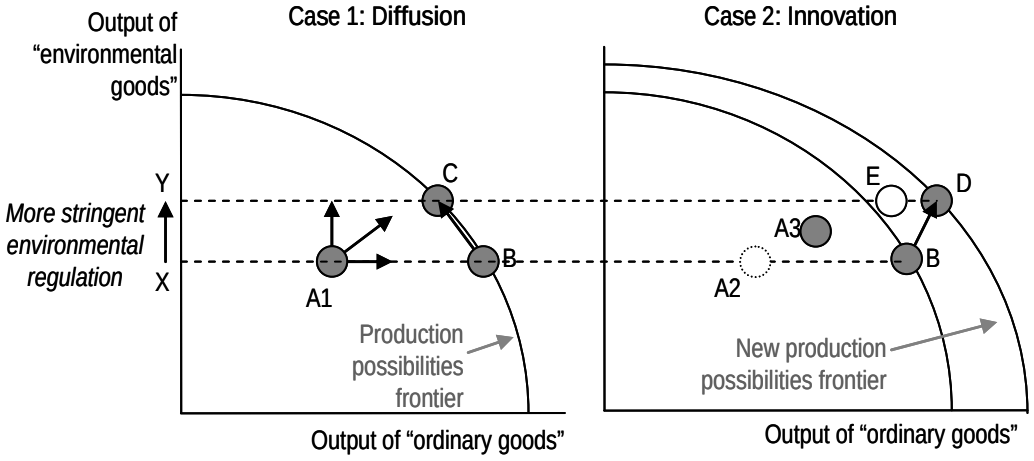
- **Policy purpose and design** will include:
  - *Policy stringency* relative to baselines of emissions and/or prevention or control methods/technologies
  - The extent to which the regulation is couched in terms of *desired outcomes* or *prescribed solutions*;
  - The degree to which the regulation provides for *certainty* of requirement and *flexibility* in meeting it;
  - *Instrument choice* which is often polarised between market based or command and control measures but can involve a wider set of options (including voluntary agreements); and
  - The *mix of measures* accompanying the regulation to support and enhance its purpose.
- **Policy implementation** refers to the processes by which a regulation is designed and introduced. It will include:
  - Provision of advance warning and prior notice to target businesses in the formulation of the regulation and its implementation and enforcement;
  - Engagement of the businesses in the design of the regulation and in increasing awareness of the most effective and efficient ways of achieving compliance;
  - Keeping to the consultation commitments and time-table to build trust between the regulated and regulator
- **Policy enforcement** - the process by which compliance with the regulation will be monitored and enforced and the resolution of the trade-off between, on the one hand, the need for intensive scrutiny of compliance processes and outcomes and, on the other, a more cooperative and learning process – sometimes expressed as a distinction between a sanctions and compliance approach

- **Innovation** is the "invention and application of new technologies, products and production processes" and contributes to improved efficiency through:
  - Direct productivity gains to the firms that invest in it to bring about improved efficiency in their products and/or processes;
  - Spill-over productivity gains when innovation assists firms to take advantage of other innovations; and
  - Spill-over productivity gains for other firms or sectors or regions that can emulate the innovation.
- There is a broad distinction between technological change (e.g. from investment in research and development – R&D) and diffusion (i.e. technological change being adopted or emulated by others either in the form of information/knowledge or embodied in goods or services). This

distinction is expressed for convenience in the report as being between *innovation* (the invention and application of new technologies) and *diffusion* (the adaptation and adoption of existing technologies).

4. The distinction plays a central role in the report and, following the review of the literature, was given the stylised depiction in Figure 1. It shows the production possibilities confronting a business as a trade-off between the production of 'ordinary goods' and non-traded 'environmental goods'. Environmental regulation will require businesses to generate a certain amount of environmental goods – to the value of X in the figure. Where regulation becomes more stringent, firms will have to increase their output of environmental goods (to value Y).

Figure 1: Innovation and diffusion responses to more stringent environmental regulation



Source: Adapted from DeCanio (1997)

5. In Case 1, the required increase in the output of environmental goods can only be achieved with an increase in the output of ordinary goods where firms (as at A1) are prompted to move towards the frontier through adoption of existing technologies – i.e. *diffusion*. Efficient firms, like those at B, can only increase their output of ordinary goods (and meet the more stringent environmental requirement) if their situation changes to Case 2 where there is an outward shift in the frontier through technological change and they can move to point D (rather than C in Case 1) – i.e. *innovation* rather than *diffusion*.

6. There are three other effects potentially beneficial to productivity that might occur in Case 2 – inefficient firms might be forced to exit (like those at A2),

firms might be pulled up the supply chain towards the frontier by their prime contractors (as at A3), and/or the new frontier might prompt new entrants (as at E). On the face of it, any beneficial effects on productivity and competitiveness are most likely to be induced if the regulatory form induces technological change in the production possibilities. However, diffusion could also play a significant role where there are a large number of businesses that are located within the existing production possibilities frontier – these will tend to be the smaller firms.

7. Three basic propositions were drawn from the above and tested through the case studies:

- **Moving to the frontier –** Regulatory form can prompt faster and more extensive diffusion of existing technologies and enable firms to move towards the prevailing production possibilities frontier.
- **Moving the frontier –** Regulatory form can provoke an outward shift in the production possibilities frontier by stimulating innovation, enabling firms to shift to new technological trajectories, reinforcing competitive pressures on less efficient firms and encouraging new entries.
- **Shaping regulation** – Regulations can be shaped to achieve both 'moving to the frontier' *and* 'moving the frontier' outcomes, but it is likely that a policy trade-off between the two will be necessary and regulation configured according to the resolution of the trade-off – consistently with the desired environmental outcomes.

Aspects of regulatory form that prompt innovation and productivity

8. The key features of regulations exercising an influence on innovation and productivity are set out in Table 2 in a way which shows how the influence is most likely to be positive.

Table 3: Aspects of regulatory form most likely to influence competitiveness positively

Regulatory purpose	• Clarity in the definition by the policy-makers of the environmental problem to be addressed and the metrics used to specify it. • Precision with which the relative scale or stringency of the regulatory requirement is specified compared with the current situation and current practices/standards – incremental or radical change? • Awareness of the extent to which the regulatory purpose and intended stringency are shared by competing countries and the degree to which there is likely to be a 'level playing field'.
Context	• Acknowledgement by the policy-makers of the different contexts in which the regulation will be applied – a tailored as compared with a 'one-size fits all' approach. • Assessment of market structure and demand characteristics, the technologies available or in prospect to deal with the environmental issue and the constraints on their development and diffusion, and the incentives to which market and technology players may be expected to respond. • Recognition of the complementarity or otherwise of existing or planned policy measures with regard to the relevant markets and technologies.
Instrument choice and mix of measures	• Preference given to market related Instruments and other forms of regulation (e.g. self-regulation, voluntary agreements and 'informational regulation') rather than 'command and control' mechanisms. • Articulation of the means for achieving the regulatory purpose in terms of 'pollution prevention' and recycling/re-use wherever possible rather than pollution control through treatment and disposal. • Introduction of complementary measures designed to reinforce the anticipated effects of the chosen instrument – e.g. R&D support, information provision and public procurement practices
Other aspects of regulatory design	• Preference given to 'outcome forcing' regulations rather than 'solution forcing' (e.g. specific technologies or practices) – providing flexibility for regulated firms (especially larger firms) to find their own solutions.

Table 3: Aspects of regulatory form most likely to influence competitiveness positively

Implementation	• Commitment to the regulatory form and requirements over the long term where radical innovation is needed – building in 'technology escalators' for periodic up-dating and, where possible, giving advantages to 'first-movers'. • Minimising the cost burden of the regulation both to the regulator and the regulated taking account of resource as well as administrative costs – e.g. the public sector costs associated with setting price guarantees. • Advance warning and prior notice given to target businesses both in the formulation of the regulation and in its implementation. • Engagement of the target businesses in the design of the regulation – looking for ways in which they can buy into the regulation through some degree of self-regulation/voluntary agreements/information provision. • Keeping to the consultation commitments and time-table to develop trust between the regulated and the regulator and to secure a compliant rather than a sanctions based approach to the enforcement of the regulation.
Enforcement	• Clear demonstration of the monitoring and enforcement process so that all parties are clear about compliance requirements, sanctions and penalties. • Trade-off made between, on the one hand, need for intensive scrutiny of compliance processes and outcomes where stakes and risks are high and, on the other, more co-operative, capacity building and learning processes.

Innovation and diffusion

9. Some factors are unequivocally important in providing the necessary conditions for inducing both diffusion *and* innovation by means of regulation. The most important ones are:

- the clarity, ambition and determination of the regulating bodies to increase pollution prevention requirements;
- use of a hybrid of instruments involving development of the relevant markets; and

- combination of certainty with regard to the desired environmental outcomes and flexibility in getting there.

10. The emphasis on pollution prevention is deliberate because the alternative of pollution control, treatment and disposal tends to prompt the adoption of 'end-of-pipe' solutions often with adverse effects on productivity and competitiveness. This should not be taken to mean that the combination of 'command and control' instruments and pollution control has not had major environmental benefits in the past. But, our reading of the evidence is that it is less likely to generate competitiveness outcomes, can 'force' inefficient technologies to be adopted and may involve high resource costs.

Innovation or diffusion

11. Some of the aspects of regulatory form are more important when it comes to inducing innovation as compared with diffusion. The key distinctions are, in our view, as follows:

- **Long time-scales**: The regulatory form that encourages *innovation* will need to be designed to offer a long time horizon to induce the private sector to carry out investments that will have an impact often some considerable time in the future. By contrast, regulations that stimulate *diffusion* need to work in the 'here and now' and can be expected to have their beneficial effects in the short term.

- **Flexibility of response**: Regulation will be more likely to promote *innovation* where it allows firms the flexibility to explore and develop their own solutions to meeting the regulatory requirement – hence, the preference for performance (outcome forcing) standards. This flexibility is also more likely to prompt *diffusion* of cleaner technologies and pollution prevention. However, whilst diffusion of end-of-pipe technologies may not offer as much by way of productivity gains, it might be effective and cost-effective in securing environmental outcomes quickly. It may also be preferred by businesses, especially SMEs, who like to know what's required and what to do about it.

- **Externalities**: The main justification for designing environmental regulation that prompts *innovation* is to encourage the private sector to internalise an externality (the environmental outcome) through

investment. This is likely to require a tangible shift in relative prices and/or a stringent regulatory requirement to induce significant investment in new technologies. However, *diffusion* is more about tackling asymmetries in information and can best be encouraged through the establishment of information and knowledge transfer networks.

- **Technology support:** *Innovation* is prompted by mixed or hybrid regulatory instruments involving some degree of support for technological development. This is introduced either as an integral part of the regulation (e.g. as with the German REFIT) or as a complementary measure (e.g. through R&D or capital grants). It is generally the case that some technological preference is implicit or explicit in the regulation and its complementary measures. In contrast, *diffusion* requires 'demand pull' supportive actions but, as with innovation inducing measures, this invariably means some choice by the policy-maker of the preferred technological options.

- **Innovation leading diffusion:** Successful innovation tends to breed innovation and will usually give rise to diffusion. Therefore, it seems plausible to envisage regulation working in two phases. The first might be designed to prompt *innovation* in some firms (and indeed encourage them to go beyond compliance with minimum standards) and the second might make it mandatory that successful innovations are more generally adopted - *diffusion*. This would provide an incentive for businesses to achieve 'first-mover' advantage and to avoid being left behind.

Differential regulatory impacts between large firms and SMEs

12. Some of the case studies confirmed the general point in the literature that regulation can be problematic for small and medium sized enterprises (SMEs) in terms of their capacity and/or willingness to wring competitive advantage out of its requirements (as compared with larger firms with more market power and resources). This is partly to do with the administrative burden that the requirements can impose, the lack of resources for innovation and the adoption of technologies, and the vulnerability of smaller firms to closure as costs are increased through regulation.

13. The corporate conditions most conducive to take-up of Best Available Technologies tend not to be those typically associated with the generality of SMEs (i.e. large plants, high investment and R&D rates, high skills endowments and high productivity). However, the inference from the literature and the case studies was not that SMEs should necessarily be exempt from regulations. Rather it was that regulatory design should acknowledge the disadvantages under which SMEs often operate and should be accompanied by complementary measures to support technology diffusion.

The importance of context

14. It is generally recognised in the literature and verified from the case studies that it is crucial in designing regulation to tailor its form to the circumstances in which it will be applied. 'One size does not fit all' especially when it comes to designing regulation that prompts innovation and/or diffusion. Not only must account be taken of the characteristics of the market-place and the structure of businesses but consideration also needs to be given to current and prospective technological developments and to the extent of diffusion of existing technologies (and the obstacles to both innovation and diffusion).

15. The very diversity of the market and technological conditions in which regulation will be implemented, and the variety of other drivers of innovation and diffusion, tend to make it difficult for policy-makers to be sufficiently informed about the diversity of conditions that they can fine-tune the design of sanctions-based, command and control instruments to reflect that diversity.

16. There may be occasions when it becomes necessary to cut through the diversity with relatively crude sanctions based instruments to achieve the desired level of pollution control and/or prevention. This might be appropriate where the risks of environmental damage are high, the adverse consequences of the risks materialising are significant and/or irreversible, and the capacity, culture and/or inclination of the businesses in question may not necessarily be attuned to delivering the necessary environmental protection or enhancement.

17. In other circumstances it might be appropriate to use alternative approaches – ones based on cooperation, trust and compliance and the use of instruments that provide for much greater corporate flexibility. Even in these conditions it

will still be difficult for the policy-makers to be sufficiently well-informed and astute to be able to fine tune the regulatory instruments to reflect the nuances of market and technological characteristics.

18. This suggests that particular attention should be given to the aspects of regulatory form that increase the flows of information and knowledge on the environmental and other outcomes associated with the adoption of specific technologies and practices. The requirement for use of process or procedural standards could prompt the wider use of environmental information and management systems which have the potential to deliver continuous improvements in general resource management and efficiency. They could also provide the foundation for benchmarking between businesses on a comparable basis which would help to identify regulatory leaders and laggards, their respective characteristics and the technologies and practices they use. This would not only increase competition between regulated businesses but would also provide a stronger evidence base on their environmental and other credentials for their consumers and suppliers and policy-makers.

Regulatory design principles

19. The Terms of Reference for the review required that it address the question, how can regulation be designed and implemented to induce diffusion and innovation and bring about positive competitiveness effects? This question has been reformulated in Table 4 as a statement of the purpose of regulatory design and our response has been couched in terms of a set of regulatory design principles.

20. Central to these principles is the proposition that '*pollution prevention pays'* and that all environmental regulation should seek to pursue the route of pollution prevention wherever feasible. Even though pollution prevention has been an aspect of environmental regulation for some years in the UK and elsewhere (especially the US), we are suggesting that the *'pollution prevention pays'* principle should become a central policy thread running through all approaches to environmental regulation and its supportive complementary measures (e.g. public procurement, R&D support, technology transfer, education and training, and information and advice provision).

Table 4: Prompting innovation and diffusion through environmental regulation: Design principles

Purpose of the regulatory design

- To maximise the effect of the regulation on the productivity of regulated and other businesses through innovation and/or diffusion subject to achieving its environmental objectives/targets.
- To adopt a *'pollution prevention pays'* approach to the design of the regulation and its supportive measures whenever possible.

Rationale

- Define the environmental problem to be addressed and the extent to which it is to be reduced against agreed baselines over specified time-scales.
- Consider whether competitor countries are seeking the same extent of reduction in the problem and the regulatory initiatives being explored to address it.
- Review the technological and other options for addressing the problem with preference given to prevention and source reduction followed by recycling and reuse, treatment and disposal.
- Identify the stage of the innovation chain relevant to addressing the environmental problem and the radical or incremental nature of the technological development and/or diffusion required
- Understand the factors prompting or constraining the development and/or adoption of technological options for addressing the environmental problem in question.
- Assess existing regulations and other policy measures relevant to the environmental problem and the technological and other options for addressing them to consider the extent to which they might hinder or assist the purpose of the proposed regulation.

Design

- Couch the regulatory requirements as far as possible in terms of outcomes rather than specific solutions where the intent is to promote innovation but provide more guidance on available options and best practice where the intent is diffusion.
- Build in process or procedural standards that embody good environmental management practices and require reporting of the results of their application.
- Create certainty of regulatory form and content over the longer term to provide steady state signals (e.g. with regard to prices) that are conducive to investment in radical technological options whilst minimising market distortions and public sector costs.
- Develop packages of measures to complement and reinforce the regulatory intent/process through R&D/capital grants, public procurement, technology transfer and information/advice provision.

Implementation and enforcement

- Engage with the corporate and research community to build trust, cooperation and compliance and build in elements of self-regulation, voluntary agreements and informational/procedural standards especially where solutions through innovation are being contemplated.
- Provide advance warning and prior notice to target businesses in both implementation and enforcement and keep to the scheduling and other commitments announced at the outset.
- Render transparent the monitoring and enforcement process and ensure that learning about the effectiveness of solutions is generally disseminated and adopted – 'herding' of laggards from the example of the 'leaders'.
- Adopt a risk-based, compliance rather than sanctions based approach to enforcement where possible.

1 Introducing the study purpose and method

Background to the study

1.1 The conclusion of a literature review for Defra (Defra 2006) was that the form of environmental regulation could affect competitiveness outcomes and that the following questions deserved priority in future research on the topic:

- The costs and benefits of different forms of market-based regulatory instruments and associated measures;
- The broader policy packages and their components that can enable businesses to respond effectively to more stringent regulations; and
- The role of technology and innovation in providing a response to more stringent regulation in ways that achieve both competitiveness and environmental outcomes.

1.2 A very recent OECD study (Johnstone 2007[1]) provided an analysis of an extensive database of manufacturing sectors in seven countries and concluded that the public policy framework exercised an important influence on corporate environmental management, performance and innovation. Policy stringency was found to be more significant in this regard than the choice of regulatory instrument (although more flexible instruments were found to have a positive influence on technological innovation). However, whilst the study found evidence of 'win-win' outcomes (i.e. improved environmental and commercial performance), it concluded that these were negatively associated with the stringency of the policy framework and rather more important was likely to be the choice of instrument.

1.3 Both these studies, therefore, reflect the current state of the literature which leaves open a key question from a policy point of view, namely how should environmental regulation be designed and delivered in order to generate *both* increased environmental and economic outcomes? Defra commissioned the current study to follow its literature review to address this question and to "*gather and analyse evidence on the impact of the design of environmental regulation on competitiveness*".

[1] Johnstone, N (2007) Environmental Policy and Corporate Behaviour, OECD.

Study objectives

1.4 SQW was commissioned in October 2006 to carry out the study whose specific objective was to look at the productivity impacts of different regulatory designs and to identify what forms of regulation were most likely to stimulate innovation. The study was to include consideration of the following:

- The impact of the design and implementation of regulation on small and medium sized enterprises (SMEs) as compared to larger businesses;
- The forms of regulation most likely to induce innovation taking account of the different stages in the innovation process, the impact of timing of regulatory announcement and implementation, and the flexibility that can be built into regulations to reflect the specific market circumstances in which the regulated firms operate; and
- The importance of context (i.e. business sectors and/or environmental policy areas) in determining the extent of inducement effects of regulation on innovation, the areas where the inducement potential is highest, and the characteristics of sectors most likely to prompt firms to react to regulation in positive ways.

Study method

Up-dating the literature review

1.5 The literature review of 2006 was up-dated with three distinct purposes:

- To refresh the review in the light of:
  - any evidence produced since then (including the results of the companion research studies carried out for Defra at the same time as the literature review); and
  - the emphasis attached in the brief to consider the effect of regulation on competitiveness through the specific mechanism of innovation;
- To review the methods used in the literature to select, carry out and report case studies so that the study and its case studies could be informed by past practice;

- To identify case studies used or suggested in the literature that might be candidates for the current study in order to address its objectives with minimal extra work.

1.6 A wide range of sources was investigated for the review up-date – academic journal databases such as JSTOR, Elsevier, Sciencedirect and institutional websites (such as EC Environment, OECD, AEI Brookings Joint Center for Regulatory Studies and Resources for the Future) to specific academic journals (such as the Journal of Environmental and Resource Economics) and the bibliographies in the most cited articles. In addition to the 130 articles and reports reviewed in the earlier literature review, over 50 further articles, papers and reports were identified as relevant and reviewed.

Stakeholder workshops

1.7 Two stakeholder workshops were held during the course of the study:

- The first was held prior to the completion of the literature review and designed primarily for the technical purpose of informing the conclusions of that review and the proposed selection of, and methodology for, the case studies. Therefore, the workshop participants were drawn from technical experts in Defra and other departments and agencies and from the academic community.

- The second workshop was conducted at the point in the study where the case studies were close to completion but the job of synthesis of their results had only just begun. Its purpose was to provide a sounding board for the preliminary findings from, and policy implications of, the case studies. As the workshop was designed to inform the final conclusions of the study, its participants were drawn from both the research and policy communities.

Case Studies

1.8 The Terms of Reference for the study suggested the use of case studies to examine the research issues although it was acknowledged that alternative methods of investigation may be appropriate.

1.9 From a methodological perspective, there are limitations to the case study approach in terms of its ability to allow generalisation of findings. However, our reading of the literature led us to the view that case studies are, indeed,

- Whilst alternative methods such as cross sectoral, firm or establishment econometric studies – either cross-sectional or longitudinal – have the potential for offering generalisable conclusions, the evidence suggests[2] that there were difficulties in specifying variables and capturing appropriate data. Consequently, the studies have had problems of 'missing variables' – particularly with regard to the nature of the regulatory form and business responses.

- These alternative methods have rarely been used in the UK or elsewhere in Europe because of greater difficulties in accessing the appropriate data over time and over a range of sectors, businesses and plants as compared with the US.

- There is a stronger tradition in the literature in the use of case studies and, therefore, there is a body of research evidence and experience in the conduct of case studies that can be drawn and built on for the purposes of this study.

1.10 The findings of the review enabled us to identify case studies undertaken or suggested in the literature, to develop a set of criteria for selecting the most appropriate case studies, and to arrive at an initial 'long' list of case studies. The selection criteria used are listed in Table 1-1.

1.11 The potential case studies were allocated to the following categories representing the different levels of effort that they might involve to make them fit for the purposes of the study:

- **Ready to review** – case studies drawn almost entirely from existing evidence and investigated to address the research purpose of this study

- **Extensions** - case studies that could build on existing or ongoing studies to address the research issues by a combination of analysis of existing research and consideration of evidence gathered via interviews with key stakeholders

[2] See Jaffe and Palmer (1994), Jaffe and Stavins (1995), Cohen (1999), Lajeunesse (2001), Hanel (2003), Cole et al (2004) and Savageau (2004) – see bibliography of SQW (2006) Phase 1 study.

- **Adaptations** – case studies based on overseas experience but adapted to provide a UK perspective and, as above, involving reviews of existing evidence and key UK stakeholders' views

- **New** case studies focused on gathering new evidence via interviews with stakeholders and industry representatives.

Table 1-1: Criteria for case study selection

The mix of case studies was to incorporate:

- Different types of technology (end of pipe / process / product technologies)
- A variety of economic sectors including sectors sensitive to energy and material prices in both manufacturing and services as well as 'pollution-intensive' sectors
- Case studies of regulations:
  - ✓ focused on a particular industrial process or function that permits assessment of the evolution of different regulatory regimes
  - ✓ related to a policy area where inter-country comparisons can be made between regulation methods adopted to the same end
  - ✓ directed at high-level and ambitious policy objectives - reflecting the serious policy concerns of the day such as climate change
  - ✓ posing specific issues for the UK in terms of the potential trade-off between the achievement of environmental, innovative and competitiveness outcomes - e.g. in areas of UK trade comparative advantage

Note: All case studies were to be based on ex post assessments of the consequences of regulation of different forms and to have some degree of access to readily available data and evidence that might inform an understanding of the relationship between competitiveness and the form of regulation.

Source: Adapted by SQW from Oosterhuis and ten Brink (2006)

1.12 Following the first stakeholder workshop where a long list of potential case studies was presented and discussed, a short-list was drawn up and submitted to the study Steering Group along with a rationale for the proposed selection. The proposed 6 'core' case studies and 5 'reserve list' case studies were considered by Defra analyst and policy colleagues who agreed to the six case studies presented in Table 1-2.

Table 1-2: Case study selection

- SO_2 and NO_x regime in the UK and in the USA and other EU countries to provide cross country comparisons of instrument choice and its impact on innovation -
- Extended Producer Responsibility (EPR) and the UK Packaging Waste Regulations: Links between regulation and innovation
- Nitrates Directive to provide a comparison with other EU countries where the Directive has been fully implemented

- IPPC to be reviewed for its effect on competitiveness and innovation with particular regard to the food and drink sector
- Energy Labelling with particular reference to the EU Energy Labelling scheme to provide a cross-border comparison of regulatory design and its effect on competitiveness
- Renewable Obligation (RO) regulation in the UK compared with the Renewable Energy Feed in Tariff (REFIT)regime in countries such as Germany and Denmark to assess the relative impact on the development of renewable technologies

See Table 1-4 at the end of the section

1.13 The methodology adopted for each of the case studies was broadly the same and involved the tasks set out in Table 1-3.

Table 1-3: Case study methodology

Approach	Purpose
Review of evidence from the existing case studies where available	• The markets, technologies and sectors involved • Programme design and implementation, and where applicable description of instruments used in different countries • Effectiveness of policy • Economic outcomes where available
Review and analysis of secondary data	• Trends in economic outcomes • Ex-ante and ex-post (where available) regulatory costs • Environmental outcomes (such as emissions) within sectors and countries • Economic characteristics of sectors/countries relevant to the case study in question • Proxy indicators for innovation and productivity impact
Consultations with policy and industry stakeholders	• Programme design and implementation, and where applicable description of instruments used in different countries • Effectiveness of policy • Economic outcomes where available
Consultations with researchers	• Priority research issues • Robustness of the evidence and how they compare with other available evidence from case studies and other sources

1.14 The framework for analysing the evidence comprised a descriptive and an analytical element:

- The descriptive element included an account of the background and context to the environmental problem, the policy objectives, policy

development over time, international comparisons of the instruments studied and description of the specific design and implementation features of the instruments

- The analytical element was designed to test specific propositions in the study with particular focus on the evidence on policy effectiveness, evidence on innovation and competitiveness effects, and any evidence on cross-country differences in outcomes

1.15 Individual reports for the case studies are provided separately.

The structure of the report

1.16 The findings of the study are presented in the following four sections:

- Section 2: Laying the foundations: Key conceptual issues and distinctions
- Section 3: Reviewing the case studies: An overview
- Section 4: Assessing the influence of regulatory form on innovation and competitiveness
- Section 5: Drawing conclusions and regulatory design principles

1.17 Individual case study reports are being published separately.

Table 1-4: Case study selection – core list

Case Study	Policy Area	Category	Different types of technology	A variety of economic sectors	Permits assessment of the evolution of different regimes	Allows inter-country comparisons	High-level and ambitious policy objectives	Posing specific competitiveness issues for the UK	Based on ex post assessments with access to available data and evidence
Cross country instrument choice and its impact on innovation: Comparing Sox and Nox regime in the UK with the USA and other EU countries	**Air quality** Reduce SO_2 and NO_x emissions from plants in pollution intensive sectors **Instrument choice** USA – Market based instrument in the form of trading Germany – Command and control EU/UK – Command and control with some flexibility in implementation	Ready to Review	√		√	√	√		√
Impact of the Implementation of the Nitrates Directive on farmers in the UK, with comparisons with other EU countries where the Directive has been fully	**Water Pollution** Reduce levels of non point source pollution of nitrates in water Instrument choice UK – command and control Denmark –	Extensions		√		√	√		

Case Study	Policy Area	Category	Different types of technology	A variety of economic sectors	Permits assessment of the evolution of different regimes	Allows inter-country comparisons	High-level and ambitious policy objectives	Posing specific competitiveness issues for the UK	Based on ex post assessments with access to available data and evidence
implemented	command and control Germany – complementary subsidies France – enforcement at regional level								
Extended Producer Responsibility (EPR) and the UK Packaging Waste Regulations: Links between regulation and innovation	**Solid Waste** Increase recycling and reduce packaging **Instrument choice** Mandatory EU targets with market based instrument used for implementation in the UK	Extensions	√	√			√	√	√
The impact of PPC on competitiveness and innovation with particular regard to the food and drink sector	**Climate Change** Control the environmental impact to air, land and water of emissions arising from industrial	Adaptation	√	√			√	√	√

Case Study	Policy Area	Category	Different types of technology	A variety of economic sectors	Permits assessment of the evolution of different regimes	Allows inter-country comparisons	High-level and ambitious policy objectives	Posing specific competitiveness issues for the UK	Based on ex post assessments with access to available data and evidence
	activities at plant level **Instrument choice** Technology standards and emissions limit based on Best Available Techniques (BAT)								
Energy Labelling with particular reference to the EU Energy Labelling scheme- cross-border comparison of the design and competitiveness impacts of the scheme	**Consumer Products** Facilitate comparison of energy consumption between different appliances Remove the most energy inefficient products from the market **Instrument choice** UK – mandatory information based instrument combined with minimum efficiency standards (EU	New		√	√	√		√	√

Case Study	Policy Area	Category	Different types of technology	A variety of economic sectors	Permits assessment of the evolution of different regimes	Allows inter-country comparisons	High-level and ambitious policy objectives	Posing specific competitiveness issues for the UK	Based on ex post assessments with access to available data and evidence
	energy label) USA – mandatory information based instrument combined with minimum efficiency standards (Energy Guide Label) AND voluntary instrument (Energy Star) Japan – mandatory minimum efficiency standards								
Relative merits of the Renewable Obligation (RO) regulation in the UK versus Renewable Energy Feed in Tariff (REFIT) in countries such as Germany with regard to innovation in renewable technologies	**Energy efficiency and climate change** Create a market for renewable technologies, with a long term aspiration to enable the sustainability of the renewables sector **Instrument choice** UK – Market based instrument; Renewable	Extensions	√	√	√	√	√	√	√

Case Study	Policy Area	Category	Different types of technology	A variety of economic sectors	Permits assessment of the evolution of different regimes	Allows inter-country comparisons	High-level and ambitious policy objectives	Posing specific competitiveness issues for the UK	Based on ex post assessments with access to available data and evidence
	Obligation with targets for sourcing renewable energy, allowing electricity generators to hold and trade RO certificates when using renewable energy Germany – Feed in Tariff that legally guarantees renewable energy producers access to the power grid at a guaranteed price								
MIX of CASE STUDIES			√	√	√	√	√	√	√

Source: SQW

2 Laying the foundations: Key concepts and distinctions

Key concepts and distinctions

2.1 The earlier review (Defra 2006[3]) observed that there were disagreements in the literature on the definitions of competitiveness and regulation. These issues are not fully rehearsed here but it is important to set out what the key concepts and distinctions are that will be relevant to the study purpose and to identify the propositions that deserve to be tested in the case studies.

2.2 This section, therefore, considers the following:

- Competitiveness and innovation
- Regulation and its defining characteristics
- The context in which regulation is designed and implemented
- The relationship between regulation and innovation/diffusion
- Propositions to be tested in the case studies

Competitiveness and innovation

Competitiveness

2.3 The conclusion of the Defra literature review (Defra 2006) was that the fundaments of national competitiveness are founded on the efficiency with which resources are allocated and used at micro levels (i.e. within sectors of economic activity and within businesses and other organisations) and that it is at this level that the consequences of regulation are most appropriately investigated. This view of the under-pinning nature of competitiveness is endorsed by the Treasury and DTI assessment of national, regional and local productivity performance and its supply side drivers (HM Treasury/DTI, 2006).[4]

2.4 The productivity framework adopted by HMT/DTI identifies employment and productivity growth as key determinants of progression in terms of quality of life and standards of living. The framework also specifies there to be five

[3] SQW (2006) Exploring the relationship between environmental regulation and competitiveness: literature review, Defra
[4] HMT/DTI (2006)

drivers of productivity, namely investment, innovation, enterprise, skills and competition. Acceptance of this framework suggests that the influence of regulation on competitiveness should take note of the way in which the form of environmental regulation might work through the productivity drivers and specifically innovation.

Innovation

2.5 According to HMT/DTI, innovation is the "*invention and application of new technologies, products and production processes"* and has been a key driver of productivity growth, accounting for two-thirds of UK economic growth in the post-World War II period.[5] Innovation induces increased productivity through three broad channels:

- Direct productivity gains to the firms that invest in research and development (R&D) and/or innovation to bring about improved efficiency in their products and/or processes;
- Spill over productivity gains when innovation assists firms to take advantage of other innovations; and
- Spill over productivity gains for other firms or sectors or regions that can emulate the innovation.

2.6 There are some foundational issues about the role of innovation in the environmental context that deserve to be emphasised:[6]

- Innovative activity and rates of innovation are sector specific because different degrees of technological opportunities exist, with some technological problems being particularly hard to crack (e.g. how to generate solar electricity cheaply). Incentives to invest will therefore vary by sector.
- The capacity of innovating businesses to capture the benefits from their investments in, for example, research and development (R&D) will also vary by markets depending on the extent to which the innovators can protect their knowledge and property rights. Incentives for innovation will, therefore, differ by markets.

[5] O'Mahoney (1996) quoted in HMT/DTI (2001)
[6] See Nelson and Winter (1982), Utterback and Suarez (1993), Rosenberg, (1997), Freeman and Soete (1997), Jaffe et al (2002), Foxon et al (2004) and Grubb (2004) for consideration of innovation in general and specifically in the environmental context.

- The benefits from improved environmental performance arising from innovation may not be limited to specific users but shared with many others (the public goods problem). The incentive to invest in environmental innovations may therefore be doubly-disadvantaged by public good and externality issues.

- Innovation requires a combination of technological and cultural systems to support it. It tends to be context-specific emerging from specific capabilities and networks and conforming to standards imposed by complementary technologies and infrastructure. This can lead to technological trajectories that favour incumbents, encourage 'lock in' or path dependency and set up barriers to entry for new technologies that are further away from the market even though they may offer technical and other advantages.

- Finally, all innovation is circumscribed by problems of uncertainty – technical, market, environmental and social. It is never clear beforehand what the impact of a specific innovation might be. This uncertainty is compounded where, as often the case in the environmental domain, consumers may not be able to recognise the advantages of new environmental technologies, goods and services and will therefore be reluctant to pay for them.

2.7 There is a broad distinction in the discussion of the role of technological change between innovation (e.g. from investment in R&D) and diffusion (i.e. the technological change being adopted or emulated by others). This important distinction is picked up in the literature on technology and environmental regulation as the difference between the influence that regulation can exercise in prompting new technologies (induced innovation) and in encouraging the faster and more widespread adoption of existing and competitive technologies (diffusion) (Jaffe et al 2002).

2.8 The distinction is similar to the one that is also made in the literature between the 'technology push' influence on innovation and diffusion and 'demand pull' (Grubb 2004). This distinction is not made to suggest that one influence is necessarily inconsistent with the other but to acknowledge that the market failures that limit their operation may vary between the two and, hence, may justify different policy designs to address the failures. Thus, while technology push is likely to be more significant in the early stages of innovation – with regard to basic R&D, prototype development and demonstration, the demand

pull influence is more likely to feature at the latter stages of commercialisation, market accumulation and diffusion.

2.9 For convenience, this distinction is described in the rest of this report as being between *innovation* (the invention and application of *new* technologies) and *diffusion* (the adaptation and adoption of *existing* technologies).

Regulation and its defining characteristics

2.10 The terms of reference for the current study suggested that regulatory form should be taken to refer to the way the regulations are designed, the manner of their introduction and implementation and the way in which they are mixed with other regulations and interventions. The literature concerned with the influence of these characteristics on innovation and diffusion uses a variety of terms to reflect their nature. Adjectives like stringent, flexible, certain, technology 'forcing' are used to describe regulatory form but sometimes there is lack of clarity about what is meant and there are often differences of definition between the research studies. This sub-section provides a discussion of the various components of regulatory form and offers definitions for use throughout the rest of the report.

Policy design

2.11 There are a number of aspects to policy design referred to in the literature but difficulties have often been encountered in obtaining quantitative measures of them. These various aspects are as follows:

- **Policy stringency**:[7] This refers to the strength of the requirement for environmental abatement/protection as written into the regulation compared with current practice. A measure used in the literature at both macro and micro levels has been pollution control or abatement costs or expenditure (Lanjouw and Mody 1996). All sorts of measurement problems have been associated with use of this variable – mostly to do with lack of consistency in the definition of such expenditure. An alternative has been the use of a subjective measure of perceived increased stringency (Johnstone 2007).

- **Outcome or solution forcing:** This distinction refers to the potential for policy design to be prescriptive about the solutions needed to meet

[7] Note: Some of the literature (e.g. Brunnermeier and Cohen 2003) uses the number of inspections carried out by the regulatory authorities as a measure of the strength of emission reduction pressures. However, in the treatment of regulatory form proposed in this report, this measure would more appropriately be used to capture the strength of regulation enforcement/compliance.

the policy objective (for example, with respect to the particular technologies that the regulation 'forces' to provide the desired level of pollution abatement). The alternative – outcome forcing -is a regulation couched in terms of the reductions required in the abatement outcomes – e.g. reduced levels of specified emissions or reduced intensities of inputs.

- **Certainty and/or flexibility:** Certainty is a prerequisite of any regulation but there can be more or less certainty with regard to the specificity of its terms and conditions (e.g. the outcomes or the solutions that are required, the schedule over which they will have to be met and the time-frame over which the regulatory terms and conditions will prevail). Flexibility can co-exist with certainty (e.g. the required outcomes may be certain but flexibility could be offered to firms in terms of options for compliance and the technology solutions to be pursued). But flexibility can also provide for countries or firms to negotiate their own regulatory terms and conditions – rendering the regulation less certain and consistent.

- **Instrument choice:** This is often expressed in the literature as a choice between *market based instruments* and *command and control regulations* and it is this distinction that the literature often has in mind when it refers to regulatory form. There are, in fact, a variety of regulatory instruments that have been deployed – voluntary agreements, self-regulation, technology based standards, performance or outcome based standards, input (including energy) taxes, emission or effluent taxes, emissions trading and tradable permits. However, research studies (especially cross-section econometric studies) have found it difficult to discriminate between this variety of instruments in terms of the influence they can exert on environmental and commercial performance. For this reason, use is often made of a binary distinction between more or less flexible instruments – where instruments that use market based mechanisms are referred to as flexible.

Policy implementation

2.12 Policy implementation refers to the processes by which a regulation is designed and introduced. It includes consultation exercises during regulation

design, advance announcements of the regulation, publicity or information campaigns and prior notice being given for implementation. There is evidence from the literature that implementation factors can be important in both enhancing the effectiveness of the regulation *and* watering it down.

- **Advanced notice of the introduction of a new instrument -** The European Environment Agency (2006) found that giving advanced notice of the introduction of a regulation via phasing-in schemes allowed time for fine-tuning the system which led to a more successful implementation of the instrument.

- **Awareness campaigns** - Ekins and Etheridge (2006) assessed the UK Climate Change Levy and suggested that success in meeting targets was down to an 'awareness effect' through the negotiation process by which industrial managers become aware of potential improvements in industrial energy efficiency.

- **Dilution of regulation intent** - Hawksworth (2006) found that the impact of the Norwegian Carbon tax has been limited as a result of political difficulties and lobbying about the potentially adverse effects on competitiveness.

Policy enforcement

2.13 There is a distinction to be made between policy implementation and enforcement which acknowledges that extensive consultation, negotiation and flexibility prior to the specification of the regulation can work hand-in-hand with very stringent enforcement once it is in place. The literature suggests that the effects of regulation on innovation to some extent depend on the severity of penalties exacted for lack of compliance, the rigour with which the regulatory authorities carry out inspections/audits of compliance and their willingness to enforce the penalties for non-compliance. An advantage of being a small or medium-sized enterprise (SME) in this context is that there are so many of them that it can lead to very infrequent inspections and, hence, limit the effectiveness of the regulation on SMEs (Gunningham 2004).

Policy stand-alone or mix

2.14 The European Environment Agency (2006) conducted a review of the use and experience of market based instruments (MBIs) in Europe and found evidence to suggest that MBIs are more effective if they are well-designed and implemented as part of a wider package of instruments.

2.15 The effectiveness of using a mix or hybrid of instruments as opposed to a stand-alone instrument has also been investigated in other research. For example, Varma (2003) supported the use of mixed instruments as a result of his investigation of the cost-effectiveness of the UK's Climate Change Levy (and a comparison with an emissions trading scheme) and the implications for the competitiveness of firms. The study found that a mix of levy and permit trading provided the best solution, with emission trading covering emissions related to production of good and services exposed to international competition and energy taxes focused on smaller or mobile sources whose emissions are difficult or expensive to monitor and the 'non-process costs', such as space heating for industrial and commercial use that is not exposed to the same pressures of international competition.

The context in which regulation is designed and implemented

The evidence base

2.16 The terms of reference for this study emphasised the need to investigate whether and how the sectoral or market context in which regulation was designed and implemented might affect its influence on innovation and productivity. There are various findings in the literature that confirm that this is a legitimate area for investigation, i.e. that market, sector and firm characteristics can influence the extent to which innovation and diffusion are prompted by a given form of regulation:

- **Differing firm level marginal costs –** Butraw (1996) found that performance standards can work well to achieve cost effectiveness if firms have similar marginal cost as this allows firms the capacity to innovate in a similar fashion. However, when the marginal cost of compliance differ significantly between firms, performance standards are thought to be less effective.

- **Institutional knowledge and internal expertise** - Newell et al (2006) conducted a review of recent research into the effect of policy instruments and economic incentives on technological change. This study emphasised the importance of technology information programmes for SMEs, which in contrast to larger corporations are unlikely to benefit from a large pool of internal expertise and institutional knowledge and hence find it more difficult to adapt to new regulatory regimes/instruments.

- **Organisational capability and location of a firm -** Hillard and Jacobson (2003) highlight the fact that firms differing responses to technology forcing regulations are largely influenced by differing organisational capabilities as opposed to locational differences.

- **Industry structure** – The Management Institute for Environment and Business (1996) propose that an industry's ability to respond innovatively to regulation is partly determined by the number and size of companies in the industry and by its rate of technological change. Generally, large companies in industries with a high rate of change have the most resources for innovation.

- **Market demand –** research undertaken on the passenger cars sector by Beise (2005) found that regulation was an important factor in terms of innovation but that regulators are often not able to steer effectively against market trends, as a result of their dominant influence in shaping the sector.

- **Purpose/type of product** – Research conducted by The Management Institute for Environment and Business (1996) found that when regulation focuses on substances which have a purpose in production, such as solvents for cleaning, or are present in the final product, manufacturers have a direct incentive to replace the substance. This is in sharp contrast to the situation where by-products are produced, where the incentive to change is less immediate and more likely to result in the installation of control technology.

The relationship between regulation and innovation/diffusion

The evidence base

2.17 The conclusion from the literature is that technological change can be a very important mechanism by which environmental regulation affects productivity and competitiveness. Theoretical considerations suggest that the distinction between innovation and diffusion is relevant in understanding the nature of this mechanism. But there is little by way of empirical work that confirms this or provides insights into the way in which the distinction works. And, although there is growing empirical evidence on the relationship between instrument choice and technological change, the evidence does not adequately

distinguish how various regulatory characteristics work to influence innovation separately from diffusion.

2.18 A sample from the relevant findings from the research is set out below:

- There is some evidence to suggest that market based instruments are more likely to induce innovation than command and control approaches (Jaffe et al 2002).

- Technology forcing standards and targets tend to induce diffusion of end of pipe, market ready technologies, while market based approaches drive innovation in cleaner processes and technologies (Johnstone et al, 2007). Indeed, Jaffe et al (2002) suggest that technology standards can be particularly problematic - "*no financial incentive exists for businesses to exceed control targets and the adoption of new technologies is discouraged*".

- Kerr and Newell (2003) found that market-based instruments such as tradable permits used in the USA during the phasedown of leaded gasoline provided significant incentives to the petroleum industry to adopt efficient technological solutions.

- Taylor et al (2005) investigated the role of regulatory instruments in inducing innovation in the control of SO^2 emissions from power plants. The authors combined quantitative and qualitative methods to test whether 'technology push' or 'market pull' instruments were most effective, and found that demand pull factors such as legislation and regulation had a more direct effect on inventive activity than technology-push factors such as R&D subsidies.

- Hitchens et al (2001) found that Best Available Techniques (BAT) under IPPC were more conducive to firm profitability when firms adopted pollution prevention measures (innovation) than end of pipe measures (diffusion).

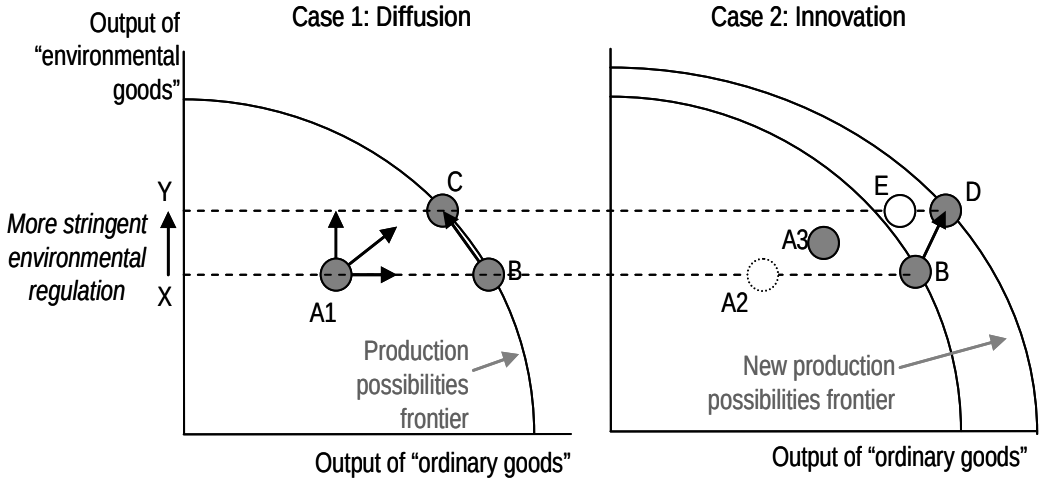
- Flexibility with regard to compliance options can be more suitable for diffusion than innovation as such. Burtraw (1996, 2000) concluded that flexibility in compliance options under the SO_2 trading system in the USA enabled firms to plan and adopt suitable abatement technologies.

2.19 It is evident from this sample of the evidence that some of the issues raised in this section of the report have been addressed in the literature. But, the largely unexplored territory is the way in which the different characteristics that make up regulatory *form* influence *innovation* separately from *diffusion* and how the direction and force of this influence might be affected by the sectoral, market and business *context* – i.e. the focus of the current study.

A stylised depiction of the relationship

2.20 The Defra literature review used a graphical depiction of the relationship between more stringent regulation and productivity change that was adapted from De Canio (1997). This has been further adapted in Figure 2-1 to suggest the different roles of innovation and diffusion in the relationship. The figure shows the production possibilities confronting a business as a trade-off between the production of traded 'ordinary goods' and non-traded 'environmental goods'[8].

Figure 2-1: Innovation and diffusion responses to more stringent environmental regulation



Source: Adapted from DeCanio (1997)

2.21 Environmental regulation will require businesses to generate a certain amount of environmental goods – depicted by the value X in the figure. Where regulation becomes more stringent, firms will have to increase their output of environmental goods (to value Y in the figure). The consequences of this for firm behaviour and performance will be critical in determining whether the outcome is an overall increase in ordinary goods and conventionally defined productivity.

[8] An 'environmental good' in this formulation is defined as positive environmental outputs/outcomes which could take the form of *reduced* pollution or emissions.

2.22 The figure depicts two situations.[9] The first – Case 1 – maintains the existing PPF and the second – Case 2 – allows for an outward shift to a new PPF.

Case 1: Diffusion

Firms located within the PPF (e.g. at position A1) can meet more demanding regulations at the same time as increasing their production of ordinary goods by moving upwards and to the right – towards the PPF. One way that they can do this is by more quickly and extensively adopting existing technologies that enable them to meet the new regulations – i.e. *diffusion*.

This can still take time to achieve because firms may lack information about existing technologies and are likely to resist adoption of such technologies until such time as they have to replace the relevant capital assets or have built up the skills to manage new processes using the technologies.

Efficient businesses on the PPF – at point B – can only produce more environmental goods by producing less ordinary goods (at point C). Overall, the effect on productivity may be positive but this will depend on the extent to which and the speed with which diffusion is prompted by the regulation.

Case 2: Innovation

Case 2 is where there is an outward shift in the PPF that allows businesses located on the frontier (e.g. at position B) to move upwards to the right to point D and increase their output of both environmental and ordinary goods. This effect depends on the more stringent regulation prompting significant technological change – *innovation*.

There are three other effects that might be generated by the outward shift in the PPF:

- Firms at point A2 could simply be forced to exit – they were below the margin anyway and the more demanding regulation may tip them over the edge.
- But these firms may be part of a supply chain and they may be pulled towards the frontier (as shown at A3) by the firms they supply as they move closer to the new PPF.
- The outward shift in the PPF changes production possibilities and could prompt new entrants either by start-up or diversification or inward investment – i.e. point E.
- The overall effect on productivity will depend on the extent to which the more stringent regulation prompts technological change – innovation – and associated diffusion down supply chains.

Propositions to be tested

2.23 Three basic propositions can be drawn from the above review that deserve to be tested through the case studies:

[9] The depiction in Figure 2-1 should be subject to the qualification that some environmental regulation may require reduced production of ordinary goods (as in the case of the Montreal Protocol on CFCs and other ozone depleting substances). Consequently, all shifts will be to the left including the PPF.

- **Moving to the frontier -** Regulation can be designed in ways that prompt faster and more extensive diffusion of existing technologies and enable firms to move towards the prevailing production possibilities frontier.

- **Moving the frontier -** Regulation can prompt an outward shift in the production possibilities frontier by stimulating innovation, enabling firms to shift to new technological trajectories, reinforcing competitive pressures on less efficient firms and encouraging new entries.

- **Shaping regulation** – Regulations can be shaped to achieve both 'moving to the frontier' *and* 'moving the frontier' outcomes, but it is likely that a policy trade-off between the two will be necessary and regulation configured according to the resolution of the trade-off – consistently with the desired environmental outcomes.

3 Reviewing the case studies: An overview

Key features of the six case studies

3.1 The six case studies are described and their findings summarised in Table 3-1 at the end of the section. The table highlights the key aspects of the regulations that were identified in the previous section as possibly having a bearing on their influence on innovation and productivity. The following features of the case studies are set out in the table:

- Regulations covered by the case study and the insights they might provide;
- Their purpose, the instrument choices and their policy effectiveness;
- Effects on technological change – specifically whether the primary effect was through innovation or diffusion;
- Overall observed or anticipated effect on productivity and competitiveness;
- Regulatory characteristics that might have influenced the relationships between the environmental regulations, innovation/diffusion and productivity; and
- Other drivers that might have had an effect on innovation/diffusion and productivity.

3.2 Findings from the six case studies are largely based on secondary analysis of literature and data, and the views of policy and industry stakeholders as well as academic researchers. The case studies did not collect any primary data or involve consultations with firms or any statistical analysis of the relationships to be explored.

3.3 The individual reviews of relevant literature were conducted using appropriate search terms and methods, as well as credible sources that allowed us to identify and review academic peer reviewed journal articles, reports from individual research organisations and documents published by international and national government agencies.

3.4 The secondary data used in the individual case studies was mostly drawn from published government sources such as National Statistics, DTI Energy Statistics, Environment Protection Agency (EPA) in the USA, International Energy Agency (IEA) statistics.

3.5 We also conducted a thorough and robust process of identifying the most appropriate stakeholders to consult with, in each of the case studies, and used the findings from these consultations to triangulate and validate the findings from existing evidence and any inferences that can be drawn from secondary data.

3.6 We were conscious of the risks of generalising from the evidence of a limited number of case studies even where they comprised a diverse range of regulatory instruments and circumstances. Therefore, the case studies have not been treated in isolation but integrated with the conclusions of the earlier literature review as updated at the outset of this study and with the evidence from our consultations with stakeholders.

Findings from the case studies

3.7 The evidence on the influence of regulatory form on innovation and productivity is mixed although there are some clear cross cutting themes emerging from the six case studies:

- In general, standards and targets work better in terms of achieving environmental outcomes but they tend to be less cost effective than market based instruments – the German GFA-VO was extremely successful in achieving reductions in SO_2 but not as cost effective as the cap and trade program in the USA where significant cost savings and benefits were achieved.

- Market based instruments tend to provide greater incentives for firms to choose cost effective compliance options and accrue benefits of investment. However, in some cases, they need to be well defined in terms of the environmental resource being targeted - for example, EPR targets were weight rather than outcome based with the aim to reduce packaging as well as recycling but with only the latter being achieved. The use of weight as a proxy for the resource to be conserved various innovation incentives (reduced weight, reduced use of specified packaging materials) but very few directly related to minimizing use of the environmental resource in hand, i.e. reduction of packaging waste.

- Market based instruments have also tended to encourage sustained but incremental diffusion and innovations rather than radical transformations. This was the case for the SO_2 cap and trade system in the USA, the Renewable Obligation Certificates (ROC) and the Packaging Recovery Notes (PRN) in the UK. The cap and trade system in the USA introduced competition in downstream supply markets such that dramatic fall in low sulphur coal prices and the operating cost of scrubbers led to significant cost savings for firms complying with the programme. In the case of PRN, the variability and unpredictable nature of process made it difficult for reprocessors to plan income and investment. The market based nature of the RO has enabled the development of close to market technologies only, as firms trade in ROCs to make cost-effective investments.

- A mix of policy instruments is more conducive to innovation than stand alone instruments – the UK Energy Label (an information based instrument) worked effectively in conjunction with minimum efficiency standards (a standards based instrument) to bring about market transformation in the cold appliances market; evidence suggests that EL would not have been effective as a stand alone instrument. Similarly, the mixed use of mandatory and voluntary measures has proved a success in the US and led to innovation in energy efficiency for several sectors.

- Instruments aimed at the introduction and use of new technologies work best if they combine price and policy certainty, regardless of form, and may need a package of measures - Despite the long term nature of the RO in the UK, it appears to have created markets for technologies close to the market but not for technologies that were embryonic in nature.

- There was some evidence on competitiveness effects due to regulation – ex post assessment of the impact of BAT and IPCC on specific sectors indicated positive competitiveness effects when plants had adopted process measures rather an end of pipe measures. The price competitive nature of RO (through ROCs) has, to some extent,

- "One size fits all" instruments do not work – specific sector, firm and market characteristics result in differential impact of regulation. For example, IPPC tends to favour large firms that have sufficient capital stock and R&D capacity to respond to the regulation. In the case of the Nitrates Directive in the UK, evidence suggests that innovation is most likely to occur in larger, more intensive farming that closely resembles industrial production and where economies of scale allow swifter returns on investment. The *de minimis* element of the Packaging Waste Directive meant that only larger firms were subject to the regulation.

- There are other significant drivers that operate in conjunction with regulation and sometimes more significant than regulation in driving innovation and diffusion – factors such as consumer demand, input prices and other economic conditions such as firm size, market structure and industry structures. Technological progress external to the regulation and consumer preferences were cited as significant drivers in the case of energy efficiency policies such as the Energy Labelling. The Large Combustion Plants Directive (LCPD) was implemented in the UK at the time when the energy markets were being liberalised, and a new technology called Combined Cycle Gas Turbine was being introduced. Both of these factors encouraged firms to comply easily and cost-effectively.

3.8 What is evident from the case studies is that the design, implementation and enforcement characteristics of regulation appear to drive innovation and diffusion more than others. Moreover, some tend to affect diffusion more while others appear to be more conducive to innovation. Table 3-2 summarises our assessment of the aspects of regulatory form that are most likely to induce innovation and/or diffusion.

Table 3-2: Regulatory characteristics and their influence on diffusion and innovation

Characteristics	**Diffusion**	**Innovation**
Policy design		
Policy stringency	√	√

Characteristics	Diffusion	Innovation
Clarity in defining the environmental problem	√	√
Outcome based		√
Solution forcing	√	
Certainty of outcome	√	√
Certainty of long term schedule for outcomes		√
Certainty in technology prices/investments		√
Flexibility in technological options	√	
Flexibility in terms of time frame and (permitting) conditions to achieve compliance	√	
Flexibility of targets to respond to changes in external drivers, e.g. technological changes	√	√
Instrument choice – MIBI/CAC	MBI	Mixed
Policy implementation		
Advance warning and prior notice		√
Phased implementation/announcement effects		√
Awareness campaigns	√	
Early and continued engagement with industry	√	√
Enforcement		
Stringency in monitoring and enforcement	√	√
Policy stand alone/mix		
Stand alone	√	
Hybrid instrument – combination of mandatory and voluntary for example		√
Stand alone with support mechanisms e.g. financial support, R&D networks	√	√

3.9 The most significant of these regulatory characteristics will be discussed in more detail in the next section, with specific examples from the case studies, to demonstrate the nature and extent of the ways in which they encourage firms to move to the frontier (diffusion) and/or move the frontier (innovation).

Table 3-1 Summary of findings from case studies

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
Comparing SO_2 and NO_x regime in the UK with the USA and other EU countries: **Cross country instrument choice and its impact on innovation**	**Positive**; across all types of instruments	**Positive for economic instrument** Significant cost savings to US firms under SO_2 trading but command and control approach (in Germany) not as cost effective	**Diffusion effects** **Positive to some extent**; trading associated with incremental innovation across the supply chain Command and control approach associated with introduction of new end of pipe technologies Inconclusive for the UK instrument as technical change external to the regulatory regime enabled firms to comply effectively	**Policy design** Policy stringency Flexibility with regard to compliance options and allocation of emissions targets In the case of trading, allowance prices and banking of allowances Policy certainty **Policy implementation** Effective and continuous engagement with industry **Stringent monitoring and enforcement, regardless of form**	Changing market structures in affected sectors Technological change outside of the regulation Fuel mix and prices Energy prices and energy demand Firm size and share of the market
Extended Producer Responsibility (EPR) and the UK Packaging Waste Regulations: Links between regulation and innovation	**Neutral;** success in achieving recycling and recovery but not so in terms of reducing waste	**Positive to some extent** and only amongst reprocessors and exporters who have been able to use the increased income in some cases to develop processes and recycling capacity	**Innovation effects** **Inconclusive**; some evidence on innovation in specific parts of the supply chain Presence of compliance schemes	**Policy design** Insufficient clarity in defining the environmental problem Price of the tradable instrument too low to encourage firms to	Consumer demand and end user marketing significant drivers of innovation

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
			which take direct responsibility for the tradable instrument with reduced incentives for the individual firm. Free rider effects	innovate **Monitoring and enforcement** Mixed evidence on effective enforcement **Policy stand alone/mix** Better targeting of Packaging Recovery Notes (PRN) receipts Media campaigns to raise awareness Working closely with Local Authorities to link their goals with EPR goals	
Impact of the Implementation of the Nitrates Directive on farmers in the UK compared with other EU countries where the Directive has been fully implemented	**Inconclusive**; no evidence as yet that policy has been effective in achieving its environmental objectives in the UK although 80% of firms comply Some evidence of significant administrative costs to the sector, mainly record keeping	**Inconclusive;** some evidence of resource efficiencies but farmers are seen as price takers and the high economic costs are not believed to have been passed on to consumers Shift from less efficient to more efficient farms, shift	**Diffusion effects** **Positive to some extent;** Uptake of new technologies and improvements in resource efficiency - using optimum amounts of fertilizer, construction of slurry stores, commercialization of manure production	**Policy design** Stringency in specifying the approach or process Clarity, certainty and transparency of policy objectives and desired outcomes Flexibility for firms in choosing compliance options **Policy**	Firm and sector characteristics – available income for investment in R&D, farm size and nature, economies of scale Farm and soil characteristics

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
		from dairy to less intensive farming, shift in land use	**Innovation effects** **Positive to some extent**; Some evidence on specific innovations in the EGS sector – agronomic tools developed when the Directive was anticipated, penetration of precision manure application products in farms	**implementation** Information advice and guidance Engagement and awareness among firms in the sector **Enforcement** Agency latitude – enforcement is more effective when function is separate from the policy maker **Policy stand alone/mix** Capital grant scheme to support slurry store construction worked well	

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
The impact of IPPC on competitiveness and innovation with particular regard to the food and drink sector	**Inconclusive and too early** for the food and drink sector as ex ante evidence but positive for other sectors such as pulp and paper where the regulation has been in operation was some time	**Inconclusive**; positive effects observed in other sectors such as cement and pulp and paper but only for process related BAT measures; mixed evidence on secondary or end of pipe measures Too early to say about the Food and Drink sector but some evidence on high application costs Some evidence on improved resource efficiency First mover advantage among firms in sectors using water and energy where cost savings are likely to occur Older and smaller plants at risk of closure	**Diffusion effects** **Positive to some extent**; some evidence on take up of specific technologies already available in the market	**Policy design** Flexibility in allowing firms to reach the frontier (BAT setting minimum standards to be reached for all firms) Flexibility to choose from market ready and available technologies Acknowledges contextual plant and spatial conditions **Policy implementation** Speed of implementation Variation in terms of implementing the regulation in EU countries The ways in which BAT conditions are determined nationally Effective Information flow/generator Effective engagement with industry	Market structure, industry structure Firm size and the ability to invest in minimum R&D BAT associated costs of technologies Sophistication and skills sets of employees Organisational structures Timing and investment cycles

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
Energy Labelling with particular reference to the EU Energy Labelling scheme- cross-border comparison of the design and competitiveness impacts of the scheme	**Positive**; UK EL in conjunction with minimum standards has enhanced energy efficiency in household appliances	**Inconclusive;** Price competitive market but evidence may suggest market transformation and consumer demand could both drive productivity improvements	**Diffusion effects** **Positive to some extent;** firms adapted suitable technologies as a result of the label; also diffusion of energy efficient appliances in wider product markets **Innovation effects** **Positive to some extent**; production of energy efficient appliances inducing market transformation However, limited as a result of non stretching nature of standards and more emphasis on 'cutting out the bottom of the market' Also standards not being updated since 1999 and hence not taken into account changing consumer preferences and market transformation	**Policy design** US Energy Star has dynamic grading and targets that allow for updating to promote innovation **Policy implementation** Staging the introduction of EL in advance of the minimum standards induced the process of market transformation) Industry is also given the opportunity to develop voluntary schemes in advance of the statutory measures to gain first mover advantage **Stringent enforcement and monitoring** **Policy stand alone/mix** EL would not have been effective as a stand alone instrument	Consumer preferences, energy prices, general technological progress, product and price competition

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
				Technology procurement mechanisms used effectively used in the US in the case of Energy Star	
Relative merits of the Renewable Obligation (RO) regulation in the UK versus Renewable Energy Feed in Tariff (REFIT) in countries such as Germany with regard to innovation in renewable technologies	**Positive to some extent**; RO has engaged the six main electricity producers in the UK and doubled the production of renewable energy in the first three years of operation German REFIT enabled significant increase in wind power capacity compared to UK RO was found to be not more cost effective overall when compared to the German REFIT system, although the former can drive down costs of production for generators due to its market based nature.	**Positive to some extent and more for REFIT than RO**; RO created a market for the most efficient and productive firms in the renewable sector It is believed to have induced competition among generators to increase efficiencies and reduce costs RO also resulted in consolidation of the market and generating vertically integrated electricity supply Associated growth in environmental consultancy market Under REFIT, high fixed prices for renewable generators could have resulted to productivity	**Innovation effects** **Positive to some extent but REFIT more successful** ; RO designed to further the development of advanced but near available technologies REFIT has been more successful in developing markets for embryonic technologies such as photovoltaics	**Policy design** Targets set for specific technologies in REFIT but technology neutral for RO RO tended to encourage market ready technologies only Price security (long term contracts between generators and suppliers of renewable technologies in case of REFIT) Price certainty, security and obligatory purchase in case of REFIT **Instrument choice** - ROC design may discourage investment as prices would fall as	Access to the grid and effective planning process Wider government policy on climate change

Case study	Policy effectiveness	Productivity/ Competitiveness Impact	Impact on technology diffusion /innovation	Key regulatory characteristics influencing relationship	Other key drivers
		improvements		supply increases But RO not more cost effective than REFIT **Policy implementation** Simple structure and low administrative costs in RO Advance notice and extensive consultation for RO **Stringent enforcement in RO** **Policy stand alone/mix** Complementary policy instruments (REFIT includes access to interest free loans proposed revised RO combined with capital grants) Integration with other policy options	

4 Assessing the influence of regulatory form on innovation and competitiveness

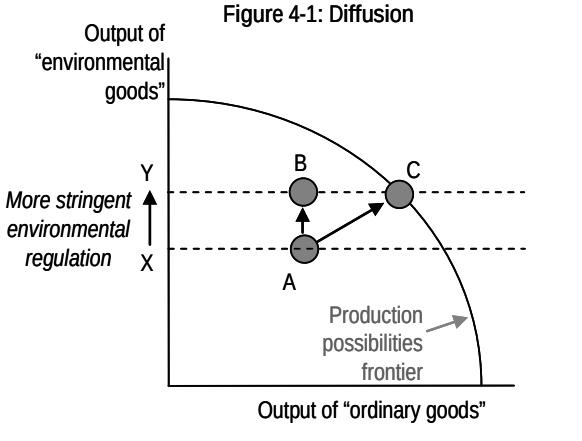
Introduction

4.1 The distinction made in Section 2 between the diffusion of technological change (moving to a production possibilities frontier) and innovation (moving the frontier) is fundamental in understanding the potential contribution of regulatory form to increased productivity. Several of the case studies deal with environmental policy instruments whose effect has primarily been through diffusion (i.e.Nitrates, IPPC). Others provide evidence more closely related to induced innovation (i.e. EPR, Energy Labelling, Renewable Obligations) and there are some that deal with both (i.e. SO_2 and NO_x regulations, Energy Labelling).

Technology diffusion – moving to the frontier

4.2 There is a trade-off that has to be made in using diffusion as a mechanism to achieve more stringent environmental regulations. Put simply, the trade-off is between the following two approaches:

Figure 4-1: Diffusion



- On the one hand, the environmental objective could be achieved speedily by requiring the diffusion and adoption of readily available technologies – mainly of an 'end-of-pipe' form. This is represented in the figure as a move from A to B where the output of ordinary goods remains unchanged. Given that the higher output of environmental goods will incur costs for the business, the effect on productivity is likely to be adverse. However, this is a much simpler approach from a regulatory point of view.

- On the other hand, the objective could also be achieved by encouraging the adoption of practices that change the way businesses operate and enable them to increase the production of ordinary as well

as environmental goods (to point C in the figure) – hence, offering better prospects of productivity gains. This approach is not so straight-forward from a regulatory perspective because it requires firms to be persuaded to make transformational changes to the way they carry out their business and is likely to be a slower process.

4.3 From the evidence of the case studies, the regulatory aspects that are most likely to prompt diffusion along the lines of the second approach are as follows:

- Policy design
  - Stringency with regard to the policy objective and being unequivocal about the policy intention
  - Provision of flexibility in enabling firms to choose and apply technological options in a cost effective manner
  - Provision of flexibility in terms of setting minimum standards and allowing firms to achieve the frontier
- Policy implementation
  - Setting up and facilitating information flow and networks around suitable technological options
- Stringency in enforcement and monitoring of firm activities

Stringency of the policy regime

4.4 Stringency of regulatory intent to achieve the desired environmental outcomes can spur diffusion of existing technologies by necessity. It forces firms to plan ahead with regard to investment in technologies for compliance, although it is often associated with lower financial benefits and higher costs of compliance. This characteristic can be an important feature of policy regardless of whether it is technology forcing or outcome based in nature but, when coupled with speed of implementation of a specific set of technologies, it may well be associated with adverse efficiency effects.

4.5 The strong and unequivocal intent of the German GFA-VO legislation for SO_2 was to achieve ambitious environmental targets quickly. It proved to be successful in speeding up the diffusion of advanced SO_2 systems on a large scale as all plants had to be retrofitted accordingly. Firms were also offered a short time to comply. The Ministry set strict standards even when they required technologies that were either not available at that time or not well

tested. It insisted that abatement technologies were implemented and consulted with suppliers to ensure that they had their support in delivering the goods.

4.6 However, the downside was that, at the time when GFA-VO was implemented, knowledge of end of pipe technologies and especially the use of desulphurisation technologies was limited and restricted to additive technologies and wet flue gas scrubbing used in Japan. In order to meet the requirements of the prescriptive and strict regulation, plant operators had to ensure that their plants were retrofitted quickly, which put immense pressure on FGD suppliers, and quality of equipment suffered as a consequence according to some sources of evidence.

4.7 The EC Nitrates Directive was implemented in different forms and with different levels of stringency across the EU Member States. For example, Denmark has taken a more stringent approach across its whole territory compared to other States, which involved designating the entire country as a Nitrate Vulnerable Zone. The take up of specific technologies such as precision manure application equipment has been faster and more widespread in Denmark, because of greater clarity about the intended stringency of the regulation. There is no evidence on cost effectiveness of the Danish implementation of the Nitrates Directive.

Flexibility in technological options

4.8 An instrument that offers flexibility with regard to options to invest in cleaner processes and adoption of suitable technologies is effective in inducing diffusion. Unlike prescriptive policies, flexibility in instruments can provide firms the right incentives for cost savings while adopting technologies to comply.

4.9 It also appears to be the case that such flexibility is more likely to induce efficient technology diffusion decisions under market based instruments than under command and control approaches although they can feature in both of these types of instruments. This characteristic is also more likely to be a part of an outcome based regulation, regardless of whether it is market based or direct regulation, although our evidence suggests that it is more likely to be designed within the former than the latter.

4.10 In the case of trading of SO_2 in the US under the Clean Air Act, firms had options to choose a range of technological options, i.e. retrofit plants with flue gas desulphurization (FGD) or use low sulphur coal that reduces emissions overall. They were also able to bank any unused emission allowances from one year to the next, allowing them to plan their investments inter-temporally

while meeting the environmental objectives. The choice of whether or not to adopt a "scrubber" to remove sulfur dioxide — rather than purchasing (more costly) low-sulfur coal was more sensitive to cost differences (between scrubbing and fuel-switching) under the tradable permit system than under the earlier emissions rate standards that were in operation prior to the trading system.

4.11 In the UK, the flexibility offered to plants under the original Large Combustion Plants Directive (each company could swap quotas allocated to them so long as annual emissions limits for plants were not exceeded) allowed the largest players to absorb their abatement costs, with some smaller than average plants closing, leaving a concentration of larger and more economically efficient plants in the electricity market. However, there were external factors in operation such as the privatization and the liberalization of electricity markers in the UK that may have driven down costs of abatement at the same time.

4.12 But, direct control instruments can also offer some degree of flexibility in terms of compliance options, albeit with regard to readily available technologies. For example, BAT under IPPC sets guidelines for individual plants to decide the production paths/abatement technologies that they can opt for to achieve prevention as well as control of pollution. It, therefore, seeks to combine the two approaches to diffusion outlined earlier. It also provides a single framework for addressing a number of environmental problems and helps to consolidate rather than proliferate environmental regulations.

Flexibility in allowing firms to achieve the frontier

4.13 As well as allowing flexibility in the choice of technological options, the form of regulation can also provide for a flexible implementation process. To achieve diffusion of both end-of-pipe and cleaner technologies, the role of the regulator must be to facilitate the process by working with the regulated businesses (being on their 'side') without diluting the competitive pressures on the more inefficient firms.

4.14 Under IPPC, operators that go through a permitting process must apply "Best Available Techniques" and meet other requirements, taking account of local contextual factors. The differential cost structures of operations cannot be used as a reason for not achieving the environmental frontier. But, of course, it may be the reason that the operation fails or would not be compliant once it was achieved.

4.15 The regulator under IPPC can also refuse permits when it thinks that the operator may not comply with the conditions based on environmental and location specific factors as set out by the regulator. At the same time, it provides firms with the flexibility of achieving the frontier in a cost effective manner through the adoption of BAT as it sets the minimum standards that encourage firms to approach the frontier. Regulators must see that BAT in itself may induce failure to comply which could in turn lead to site closure, but that it may still adopt a facilitative and cooperative role with regard to operations that are less efficient.

4.16 Stakeholders consulted as part of the study were of the view that this element of BAT could have a positive influence on diffusion of available technologies. It will also make sure that all companies move at least to a common baseline of environmental performance so that bad performers do not distort the market or competition.[10]

4.17 In the case of the Nitrates Directive in the UK, the regulator designates Nitrate Vulnerable Zones under the Nitrates directive and farmers located within the zones must apply Action Programme Measures to reach the targets set in the Directive. Action Programme measures promote best practice in the use and storage of fertiliser and manure and build on the guidelines set out in the Code for Good Agricultural Practice for the Protection of Water.

4.18 The Directive provides for some discretion and flexibility over the content of Action Programme Measures although there are certain measures that must be included. Farmers are encouraged to achieve the technological frontier over time, enabling them to perceive the costs of doing so and making the appropriate exit decision if necessary. The Government also encourages farmers outside of the NVZs to follow the voluntary Codes of Good Practice for the protection of the environment. This is intended to help prevent nitrate levels rising to the point where regulation becomes necessary.

Creating information networks

4.19 Imperfect information about available technologies and uncertainty about costs can lead to reduced adoption of technologies by firms. Hence one of the basic functions for the regulator will be to establish and develop effective information network by which information is generated about alternative solutions at specific sites, shifted toward a centralised information hub and then diffused outwards again to firms considering the options to adopt. Some of the case studies show that there is both the need for the hub (regulatory

[10] There was some, albeit limited evidence that this was the case for the Food and Drink sector for specific technologies.

function) and an incentive system that will move the information back and forth across the network.[11]

4.20 This was most apparent in the BAT discussion under IPPC, and the explicit development of BAT Reference Documents. A key feature of the IPPC Directive is to stimulate an exchange of information on Best Available Techniques between European Member States and the industries falling within the scope of the Directive. At the European level the EC issues a BAT reference document (BREF) for each sector. The Bureau carries out its work through Technical Working Groups (TWGs) comprising nominated experts from EU member states, industry, and environmental NGOs. BREFs bring together technical and economic information and are not legally binding.

4.21 The role of the permit system may be seen as one of compulsory information generation and sharing (providing the incentives to share information). This would enable policy makers to see that the permitting system needs to be an ongoing process, by which the agents are continually asked to update information and provided with the need to check their information against that existing at the hub.

Facilitating information flow

4.22 This sort of system emphasizes the role of the regulator as a facilitator of information flows. This was most apparent in the Nitrates case study. Stakeholders consulted as part of the study believed that the way in which the Directive was enforced encouraged take up of best practice approaches and innovative technology rather than imposing prescribed and 'quick-fix' solutions through a sanctions approach. The Environment Agency worked with farmers to advise on, and provide information about, techniques to assist in compliance and a Defra-funded portal for cross-compliance was also set up to facilitate the process of information exchange and technology transfer. The compliance process is in advising and guiding the agents toward the best information and practice. The emphasis is on the development of cooperative relationships that enable all parties to see clearly the practices that are taking place across the industry.

4.23 Raising awareness about the design and implementation of the policy as well as the potential benefits of compliance was identified in several case studies as a significant supporting measure, especially in markets that are mostly driven by consumer preferences and demand. In Packaging Waste, media campaigns aimed at stimulating consumer awareness and, hence, demand

[11] The importance of information flows as a mechanism for achieving the regulatory purpose has been recognised in the literature where 'informational regulation' has been suggested as an alternative or supplement to conventional regulation (Sabel, Fung and Karkkainen (2000)).

for packaging was particularly likely to influence packaging design. Similarly, the use of additional marketing to raise the awareness of an energy label and its contents could influence preferences and lead to an increased pressure on manufacturers to produce only the most efficient appliances.

Stringency of enforcement and monitoring

4.24 Effective enforcement and monitoring and frequency of inspections can be significant determinants of take up of compliance technologies. Not only do they send strong signals about policy intent and the desired environmental outcomes but they also can provide information about solutions being adopted successfully by leading businesses. This characteristic is an important feature regardless of whether the instrument of choice is market based or direct regulation.

4.25 In the SO_2 and NO_x case, one of the key success factors of the German GFA-VO direct regulation was its effective monitoring and enforcement system. The regulation stipulated specific monitoring and reporting requirements from plant operators which induced them to install equipment and prepare regular reports for the supervisory authority. Over time, these systems became more sophisticated, automated and reliable, enabling swift detection of non compliant firms.

4.26 The cap and trade program for SO_2 in the US also put an emphasis on monitoring through continuous emissions monitoring systems (CEMS) and there were detailed and well maintained emissions tracking systems that were publicly available. There were also automatic penalties when there was non compliance.

4.27 Stakeholders consulted as part of the Nitrates case study confirmed the view from the literature[12] that enforcement is more effective when its function lies with a body other than the policymaker. For example, one industry association reported that enforcement has been more effective in England, where it was led by the Environment Agency, than Scotland, where the Scottish Executive Environment and Rural Affairs Department (SEERAD) is in charge of the enforcement rather than SEPA.

Summary

4.28 The evidence reviewed from the case studies suggested that the trade-off set out earlier between the two approaches to diffusion as a means of achieving environmental outcomes was not just theoretical. Whilst facilitation of

[12] Keyworth *et al* (2005) argued that 'the emergence of autonomous regulatory agencies with delegated powers has facilitated the development of more professional, less politicised and more consistent regulatory policy.'

information networks and flows are central to both regulatory approaches, diffusion which brings about changes in business processes through the adoption of cleaner technologies is more likely to have beneficial effects on productivity and business performance.

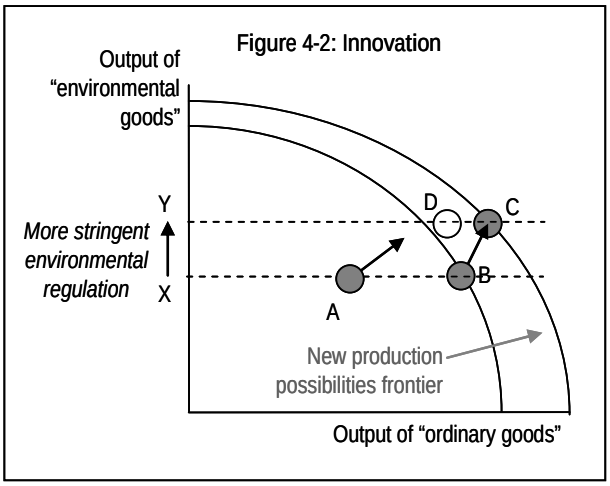
4.29 By contrast, 'technology forcing' approaches, especially through the adoption of end-of-pipe equipment and systems, is more likely to have adverse effects on competitiveness. This should not be taken to mean that diffusion of end-of-pipe technologies is an inappropriate solution to achieving environmental outcomes. It may be the best technological solution or the most cost-effective and it may work most effectively and quickly to achieve the objectives of the regulation. It may also be the solution that is preferred by business, especially SMEs, if it creates more certainty and helps them to identify solutions to the environmental problem being addressed (they know where they are and what they have to do).

4.30 However, if regulation is to secure economic outcomes in the form of increased productivity at the same time as it achieves its environmental purpose, it should provide flexibility in the choice of technological and other solutions and, through the regulatory process itself and/or the provision of complementary networks and facilities, encourage flows of information about the available solutions and their respective costs and benefits.

Technological innovation – moving the frontier

4.31 Prompting innovation through regulatory means is likely to be more difficult than encouraging diffusion. It requires a shift in the production possibilities frontier so that efficient businesses (at point B in Figure 4-2) can increase their output of both ordinary and environmental goods (to point C), less efficient firms (like those at A) can be pulled towards the new frontier, and start-up businesses (at D) are created around the new possibilities. Regulation can do this (although rarely on its own) by changing relative prices and effectively conferring property rights on those businesses most adept at economising the use of the relevant environmental resource. For this to happen, some firms will have to invest heavily in research and development (R&D) and be prepared to commit over the longer term to the

Figure 4-2: Innovation



exploration of the range of potential substitutes for the resource and new ways of working and using both established and new technologies.

4.32 Innovation is more likely to be prompted if the regulation has the following features:

- Design
  - Clarity in defining the environmental problem, identifying the relevant environmental resource and communicating what has to be achieved and the range of possibilities for doing so;
  - Stringency with regard to the policy objective and commitment in unequivocal ways about the policy intention and mechanism over time;
  - Certainty about the desired policy outcomes and the time frame for compliance – providing signals and commitments about use of alternative sources efficiently.
- **Implementation** through industry engagement with clear and advance warning to provide adequate lead times for investments to be made and implemented and supported by a mix of complementary policy measures.
- **Enforcement and monitoring** to ensure that the promised incentives apply and that non compliance cannot be an option.

4.33 Each of these features is discussed in the following sub-sections.

Clarity in defining the environmental problem

4.34 The regulation must be specified in a way that makes it absolutely clear what primary resource is to be conserved and what environmental problem is to be addressed. Firms will not make the necessary R&D and other long-term investments unless there is this clarity of policy purpose and focus. Such investments are risky at the best of times and the risk boundaries need to be minimized as far as possible. This is not easy especially over the longer term required by typical investment cycles in new technologies – often longer time horizons than are usual for policy-makers.

4.35 There were two different original environmental aims of the packaging waste regulations: reducing waste (through design changes and use of different materials) and achieving recovery and recycling targets. The resource to be conserved is “waste space” (whether in land, air or water). Evidence suggests

that while the EPR regulation has been successful in terms of increasing recycling to meet stringent targets, it has been less successful in terms of reducing over-packaging or dealing with problems of inefficient design.

4.36 The EU Packaging Waste Directive uses a surrogate target (weights of various types of packaging) as a proxy for defining the environmental problem, rather than an environmental outcome target that clearly defines the problem to be addressed and puts a price on them (i.e. reducing waste space or landfill, and increasing recycling). As a result, it tends to prompt a wide variety of response mechanisms such as approaches to reduce weight in packaging and reduced use of specified packaging materials but very few directly related to minimizing use of packaging itself or tackling problems with reducing waste through design changes and encouraging use of recyclable packaging.

Stringency of the policy regime

4.37 In order to induce innovation, the regulator must make it clear that there is limited or no room for maneuver or negotiation by which the imposed resource constraint can be avoided by the regulated. One of the arguments against self-regulation and voluntary agreements is that they provide the opportunity for the private sector to escape the rigours of the regulation by opting for minimal compliance levels that can relatively easily be accommodated and don't require ongoing innovation and change. Since the objective is to induce long term investment in environmental problem solving, the regulator must make a long term and hard commitment to requiring those solutions to be explored.

4.38 The EPR case study provides an example of where responsibility for compliance was taken out of the hands of individual businesses through the creation of compliance schemes ((by the purchase of the tradable instrument (i.e. Packaging Recovery Notes - PRNs) and, as a consequence, may have limited the degree of innovation that took place. Although the PRNs were designed to minimise the generation of packaging waste at source (because the producer pays according to the amount they produce), the compliance schemes effectively took direct responsibility away from producers and did not encourage their innovation in waste minimisation or product recyclability. As Smith (OECD, 2005) pointed out *"… the incentives for a producer to design products that will have low waste management costs will be sharper if the waste management costs savings translate directly into lower contributions to the running costs of the Producer Responsibility Organisation (PRO) [compliance scheme]. If all firms share PRO costs equally, without regard to*

the waste management costs of their products, the incentive for an individual firm to make waste-reducing product changes may be small".

4.39 The incentive to innovate will also be reduced where the environmental outcome targets are set at levels that can be met by use of available technologies. Although this would encourage diffusion, a regulatory strategy to prompt innovation might be to follow effective diffusion with the setting of more ambitious targets, making clear that this was the policy intention in order to prompt leading firms to push at the frontier (Jaffe et al 2001).

4.40 The Energy Labelling case study provided an example of such a strategy and suggested a contrast between the UK and the US experience:

- The innovation that occurred in the UK household appliances sector in anticipation of the implementation of the Minimum Efficiency Performance Standards (MEPS) was thought to be relatively modest because of the non-stretching nature of the standards. The ceiling on the most efficient rating meant that, once a manufacturer had achieved this level, there was no longer a regulatory incentive to innovate further.

- On the other hand, under the MEPS in the USA, targets were increased at the point at which previous targets were being met by appliance manufacturers. New standards were set at levels that existing products could not meet, thus inducing significant innovative activity by manufacturers to develop a generation of new products.

4.41 It was reported in the case study that the sequencing of the introduction of the Labelling and the standards was important in terms of regulatory effectiveness. It was considered most effective and least disruptive to the market to introduce the Labelling first in order to induce manufacturers to increase the energy efficiency of their appliances and then to introduce the MEPS to induce innovative step-changes that removed inefficient products from the market.

4.42 Stakeholders in the UK were of the view that, in future, it will be important to learn from the US example – setting a clear agenda (with indicative future targets), ensuring that the targets are stretching, and putting in place a timetable of regular reviews to take account of product developments and changing consumer preferences.

Long term policy commitments

Certainty on environmental outcomes

4.43 The effective inducement of innovation by regulatory means will require the policy maker to offer regulated businesses long term horizons within which there would need to be a phasing of the targets to enable the broadest possible range of technologies to be considered (e.g. over 10 year, 15 year, 20 years) and incentives for early achievement of targets. This can be achieved either by announcing discrete time targets and review points or, as in the case of regulated prices, by means of a technological escalator.

4.44 The EU Energy Labelling directive appears to be a good example of this kind of approach. It specified a set of targets but also developed a standard that allowed for an innovation escalator of 10-15% in the average efficiency of new appliances to get rid of the bottom end of the market. Although the Label has not been subject to review since its inception, two further categories were added to the efficiency rating scale at the top (A*, A**) which effectively pushed the frontier out further (under this Labelling scheme).

4.45 Similarly, the US MEPS ensured that the 1990 standards required a 10% improvement in efficiency, forcing the least efficient models out of the marketplace. The 1993 standards were set at a 30% improvement level which further induced firms to develop and invest in a generation of new products. The announcement of the system in advance meant that firms in the affected markets knew precisely what return will be available in 5-10 years if they initiated a new 5 year investment programme at the time the label was introduced.

4.46 One of the conclusions from the policy workshop was that, if regulation was to be effective in encouraging innovation, it not only needed to build certainty into regulatory intentions and practices but it could also provide assurance to leading businesses that their innovations would become accepted as industry 'standards' for dissemination to the 'laggards'.

4.47 Jacobsson and Bergek (2004) state that the transformation of the energy sector post 2020 depends on a range of policy initiatives taken today, and, as early as several decades ago. Policy-making must therefore be conducted with a very long-term perspective. In studying the mechanisms that have either induced or blocked the diffusion of renewable energy technologies ranging from awareness, institutions and networks, prices and infrastructure the authors find that government activity has been a major inducement mechanism, primarily by stimulating market formation or 'lead markets' through R&D funding, financial incentives, and creating 'early legitimacy' for renewable sources among firms and consumers

4.48 The implementation of Nitrates Directive in the UK, on the other hand, appeared to lack the required certainty and clarity in policy intention to persuade the industry that things really would have to change. Thus, it was reported that the industry as a whole did not believe that the NVZs would be extended to cover the area they occupied or that the stricter measures on storage requirements would be imposed in October 2002. As a result, the long notice period did not appear to have positively influenced the sector's ability to adapt to policy either because of insufficient policy clarity or because the industry was then going through a bad time. As it transpired, by the time the agriculture industry was fully aware of the compliance issues and tried to come to terms with their implications for its business, its ability to comply was constrained by rapidly declining profit margins facing the industry.

4.49 There is a trade-off to be made between, on the one hand, providing long term certainty about the regulatory requirements and, on the other, allowing for regular updating of the requirements in the light of changing circumstances. This problem of 'time consistency' plagues the design and delivery of regulations that seek to change long-term investment behaviour. Firms investing over a five year period, only to find a mid-course regulatory correction eliminating their anticipated gains, are likely to be deterred from investing again.

4.50 The different regulatory regimes for encouraging innovation and development of 'renewables' exemplifies the ways in which this trade-off can be managed.

- The Renewables Obligation (RO) in the UK requires electricity companies to source an increasing proportion of their supply from renewable technologies over the period 2002-2027 and, hence, was intended to bring about long term market security for the suppliers of renewables. However, the consistency and continuity provided by the Renewable Obligations through its long term targets appeared to have been accompanied by frequent reviews of the instrument, which industry stakeholders viewed as creating uncertainty and adversely affecting investor confidence.

- The Feed in Tariff system in Germany (REFIT), on the other hand, conducts a review every other year to take into account the technological and market developments, which may affect the price guarantee offered as part of the instrument. However, these changes are only meant to be relevant for plants that have not been

commissioned to date in order that certainty is maintained in the established market.

4.51 Another example of where certainty can be combined with regular reviews with a defined purpose can be found in the dynamic grading system and regular updating of policy of the US Energy Star label. The minimum level for this voluntary label is updated whenever there is a significant change in specified market conditions. But this procedure was built into the regulation from the beginning and firms participate in providing information to policy makers about relevant technology developments. This not only helps to manage uncertainty but also creates an incentive for businesses to innovate to influence the setting of the 'standards'.

4.52 The trade off between long term commitments and the need to accommodate changing circumstances will need to be managed particularly effectively in sectors such as power generation where investments in R&D and capital can have 30 year horizons. Where there is uncertainty about the long-term relative charges for waste and by-products (whether nuclear waste, SO_2, water run off), the regulated businesses are more likely to chose the option of purchasing end-of-pipe equipment or processes (e.g. FGD equipment) or forms of substitution (e.g. fuel substitution) rather than investing in high risk pollution prevention technologies.

Sending the right price signals

4.53 Long term price commitments also appear to be crucial when the environmental outcome requires substantial investment in creation and development of future technology markets. In terms of their design, both the German Renewable Energy Feed in Tariff (REFIT) and the Renewable Obligation in the UK is intended to move the frontier by creating incentives for firms to invest in, develop and use renewable energy technologies.

4.54 The German REFIT enables the government to legally guarantee renewable energy producers access to the power grid at a guaranteed price. It seeks to increase the amount of renewable energy by creating certainty and security in the market through the setting of a fixed price, thereby ensuring a fixed rate of return for investors. As the renewables energy market is currently not competitive with the traditional energy market, REFIT sets the price of electricity higher than the traditional price, creating the necessary incentives for the production and investment in renewable energy.

4.55 The RO is based on market based principles, using tradable certificates that allow the demand for renewable energy to be determined using the market. The RO has created a market to sell renewable energy, where in practice; a

significant number of generators are engaged in long term contracts with suppliers through the ROC market. The instrument has been effective in establishing a demand for renewable energy and a supply chain between electricity suppliers and renewable generators. It is important to note that the market has only favoured those technologies which were close to market and in that sense have enhanced the rapid development of only a small number of technologies e.g. on-shore wind and landfill gas and did not attract investment into high risk technologies that were at an early stage of development. Therefore, although there was some shift of the frontier, it was more limited as a result of bring driven almost entirely by near deployment ready technologies.

4.56 On the other hand, the German REFIT, characterized by price certainty, security and obligatory purchase of all renewable energy resulted in development of embryonic technologies and larger number of long term contracts, albeit with substantial financial support from government. The removal of price risk within the REFIT system is likely to benefit both small and large generators, with smaller players being more risk averse and require more certainty to join a market.

4.57 Evidence from the case studies also suggests that, where economic instruments are used to assign a price to the environmental resource that is being targeted, the market mechanisms need to operate effectively in order that firms trading in the market have the right incentives to innovate and invest in technologies. This was most apparent in the EPR and UK Packaging Waste case study where obligated companies need to hold enough Packaging Recovery Notes (PRNs) to meet their recycling obligations by trading with accredited re-processors.

4.58 PRNs are, in principle, a good way of encouraging more environmentally friendly companies to make additional profit over environmentally unfriendly companies. In terms of planning, this allows business-support organisations (e.g. Envirowise) to put a value on the implications of redesigning packaging, to which firms can more readily respond (Envirowise has recently helped a relatively large company make £100,000 savings by light weighting their packaging). However, in practice, firms often view PRNs as a fixed cost they have to pay and do not consider the fact that they could take actions to reduce this cost.

4.59 The price reflects both how high the EPR target is for individual sectors, and how achievable it is. Initially the PRN values were virtually uniform at the outset, although now there is more differentiation between the sectors: wood has very low prices (targets are easily achievable); glass and metals are increasing in price (due to high targets). However, changes to the regulations

4.60 The variability (and unpredictable nature) of PRN prices makes it difficult for reprocessors to plan income and, consequently, investment. It could be helpful therefore to implement some sort of price floor and ceiling for PRNs. In practice it would be difficult to devise anything more fixed in a competitive marketplace, and the PRN market was established to be an independent market.

4.61 On the other hand, the PRN was designed to be an evidence note, rather than to be used as a 'commodity'. However, whilst reprocessors are required by the regulation to reinvest PRN income into capacity-building (e.g. commercial collection, increased volumes, and different types of waste), this is difficult to monitor and enforce and some reprocessors may simply view PRNs as an alternative income stream.

4.62 On the whole, there has been no reduction evident in the amount of packaging placed on the market. This suggests that the costs imposed by the regulation are not sufficient to persuade firms to reduce the overall amount/weight of packaging they produce. Further, by delegating all of their responsibilities to compliance schemes and reprocessors, producers may lose the incentive to improve environmental performance[13].

4.63 Stakeholders were of the view that whilst the PRN mechanism is seen as a positive one, the PRN price needs to be higher than it currently is to encourage producing firms to cut back on packaging and change their behaviour. A more stable market would allow reprocessors to plan income and investment accordingly.

Advance warning and prior notice

4.64 In conjunction with sending out long term signals about policy commitments, advance warning and prior notice of the regulation provides firms with the opportunity to plan their investment activities effectively and cost effectively, in order that benefits can be realized in the future.

4.65 Discussions with stakeholders indicated that manufacturers were warned well in advance of implementation of the Label and hence sought to re-design their products and absorb the impact of the regulation prior to its implementation. Industry was also largely aware that the Energy Labelling regulation would be closely followed by the introduction of MEPS and as a result sought to up-grade or remove inefficient models from their production lines in anticipation.

[13] EEA, 2005

4.66 In the case of Renewable Obligations, several rounds of consultation were held during the policy design stage that included a preliminary exercise to discuss the role of RO in tackling climate change, a second consultation with more details about the policy and another consultation that proposed the mechanisms by which RO would work in practice. It was largely felt that the development of RO had been subject to a comprehensive consultation exercise that benefited the overall shape of the policy. Stakeholders also highlighted the importance of advanced prior notice as a means of facilitating the ability to create long term investment and generate first mover advantage. Statistics from the British Wind Energy Association reveals an increase in the number of planning applications after the announcement and prior to the implementation of the RO.

4.67 Advance warning and prior notice often have to go hand in hand with signalling long term commitments to policy intention in order to move the technological frontier of firms involved. In the case of the Nitrates Directive, despite a long notice period and an extensive consultation exercise, uncertainty with respect to future changes to the regulation and who it may affect contributed to low take up of technology and farmers being deterred from investment in new technologies.

Stringency of enforcement and monitoring

4.68 Stringent monitoring and enforcement by way of inspections and penalties appear to go hand in hand with other design and implementation characteristics, prompting firms to innovate in order to comply with the regulatory requirements at hand.

4.69 In the case of EPR, through joining a compliance scheme, businesses transfer the legal liabilities associated with the regulation (i.e. the implications of failure to recover and recycle). Until recently there was no effective way to discipline those schemes not achieving targets. There have been examples of companies not taking the regulations seriously (believing that they would not be prosecuted if they did not comply). There have also been problems with differences in local interpretation, and some instances of fraud have also been uncovered (particularly in the plastics sector, most likely because of a plethora of smaller firms). However, the vast majority of the movement of PRNs is genuinely sourced[14], and the system has become much tighter. A potential fixed penalty notice-type enforcement of administrative issues is being considered, which could make the regulation more streamlined.

[14] pers. comm. EA (February 2007)

4.70 Evidence from the case studies suggests that there has been little enforcement of the actual ratings levels given to appliances by firms at the testing stage due to lack of budget at local trading standards office level. Also, there appears to be no effective enforcement of the label for products sold online or in catalogues. Anecdotal evidence from the case study also suggests that smaller retailers have not all consistently displayed the labels correctly throughout the lifetime of the policy, and enforcement has been fairly light touch. Stakeholders consulted as part of the Energy Labelling case study stressed that it is imperative that MEPS is strictly enforced in order that manufacturers and retailers are less tempted to display and produce inefficient products, and market transformation takes place.

4.71 In the case of IPPC, the food and drink industry in Belgium has been able to introduce major innovative processes where water limits for industrial usage was strictly enforced and companies were forced to reduce waster usage.

Engagement with industry

4.72 Effective and continuous engagement of the regulator and enforcer with industry was viewed as a key factor in driving innovation.

4.73 Stakeholders consulted as part of the Energy Labelling case study were of the view that the Energy Label and any accompanying instruments must be valued by industry to ensure that they create a pressure on firms that they represent to acquire the highest level of efficiency and enable manufacturers to use the label as an 'environmental kite mark'.

4.74 In the case of EPR and UK Packaging Waste, government strategy was aimed at creating a system that was supported by industry, and according to Valpak (the largest compliance scheme), close collaboration between government and industry appeared to have a positive influence on the design of the system and regulatory burdens to industry.

A package of measures

4.75 Stakeholders consulted as part of the study across all case studies were unanimous in their view that stand alone instruments seldom prove to be effective in bringing about the desired environmental outcomes and inducing innovation and technology diffusion.

4.76 For example, a mix of mandatory and voluntary measures to tackle energy efficiency in products using Energy Labelling and standards has proved to be particularly successful in the US and has induced innovation in several sectors. Technology procurement mechanisms have been effectively used in the US alongside the Energy Start voluntary program where the purchasing

power of the largest buyer in the marker, i.e. the Government, was used to influencing endorsement of products in the market.

4.77 Whilst the IPPC Directive employs a dynamic definition of BAT, which allows for new technological developments and commercialisation, the BAT may be conceived as a static set of minimum standards at plant level. A study commissioned by the European Commission – Directorate General for Environment (2007) assessed what type of measures would encourage companies to go beyond the regulatory requirements of the IPPC and enhance the dynamic nature of the BAT. The study found that economic instruments such as taxation could provide complementary dynamic incentives to companies by internalising the adverse affect caused by the polluter within the cost function.

4.78 Stakeholders consulted as part of the Renewables case study acknowledged that RO was currently operating more as a stand alone instrument and would be more effective if it was implemented alongside a complementary set of measures that enabled the recognition and support of technologies at different stages of the life cycle, such as capital grants for embryonic technologies. The German system provides generators with the opportunity to access interest free loans to support the development of sites.

4.79 In some cases, aligning regulatory tools that have similar goals may achieve desired environmental and economic outcomes. In the case of packaging waste, consultees were of the view that a mix of tools that do not contradict each other is important; for example, the Packaging Essential Requirements regulations administered by Local Authority Trading Standards Officers could work with the Packaging Waste regulations to ensure that producers are persuaded to build essential requirements into their products as design stage.

Summary

4.80 The ability of regulation to induce innovation of a significance to shift production possibilities may be the most important way in which it can bring about productivity and performance improvements but it is hard to engineer. It requires clarity of purpose, focus and implementation process. It needs long-term commitments that extend well beyond the conventional horizons of policy-makers and a degree of certainty that may be uncomfortable for them over any length of time, especially where public sector costs are involved (e.g. for the REFIT price guarantee). Moreover, circumstances change and it will be appropriate to institute review procedures to change some of the regulatory parameters where necessary.

4.81 However, review points, triggers and procedures need to be built into the regulation from the outset, industry needs to be engaged in the process, and the passage of time must not be allowed to dilute the ambitious intent written into the regulation nor water-down the rigour of monitoring and enforcement. The inducement to innovation will need to be enhanced by complementary measures, e.g. through information provision and R&D support.

Other factors affecting diffusion and innovation

Level playing field

4.82 Evidence from the literature suggested that well-designed regulations can create a level playing field, stimulate innovation and achieve environmental outcomes at reasonable cost. Indeed, it indicated that any adverse impacts of environmental regulations on competitiveness can be mitigated via strategies such as international coordination and negotiation of the extent and nature of the regulation to be multilaterally agreed among competing nations and regions, and among competing firms and sectors. However, there could be problems of 'levelling up' or 'levelling down', and much international co-ordination tends to involve the latter, where EU regulation establishes a 'back stop' position that forces laggard countries to achieve a minimum position of stringency whilst a group of leading countries set the pace.

4.83 Under the IPPC, the EU has set common rules in order to create a level playing field for all industries and regulators. However, stakeholders consulted as part of the study were of the view that it would be more effective if EU member states had implemented the regulation in a similar way. The level of variation in member states is currently too great:

- Southern European countries have focused more on the economic feasibility of the policy in question and they consider that they have the right to impose less stringent environmental conditions in order to protect the economic impact on companies
- In some countries the implementation and enforcement processes may exist but industry is not aware of IPPC because government sees it as an administrative process rather than a regulator implementing IPPC on the ground and working alongside companies.

4.84 There is evidence of higher application costs in the UK compared to other member states in general, and in some cases this has had a negative impact on competitiveness in the context of global supply chains.

4.85 The EC Directive on Packaging and Packaging Waste aims to harmonise the management of packaging waste in the EU and increase recovery and recycling in a consistent way across all member states. It sets mandatory targets for the member states, while leaving the mechanisms to achieve these targets to the member states to decide. Stakeholders were of the view that UK has an issue in staying competitive in relation to other EU countries; there is not a level playing field and UK industry tends to struggle for survival when competing with foreign firms. Although regulation is not viewed as a key driver of innovation in packaging and waste, the different ways of implementing the Directive across the member states tends to affect competitiveness of trading firms to some extent.

4.86 The Nitrates Directive was implemented in different forms and with different levels of stringency across the EU Member States. For example, Denmark has taken a stringent approach across its whole territory, which involves emission permits and heavy taxes on farms exceeding the permitted level. In France, implementation and enforcement has been decided at regional level; and in Germany complementary subsidies have been introduced. These differences to some extent contributed to a lack of level playing field for farmers across the borders.

4.87 Participants at the stakeholder workshops held as part of the study were strongly of the view that an instrument should ideally take into account, and learn from the experiences of other EU countries lessons and approaches in implementing an instrument, be more flexible and adopt new strategies according to learning from previous errors of judgement. This will help reduce any unintended negative effects of not achieving a level playing field.

Market, firm and sector characteristics

Firm characteristics

4.88 Environmental policy design is intended to incorporate impact on small firms. Indeed the Impact Assessment Tool asks policy makers to conduct a Small Firms Impact Test as part of an ex ante assessment of regulatory impact. Evidence from several of the case studies suggests disproportionate impact on smaller firms as an unintended consequence of the regulation in question.

4.89 In the case of EPR in the UK, the main target for the regulation is larger businesses as a minimum threshold applies relating to the amount of packaging and annual turnover, intended at reducing the regulatory burden of smaller business. However, Defra's mini Regulatory Impact Assessment (RIA) concluded that increasing targets may result in some change in the market structure if those manufacturers whose output is at the edge of the obligation

were to reduce their output in order to fall within the 'de minimis' exemption and thereby avoid costs. Stakeholders were of the view that 'regulations are a daunting prospect for smaller companies' and the administration of record keeping may impose particular burdens for small firms. However, this effect is not expected to be other than small.

4.90 The EPR has also tended to favour retailers ('sellers') than others in the supply chain as they find it relatively easy to fulfil their obligations and have had more negotiating power to shape the regulations to suit themselves. The influence on competitiveness is likely to be greater for manufacturers of packaging and raw materials and 'converters', while packers and fillers bear much of the costs of the regulation.

4.91 An EU workshop on the 'Economic Consequences of IPPC' in 2002 concluded that there seems to be no one size-fits-all formula to assess the impact of BAT on the economic viability of industry, but there are a number of factors which could assist in making a more consistent and more transparent assessment of the economic consequences of the introduction of BAT:

- Five key economic criteria have been identified to make an in-depth economic assessment of an industrial sector namely, market structure, industry structure, resilience, BAT costs of total costs and speed of implementation
- Timing and investment cycles are important. It is important that a substantial renewal of plant machinery is an "optimal" moment in time to embody environmental investments, e.g. in BAT. Industries characterized by a relatively long investment cycle have less flexibility in 'combining' these investments compared to industries with shorter investment cycles
- Small and medium sized companies are potentially vulnerable. They typically lack capital stock and have limited R&D to respond to new regulation with innovations/adaptations.

4.92 IPPC in general tends to apply more to larger firms. Moreover, for the food and drink sector that operates on a low profit margin, there appears to be a significant gap between the resource efficiencies of large and small firms, particularly as 80% of the output comes from 20% of the plants. Most small plants survive on a day to day basis and investing in R&D or staff training for IPPC proves to be difficult.

4.93 The costs and impacts of the Nitrates Directive implemented in the UK have been different for different types and sizes of farms. Available income for investment in R&D or new technology is likely to influence the potential for innovation. Evidence from the case study suggests that innovation is more likely to occur in larger, more intensive farming which more closely resembles industrial production and where economies of scale allow swifter return on investment.

Market structure and characteristics

4.94 In some cases, regulation can alter the market structure in the affected sectors, including entry and exit of firms from the market. Hitchens et al (2001) found that a number of non BAT plants were at the risk of closure by the requirement to invest in BAT, although these were older and small than average, lacked the raw materials to increase production, had high water consumption and below average service/quality.

4.95 Following the implementation of the Large Combustion Plants Directive in the UK for reduction of SO_2 and NO_x emissions, smaller than average plants closed between 1990 and 1995, while the larger, coal-fired generating plants remained, allowing them the economies of scale to be cost effective.

4.96 In the case of German GFA-VO regulation of SO_2 emission, the construction of new plants and development of more environmentally friendly plants were postponed but only a minority of plants were closed or had their capacity reduced as a result of new limits. The market structure did not alter significantly and there was substantial investment in plants in the sector.

4.97 In the case of the implementation of the Nitrates Directive in the UK, it may be the case that within the overall resource efficiency improvements in the agricultural sector there has been:

- a shift from less efficient to more efficient farm operators (as those who cannot adapt are acquired or forced out of business)
- a shift from dairy to less-intensive manure-producing livestock or arable farming
- a shift in land use away from agriculture to other uses (such as recreational and residential).

4.98 Stakeholders indicated that these changes *are* taking place; and that the associated regulatory burden of the Nitrates Directive may be one of the many drivers of change. The net effect at UK level in cost benefit terms is however not yet clear; neither is the additional, discrete effect of the Nitrates Directive.

4.99 Evidence from consultations in the Renewable Obligations study suggested that RO has resulted in the consolidation of the market in a way, where a number of large suppliers have acquired renewable energy generators in order to create economies of scale. This has generated a set of vertically integrated suppliers; in 2004, nearly 70% of wind power capacity was owned by the four major electricity suppliers. Although this phenomenon may be a common consequence of competitive markets, this shift in market dominance may be particularly worrying for independent generators.

Other economic drivers

4.100 Evidence from the case studies strongly emphasized the importance of contextual factors driving innovation and productivity alongside, and sometimes, greater than, the environmental policy instruments in question.

4.101 For example, **consumer demand** was identified as the primary driver of innovation in the packaging industry –other factors such as greater fragmentation and intensified competition in the product market have all had a direct impact on innovation.

4.102 Evidence from the literature on energy efficiency policies and the views of stakeholders indicates the following drivers that tend to work in conjunction with environmental policies to induce energy efficiency:

- Ongoing technological progress
- Response to rising energy prices
- Competitive forces pressuring firms to cut costs including energy costs
- Consumer and retailer demand for more energy efficient products

4.103 Consultation with the US Environment Protection Agency (EPA) as part of the Energy Labelling study suggested that regulatory characteristics that induce consumers to demand more environmentally friendly products are most conducive to innovation.

4.104 **Technological change external** to the influences of regulation also tends to affect innovation and diffusion within sectors targeted by the regulation in question. The implementation of the Large Combustion Plants Directive in the UK coincided with the emergence of a new technology strategy for plants in the UK based on the rapid growth of Combined Cycle Gas Turbine (Eames, 2000 and Bio Intelligence Service, 2006) electricity generation. Stakeholders were of the view that most technology to some extent existed at the time when LCPD was implemented in the 1990s.

4.105 The German GFA-VO command and control approach to reduce SO_2 emissions proved not to be cost effective as retrofitting in plants was done swiftly and to target as a response to GFA-VO, but this came at a price. Suppliers of technologies were overburdened and quality was compromised as a result, which led to maintenance issues. There was little room for cost reduction due to the very nature of the regulation that imposed strict standards and aimed to achieve its environmental objectives in a technologically feasible manner, regardless of differentiating between abatement costs of technologies. However, the **market structure** in Germany was characterised by regional monopolies that were able to pass on these cost inefficiencies to customers, thereby maintaining their advantage.

4.106 Several key factors were identified as drivers of innovation in energy and especially electricity markets targeted by air quality and climate change regulations - future electricity demand, energy consumption, fuel switching, fuel prices and especially coal prices, UK policy on electricity generation mix, and recent and future policy on climate change, energy and technology.

Concluding observations

4.107 The findings from the case study evidence clearly indicate that there may be different sets of configurations of regulatory characteristics that are applicable to technology diffusion and innovation:

- A focus on the environmental outcome to be achieved along with provision of flexibility in choice of technologies for compliance, and information sharing particularly appear to induce diffusion of available technologies, prompting movements to the frontier
- On the other hand, stringent policy intentions, long term policy commitments and clear and consistent price signals, coupled with advance warning and long lead times are likely to bring about innovation in new technologies and shifts in the frontier itself

4.108 Stringency in monitoring and enforcement to ensure compliance is a significant driver for both technology diffusion and innovation, and across market based as well as command and control instruments.

4.109 There appears to be no single instrument that is ideal for inducing diffusion and innovation. Indeed, the significance of instrument choice is over-ridden by the influence of other regulatory features such as flexibility and certainty. Nevertheless, market based instruments tend to have some advantage over

4.110 On the other hand, innovation is more likely to be induced by hybrid instruments or broader packages of complementary measures that can enable businesses to respond to regulation more effectively. The nature and mix of such instruments can vary according to the technology in question and the policy intention. They can range from fiscal incentives such as interest free loans, a combination of mandatory and voluntary instruments, and measures that support the inception, development and commercialization of technologies throughout the entire product life cycle.

4.111 The evidence from the case studies also suggest that there may be other unintended effects of policy design and implementation that could positively or negatively influence diffusion and regulation.

4.112 Creating a level playing field may well be a clear policy focus. However this may not occur in practice. Variations in implementing regulations that are designed in a centrally based organization such as the EU across regions and countries can result in firms losing their comparative advantage as a result of differential regulatory and compliance costs.

4.113 Particular instruments, by virtue of their design, can disproportionately affect some firms more than others. For example, IPPC can be particularly vulnerable for small firms that do not have the financial capabilities to invest in R&D. EPR and UK Packaging Waste define a threshold that is biased towards larger firms, and those that are at the margin may be encouraged to reduce their output to avoid regulation. Some regulations can also alter the market structure by encouraging vertical integration and exit of smaller, inefficient firms.

4.114 Finally, the case studies have identified the importance of factoring in contextual factors when assessing the potential impact of regulation on innovation and competitiveness. Consumer demand and competition can be, in some cases, single most important drivers of innovation and diffusion, with regulation merely speeding or facilitating the process by reducing any disincentives associated with higher costs of compliance and communicating potential benefits to the bottom line.

4.115 These findings clearly demonstrate that there are possibilities for dynamic efficiency gains from environmental regulation, but that these will be dependent on certain assumptions – efficiency in the design, use and enforcement of policy instruments, the introduction of complementary measures, minimization of distortive and unintended effects on firms and sectors with particular characteristics, and adapting to unexpected outcomes

resulting from external drivers of importance such as technological progress and consumer demand.

5 Conclusions and policy design principles

Conclusions

5.1 The brief for this review was to gather and analyse evidence on the impact that the design and implementation of environmental regulation could have on competitiveness, specifically with regard to:

- the regulatory forms most likely to induce innovation and diffusion;
- differential impacts between SMEs and larger businesses; and
- the importance of context in the relationship between regulation and innovation.

The influence of regulatory form on innovation and diffusion

5.2 The evidence from the literature review and case studies is that the form of environmental regulation can positively affect competitiveness by:

- the *diffusion* of old or existing technologies in ways that enable businesses to become generally more efficient (moving to the *efficiency frontier*) and/or
- *innovation* in technologies that transform production possibilities and/or product attributes (shifting the *efficiency frontier*); and/or

5.3 The aspects of regulatory form that may induce these positive effects are not confined to the choice of instrument (often polarised in the literature between *command and control* and *market based instruments*). This choice will be important but so too will be the clarity of the regulatory purpose, appreciation of the context in which the regulation will be applied, the mix of measures to be deployed and other aspects of regulatory design, and the manner of implementation and enforcement.

5.4 Table 5-1 sets out the key features of regulations likely to influence innovation and productivity and the form of regulation that is generally most likely to exercise a positive influence on competitive performance. Our judgement on these matters was informed by the evidence of the literature review, the contribution of the participants at the workshops and the observations by peer group and other reviewers on an earlier version of this report as well as the case studies. Whilst the latter supplied a rich source of evidence with regard

to the particular regulations reviewed, they had to be seen in the broader context provided by the literature (particularly of more recent vintage) and the views of experts in order to suggest generalisable conclusions and lessons. This was especially so with regard to regulatory instruments such as self-regulation, voluntary agreements and information provision and awareness raising which did not feature to a significant extent across the case studies.

Table 5-1: Aspects of regulatory form most likely to influence competitiveness positively

Regulatory purpose	• Clarity in the definition by the policy-makers of the environmental problem to be addressed and the metrics used to specify it. • Precision with which the relative scale or stringency of the regulatory requirement is specified compared with the current situation and current practices/standards – incremental or radical change? • Awareness of the extent to which the regulatory purpose and intended stringency are shared by competing countries and the degree to which there is likely to be a 'level playing field'.
Context	• Acknowledgement by the policy-makers of the different contexts in which the regulation will be applied – a tailored as compared with a 'one-size fits all' approach. • Assessment of market structure and demand characteristics, the technologies available or in prospect to deal with the environmental issue and the constraints on their development and diffusion, and the incentives to which market and technology players may be expected to respond. • Recognition of the complementarity or otherwise of existing or planned policy measures with regard to the relevant markets and technologies.
Instrument choice and mix of measures	• Preference given to market related Instruments and other forms of regulation (e.g. self-regulation, voluntary agreements and 'informational regulation') rather than 'command and control' mechanisms. • Articulation of the means for achieving the regulatory purpose in terms of 'pollution prevention' and recycling/re-use wherever possible rather than pollution control through treatment and disposal. • Introduction of complementary measures designed to reinforce the anticipated effects of the chosen instrument – e.g. R&D support, information provision and public procurement practices
Other aspects of regulatory	• Preference given to 'outcome forcing' regulations rather

Table 5-1: Aspects of regulatory form most likely to influence competitiveness positively

design	than 'solution forcing' (e.g. specific technologies or practices) – providing flexibility for regulated firms (especially larger firms) to find their own solutions. • Commitment to the regulatory form and requirements over the long term where radical innovation is needed – building in 'technology escalators' for periodic up-dating and, where possible, giving advantages to 'first-movers'. • Minimising the cost burden of the regulation both to the regulator and the regulated taking account of resource as well as administrative costs – e.g. the public sector costs associated with setting price guarantees.
Implementation	• Advance warning and prior notice given to target businesses both in the formulation of the regulation and in its implementation. • Engagement of the target businesses in the design of the regulation – looking for ways in which they can buy into the regulation through some degree of self-regulation/voluntary agreements/information provision. • Keeping to the consultation commitments and time-table to develop trust between the regulated and the regulator and to secure a compliant rather than a sanctions based approach to the enforcement of the regulation.
Enforcement	• Clear demonstration of the monitoring and enforcement process so that all parties are clear about compliance requirements, sanctions and penalties. • Trade-off made between, on the one hand, need for intensive scrutiny of compliance processes and outcomes where stakes and risks are high and, on the other, more co-operative, capacity building and learning processes.

Innovation and diffusion

5.5 Some of the characteristics in Table 5-1 are unequivocally important in providing the necessary conditions for inducing both diffusion and innovation by means of regulation. The most important ones, in our view, are the clarity, ambition and determination of the regulating bodies to increase pollution prevention requirements and to use a hybrid of instruments to do so - involving development of the relevant markets coupled with strict enforcement and other supportive measures. In other words, policy-makers need to signal their commitment to making the regulation credible in bringing about pollution prevention. We emphasise the latter because the alternative of pollution

control, treatment and disposal tends to prompt the adoption of 'end-of-pipe' solutions often with adverse effects on productivity and competitiveness.[15]

5.6 These conclusions might be seen to run against the observation in some of the literature that stringency of regulatory intent and enforcement is only associated with use of command and control instruments. However, we think this is to mistake the flexibility that is offered to firms under market related and other alternative instruments as a lack of stringency. In fact, we are suggesting that the combination of stringent requirements with regard to environmental outcomes *and* flexibility in corporate response is key to inducing innovation and diffusion. Moreover, this flexibility should not be taken to mean lax monitoring and enforcement. Stakeholders consulted as part of the case studies were unanimous in the view that market related instruments (especially trading schemes) need close monitoring and enforcement if they are to ensure stability in the market mechanism and avoid artificial variability in trading.

Innovation or diffusion

5.7 Some of the features of regulatory form set out in Table 5-1 are more important when it comes to inducing innovation as compared with diffusion. The key distinctions are, in our view, as follows:

- **Long time-scales**: The regulatory form that encourages *innovation* will need to be designed to offer a long time horizon to induce the private sector to carry out investments that will have an impact often some considerable time in the future. That means making policy commitments and setting targets over the long term to reduce uncertainty and risks. Inevitably, circumstances change and allowance will need to be made for review points and/or technological escalators that affect the values of some key parameters without prejudice to the regulatory framework as a whole. By contrast, regulations that stimulate *diffusion* need to work in the 'here and now' and can be expected to have their beneficial effects in the short term.

- **Flexibility of response**: Regulation will be more likely to promote *innovation* where it allows firms the flexibility to explore and develop their own solutions to meeting the regulatory requirement – hence, the

[15] This conclusion should not be interpreted to mean that the combination of 'command and control' instruments and pollution control has not had major environmental benefits or that it has no place in the armoury of the policy-makers. It has, on the evidence of the case studies, helped to secure significant environmental outcomes and to force technological change. But, our reading of the evidence is that it is less likely to generate competitiveness outcomes, can 'force' inefficient technologies to be adopted and may involve high resource costs.

preference for performance (outcome forcing) standards. This flexibility is also more likely to prompt *diffusion* of cleaner technologies and pollution prevention. However, whilst diffusion of end-of-pipe technologies may not offer as much by way of productivity gains, it might be effective and cost-effective in securing environmental outcomes quickly and preferred by those businesses who like to know what's required and what to do about it. This may be particularly so for SMEs that have not adopted existing technologies and methods and may not even be aware of them. They are likely to need specific guidance as to how to identify problems and resolve them.

- **Externalities**: The main justification for designing environmental regulation that prompts *innovation* is to encourage the private sector to internalise an externality (the environmental outcome) through investment. This may be accomplished to some extent by information provision on relative risks and returns of different technological options but it is likely also to require a shift in relative prices and/or a regulatory requirement to induce significant investment in new technologies. However, *diffusion* is arguably all about tackling asymmetries in information and can best be encouraged through the establishment of networks which facilitate flows of information and knowledge about technological solutions and best practice.

- **Technology support:** One of the findings from the case studies was that *innovation* tends to be prompted by mixed or hybrid regulatory instruments which involve some degree of support for technological development. This is introduced either as an integral part of the regulation (e.g. as with the German REFIT) or as a complementary measure (e.g. through R&D or capital grants). Whilst methods have been tried to make such support 'blind' to the choice of technology, it is generally the case that some choice is implicit or explicit in the regulation and its complementary measures. Such technological preferences need to be articulated transparently and in acknowledgement that the priorities might change over time. Regulations intended to prompt *diffusion* tend to be most effective where the regulatory effect on 'demand pull' is complemented by support for technology transfer or 'push'. The latter invariably means

some degree of choice by the policy-maker of the technological options to be pushed.

- **Innovation leading diffusion:** Successful innovation tends to breed innovation and will usually give rise to diffusion. Therefore, it seems plausible to envisage regulation working in two phases. The first might be designed to prompt *innovation* in some firms (and indeed encourage them to go beyond compliance with minimum standards[16]) and the second might make it mandatory that successful innovations are more generally adopted - *diffusion*. This would provide an incentive for businesses to achieve 'first-mover' advantage and to avoid being left behind.

Differential regulatory impacts between large firms and SMEs

5.8 Some of the case studies confirmed the general point in the literature that regulation can be problematic for SMEs in terms of their capacity and/or willingness to wring competitive advantage out of its requirements (as compared with larger firms with more market power and resources). This is partly to do with the administrative burden that the requirements can impose the lack of resources for innovation and the adoption of technologies, and the vulnerability of smaller firms to closure as costs are increased through regulation.

- **Administrative burden**: In the case study on Extended Producer Responsibility and UK Packaging Waste it was observed that "regulations are a daunting prospect for smaller companies especially if they have a big range of product lines, seasonal products and so on". The administration of record-keeping under these circumstances can be a particular burden for the smaller firms if, as appeared to be the case for a number of them, they had not realised they could opt out of the requirement to collate and provide data each year.

- **Lack of resources:** The Nitrates case study demonstrated that the most important barrier to innovation was the poor cash-flow for farmers that inhibited investment in R&D or even the adoption of existing technologies and systems. It was suggested there that the regulation

[16] For example, by offering regulatory flexibility in return for ongoing improvements in environmental performance through the adoption of environmental management systems.

would have to be complemented by other interventions if innovation and diffusion was to take place.

- **Vulnerability:** SMEs typically lack the human resource and other capacities to be able to respond to more stringent environmental regulations through innovation or adoption of technologies. The case study of the food and drink industry demonstrated that, whilst it generally operated on low profit margins, there was a significant gap between the economics of large and small plants (with 80% of throughput going through 20% of plants) with the survival of some of the latter threatened by the increased costs associated with the IPPC process.

5.9 The study by Hitchens (2001) suggested that, more generally across industry, the corporate conditions most conducive to take-up of Best Available Technologies were not those typically associated with the generality of SMEs (e.g. large plants, high investment and R&D rates, high skills endowments and high productivity). However, the inference from the literature and the case studies was not that SMEs should necessarily be exempt from regulations. Rather it was that regulatory design should acknowledge the disadvantages under which SMEs often operate and should be accompanied by complementary measures to support technology diffusion.

The importance of context

5.10 It is generally recognised in the literature and verified from our case studies that it is crucial in designing regulation to tailor its form to the circumstances in which it will be applied. 'One size does not fit all' especially when it comes to designing regulation that prompts innovation and/or diffusion. Not only must account be taken of the conditions identified by the OECD (2000) such as the characteristics of the market-place and the structure of businesses but consideration will also need to be given to current and prospective technological developments and to the extent of diffusion of existing technologies (and the obstacles to both innovation and diffusion).

5.11 Findings from the case studies reinforced evidence from the literature that regulation will be just one of the many drivers of diffusion and innovation in a sector/market. Consumer demand and technological change that occurs independently of the regulation are seen as significant factors providing inducements for adoption and development of technologies by firms. In some instances, an existing market structure that ensures that firms are not price takers and can pass on any excess compliance costs to consumers, thus

maintaining their profitability. In other instances, and especially in energy markets, global energy prices, energy demand, fuel mix and fuel prices may drive innovation in some sectors.

5.12 The important lesson emerging from this finding is that it is not just important to acknowledge the context under which regulation may operate, it could also be crucial to incorporate this prior to designing policy to understand the extent and nature of the influence of regulation on innovation, diffusion and competitiveness.

5.13 The very diversity of the market and technological conditions in which regulation will be implemented, and the variety of other drivers of innovation and diffusion, will tend to reduce the effectiveness of command and control regulations in increasing productivity and competitiveness. It may just be very difficult for policy-makers to be sufficiently informed and have sufficient understanding about the diversity of conditions that they can fine-tune the design of sanctions-based, command and control instruments to reflect that diversity.

5.14 There may be occasions when it is necessary to cut through the diversity with relatively crude sanctions based instruments to achieve the desired level of pollution control and/or prevention – e.g. where the risks of environmental damage are high, the adverse consequences of the risks materialising are significant and/or irreversible, and the capacity, culture and/or inclination of the businesses in question may not necessarily be attuned to delivering the environmental protection or enhancement.[17]

5.15 In other circumstances it might be appropriate to use alternative approaches – ones based on cooperation, trust and compliance and the use of instruments that provide for much greater corporate flexibility. However, even in these conditions it will still be difficult for the policy-makers to be sufficiently well-informed and astute to be able to fine tune the regulatory instruments to reflect the nuances of market and technological characteristics.

5.16 This suggests that particular attention should be given to the aspects of regulatory form that increase the flows of information and knowledge on the environmental and other outcomes associated with the adoption of specific technologies and practices. For example, the 1990 Clean Air Act Amendments in the US required regulated facilities to implement a risk management programme including an historic account of accidental releases, hazard assessment and scenario and contingency planning. These process

[17] The conditions where sanctions based, command and control regulatory instruments might be appropriate were suggested by Andy Gouldson (Sustainability Research Institute, University of Leeds) in a recent submission to the Environment Agency (*Towards Modern Regulation: Developing and Building Trust and Risk-based Environmental Regulation,* 2007).

or procedural standards could be built on to prompt the wider use of environmental management systems which have the potential to deliver continuous improvements in general resource management and efficiency. They could also provide the foundation for benchmarking between businesses on a comparable basis which would help to identify regulatory leaders and laggards, their respective characteristics and the technologies and practices they use. This would not only increase competition between regulated businesses but would also provide a stronger evidence base for their consumers and suppliers and the policy-makers on the environmental and other credentials of the businesses.

Policy design principles

5.17 The Terms of Reference for the review required that it address the question, *how can regulation be designed and implemented to induce diffusion and innovation and bring about positive competitiveness effects?* This question has been reformulated in Table 5-2 as a statement of the purpose of regulatory design and our proposed answers have been couched in terms of a set of regulatory design principles.

5.18 Central to these principles is the proposition that '*pollution prevention pays'* and that all environmental regulation should seek to pursue the route of pollution prevention wherever feasible. This proposition is not new. Under the Pollution Prevention Act of 1990, the US Congress established a hierarchy of preferred options for dealing with pollution – pollution prevention or reduction as the first resort, recycling, treatment, and disposal or release into the environment only as a last resort. The Pollution Prevention and Control Regulations (2000) in the UK set down five principles for the operation of industrial sites – use of BAT to prevent pollution, minimise waste and recycle it where possible, conserve energy, prevent accidents and limit their environmental consequences and return the site to a satisfactory state after operations cease.

5.19 However, even though pollution prevention has been an important feature in aspects of environmental regulation for some years, we are suggesting that the *'pollution prevention pays'* principle should become a central policy thread running through all approaches to environmental regulation and its supportive complementary measures (e.g. public procurement, R&D support, technology transfer, education and training, and information and advice provision).

Table 5-2: Prompting innovation and diffusion through environmental regulation: Design principles

Purpose of the regulatory design

- To maximise the effect of the regulation on the productivity of regulated and other businesses through innovation and/or diffusion subject to achieving (or over-achieving) its environmental objectives/targets.
- To adopt a *'pollution prevention pays'* approach to the design of the regulation and its supportive measures whenever possible.

Rationale

- Define the environmental problem to be addressed and the extent to which it is to be reduced against agreed baselines over specified time-scales.
- Consider whether competitor countries are seeking the same extent of reduction in the problem and the regulatory initiatives being explored to address it.
- Review the technological and other options for addressing the problem with preference given to prevention and source reduction followed by recycling and reuse, treatment and disposal.
- Identify the stage of the innovation chain relevant to addressing the environmental problem and the radical or incremental nature of the technological development and/or diffusion required
- Understand the factors prompting or constraining the development and/or adoption of technological options for addressing the environmental problem in question.
- Assess existing regulations and other policy measures relevant to the environmental problem and the technological and other options for addressing them to consider the extent to which they might hinder or assist the purpose of the proposed regulation.

Design

- Couch the regulatory requirements as far as possible in terms of outcomes rather than specific solutions where the intent is to promote innovation but provide more guidance on available options and best practice where the intent is diffusion.
- Build in process or procedural standards that embody good environmental management practices and require reporting of the results of their application.
- Create certainty of regulatory form and content over the longer term to provide steady state signals (e.g. with regard to prices) that are conducive to investment in radical technological options whilst minimising market distortions and public sector costs.
- Develop packages of measures to complement and reinforce the regulatory intent/process through R&D/capital grants, public procurement, technology transfer and information/advice provision.

Implementation and enforcement

- Engage with the corporate and research community to build trust, cooperation and compliance and build in elements of self-regulation, voluntary agreements and informational/procedural standards especially where solutions through innovation are being contemplated.
- Provide advance warning and prior notice to target businesses in implementation

Table 5-2: Prompting innovation and diffusion through environmental regulation: Design principles

and keep to the scheduling and other commitments announced at the outset. • Render transparent the monitoring and enforcement process and ensure that learning about the effectiveness of solutions is generally disseminated and adopted – 'herding' of laggards from the example of the 'leaders'. • Adopt a risk-based, compliance approach to enforcement rather than a sanctions based approach except where the environmental problems need to be addressed urgently and comprehensively.

References

AEA Technology (2004), 'The direct and indirect benefits of the European Eco-label', DG Environment.

Bartelings et al (2005), 'Effectiveness of landfill taxation', Ministerie van VROM

Beise and Rennings (2005), 'Using the market for cost-effective environmental policy - Market based instruments in Europe', Ecological Economics 52 (2005) 5 - 17

Burtaw (2000), 'Innovation under the Tradable Sulphur Dioxide Emission Permits Program in the U.S. Electricity Sector', Resources for the Future.

Burtaw (1996), 'Cost savings sans allowance trades? Evaluating the S02 Emission Trading Program to Date', Resources for the Future.

Bio-intelligence Service (2006), 'European Commission Study on ex-post estimates of costs to business of selected pieces of EU environmental legislation. Case study on the Large Combustion Plants Directive', European Commission.

Davies et al (2000), 'Study on the Economic, Legal, Environmental and Practical Implications of a European Union System to Reduce Ship Emission of SO_2 and NO_x', BMT Murray Fenton Edon Liddiard Vince Limited No 3623 - for the European Commission

De Canio (1997) 'Economic Modeling and the False Trade-off between Environmental Protection and Economic Growth' Contemporary Economic Policy, Vol. 15 (October)

Ecotec (2001), 'Study on Environmental Taxes and Charges in the EU', in association with CESAM, CLM, University of Gothenburg, UCD and IEEP (CR)

Environment Agency (2006) Using the market for cost-effective environmental policy - Market based instruments in Europe.

ESRC (2002), 'Policy drivers and barriers to sustainable innovation' research specification'. http://www.sustainabletechnologies.ac.uk/Projects/policy.htm#o

Ekins and Etheridge (2006), 'The environmental and economic impacts of the UK climate change agreements', Energy Policy 34 (2006) 2071-2086.

European Environment Agency (2005), 'Effectiveness of urban wastewater treatment policies in selected countries: an EEA pilot study'.

Foxon, T J, Makuch, Z, Mata, M and Pearson, P (2004), 'Informing policy processes that promote sustainable innovation: an analytical framework and empirical methodology', STP

Working Paper 2004/4, available at
http://www.sustainabletechnologies.ac.uk/PDF/Working%20papers/106b.pdf

Freeman and Soete (1997) 'The economics of industrial innovation' (Third Edition)

Griffith, Harrison, Simpson (2006), 'The link between product market reform, innovation and EU macroeconomic performance', Institute of Fiscal Studies, European Commission Economics Papers.

http://ec.europa.eu/economy_finance/publications/economic_papers/2006/ecp243en.pdf

GHK with Bio-intelligence Service (2006), 'A study to examine the costs and benefits of the End-of-Life Vehicles Directive and the costs and benefits of the revision of the 2015 targets for recycling, re-use and recovery under the ELV Directive', DG Environment.

Grubb, M (2004). Technology Innovation and Climate Change Policy: an overview of issues and options, Keio Journal of Economics

Gunningham (2004), Compliance, enforcement and innovation, OECD.

Harrington, Morgenstern and Sterner editors (2004) Choosing Environmental Policy: Comparing Instruments and Outcomes in the United States and Europe, Resources for the Future.

Harrington and Moregenstern with Land Economy (2006), 'Comparing the ex-ante and ex-post costs of regulatory changes'. Defra.

Hawksworth (2006) The World in 2050. Implications of global growth for carbon emissions and climate change policy, Price Waterhouse Coopers

Hillard and Jacobson (2003) Systems of Innovation and their limits: the case of environmental regulation of the Irish pharmaceutical industry, Centre for Innovation and Structural Change

Hitchens et al (2001), 'The impact of Best Available Techniques (BAT) on the competitiveness of European Industry', European Commission.

Jaffe, A.B., R.G. Newell, and R.N. Stavins (2002), 'Environmental Policy and Technological Change', Environmental and Resource Economics 22, p. 41-69.

Johnstone, N (2007) Environmental Policy and Corporate Behaviour, OECD.

Jacobsson and Bergek (2004) Transforming the energy sector: the evolution of technological systems in renewable energy technology, In: Klaus Jacob, Manfred Binder and Anna Wieczorek (eds.). 2004. Governance for Industrial Transformation. Proceedings of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change,

Environmental Policy Research Centre: Berlin. pp. 208 - 236

Kerr and Newell (2003), 'Policy-induced technology adoption: evidence from the US lead phasedown', Journal of Industrial Economics Volume L1.

Keyworth, T., and Yarrow, G., (2005) Economics of regulation, charging and other policy instruments with particular reference to farming, food and the agri-environment. A supporting document for Partners for success – a farm regulation and charging strategy (Defra).

KPMG (2005), 'REACH – further work on impact assessment: a case study approach', Framework of a Memorandum of Understanding between DG Environment and DG Enterprise and industry.

Kuick, O (2006), 'Ex-ante and ex-post estimates of implementing the Nitrates Directive: case study in the framework of the project 'ex-post estimates of costs to business of EU environmental policies', DG Environment.

Lanjouw and Mody (1996), 'Innovation and the international diffusion of environmentally responsive technology, Research Policy, Volume 25, Number 4, June 1996, pp. 549-571(23)

Lindhqvist (2001), 'Extended Producer Responsibility for end-of-life vehicles in Sweden – analysis of effectiveness and socio-economic consequences', International Institute for Industrial Environment Economics, Sweden.

Luken and Grof (2006), 'The Montreal Protocol's multilateral fund and sustainable development', Ecological Economics 56 (2006) 241 – 255

Luken and Hesp (2006), 'Review of selected environmental initiatives of the United Nations System, Regional Development Banks and other International Organisations', United Nations Department of Economic and Social Affairs.http://www.unemg.org/download_pdf/EMG-IndusEnvInit-CSD14.pdf

Management Institute for Environment and Business (1996) Competitive implications of environmental regulation of chlorinated organic releases in the pulp and paper industry, US Environmental Protection Agency

Mahdi, Nightingale and Berkhout (2002), 'A review of the impact of regulation on the Chemicals industry', Final report to the Royal Commission on Environmental Pollution.

Mason and Swanson (2002), 'The impact of international environmental agreements: the case of the Montreal Protocol', Centre for Social and Economic Research for Global Environment Working Paper GEC 98-26.

Murphy and Gouldson (2000), 'Environmental policy and industrial innovation: integrating environment and economy through ecological modernisation', Geoforum 31 (2000) 33-44

Nelson and Winter (1982), 'An evolutionary theory of economic change'

Newell et al (2006), 'The effects of economic and policy incentives on carbon mitigation technologies', Energy Economics 28 (2006) 563 - 578

OECD (1998), 'Extended Producer Responsibility Phase 2: case study on the German Packaging Ordinance', Group on Pollution Prevention and Control.

Oosterhuis and ten Brink (2006), 'Assessing innovation dynamics induced by environment policy: findings from literature and analytical framework for the case studies'. A project carried out for the European Commission, DG Environment, by IVM, IEEP, PSI and MNP.

Pearson, Foxon, Makuch and Mata (2004), 'Policy drivers and barriers for sustainable innovation: final ESRC report summary', Imperial College London for ESRC. http://www.sustainabletechnologies.ac.uk/PDF/project%20reports/new%20version/106%20Report.pdf

Pearson, Foxon, Makuch and Mata (2004), 'Informing policy processes that promote sustainable innovation: An analytical framework and empirical methodology', Working Paper Series 2004/4, Imperial College London for ESRC. http://www.sustainabletechnologies.ac.uk/PDF/Working%20papers/106b.pdf

Pearson, Foxon, Makuch and Mata (2005), 'Transforming policy processes to promote sustainable innovation: policy guiding principles', a report for policy makers, Imperial College London for ESRC. http://www.sustainabletechnologies.ac.uk/PDF/project%20reports/SI_policy_guidance_final_version.pdf

POPA-CTDA (2004), 'Policy pathways to promote the development and adoption of cleaner technologies' http://www.popa-ctda.net/index.php?id=55, various studies. European Commission

Risk and Policy Analysts/Metroeconomica (1999), 'Induced and opportunity costs and benefits patterns in the context of cost-benefit analysis in the field of environment', European Commission.

Rosenberg (1997), 'Inside the black box: technology and economics'

Sabel, Fung and Karkkainen (2000),'After backyard environmentalism: toward a Performance-Based Regime of Environmental Regulation,' American Behavioural Scientist, Vol.44, No.4 December 2000

Sorrell (2003), 'Carbon Trading in the Policy Mix', Oxford Review of Economic Policy, Vol 19, No 3

Smith (2005), 'Analytical framework for evaluating the costs and benefits of Extended Producer Responsibility Programs', Environment Directorate, OECD.

Taylor et al (2005), 'Regulation as the Mother of Innovation: The Case of SO_2 Control,' Law & Policy, Vol 27, No.2

Taylor, Rubin and Hounshell (2005), 'Regulation as the mother of innovation: the case for SO_2 control', Law and Policy, Volume 27, No.2. http://www.hm-treasury.gov.uk/media/281/7F/taylor.pdf

Technopolis BV (2004), 'Policy instruments for sustainable innovation'. http://www.technopolis-group.com/downloads/483_phase2.pdf

The Carbon Trust (2006), 'Allocation and competitiveness in the EU Emissions Trading Scheme: options for Phase II and beyond'.

The Carbon Trust (2004), 'The UK Climate Change Programme: potential evolution for business and the public sector'.

Toffel (2003), 'The growing importance of end-of-life product management', University of California, Berkeley.

Utterback and Suarez (1993), 'Innovation, Competition and Industry'

Varma (2003), 'UK's Climate change levy: cost effectiveness, competitiveness and environmental impacts', Energy Policy 31 (2003) 51 – 61

Vercaemst et al (2005), 'Ex-post estimates of costs to businesses in the context of BAT and IPPC', Vitto for the European Commission, DG Environment

Walls (2006), 'Extended Producer Responsibility and product design', Resources for the Future.

Nobel House
17 Smith Square
LONDON SW1P 3 JR

www.defra.gov.uk