CABINET OFFICE

Field Work: Weighing up the Costs and Benefits of GM crops

strategy unit

Contents

Analysis papers

The following analysis papers, which accompany the main report and expand on its analysis, are available on the project web site at www.strategy.gov.uk. Paper copies of the collated papers are also available on request from the Strategy Unit (telephone: 020 7276 1881):

- Regulations and GM crops: Key Questions Answered
- Analysis of the Costs and Benefits of GM crops in Product Chains
- Analysis of the Costs and Benefits of GM crops to the Environment and Human Health
- Analysis of the Costs and Benefits of GM crops to Industry and Science
- Potential UK impact of GM crops on the decision-making contexts of developing countries: Analysis Paper
- GM foods in the late 1990s – an overview of events and the media reaction.

Foreword by the Sponsor Minister

From food to clothing, from medicines to fuel, plants are essential for sustaining human life. Plants, of course, evolve without human intervention. But man has developed a variety of techniques – from plant-breeding to organic pest control – that can give a helping hand to this process. Little of what we grow on our farms today has not benefited in some way from these techniques.

A new technique to develop novel crops is genetic modification. Genetic modification has a range of applications for both plants and animals, but has also been central to many recent advances in biotechnology research. GM micro-organisms, for example, already produce a variety of vaccines, as well as insulin for the treatment of human diabetes. Along with many other aspects of biotechnology, these applications are likely to expand rapidly over the coming decades, and I am pleased to say that the UK is at the forefront of this research.

GM crops could offer significant benefits to both farmers and consumers, and even the environment. Herbicide-tolerant and insect-resistant crops have proved very popular with farmers where they are available, while drought- and saline-resistant crops are likely to offer further benefits in future. Consumers may be able to choose foods with higher nutritional value or a longer shelf-life. GM crops could also be used to produce pharmaceuticals or as a source of renewable energy.

But as with any new technology these potential benefits are also accompanied by risks and uncertainties - and these in turn bring about public concern. In the case of genetic modification, particular attention has been paid to potential impacts on consumer choice, to the possibility of risks to health and the environment and to the speed of technological development. The challenge for any government is to regulate the use of this new technology in a way that safeguards the public and our planet, commands public confidence, but also ensures that our society does not unnecessarily throw away the benefits science can provide. This is no easy task.

It was because of this challenge that the Government last summer launched a wide-ranging public dialogue on all the issues raised by genetic modification. The aim has been to provide more evidence on the potential risks and benefits and to draw together all the conflicting opinions on GM. In parallel with the public debate 'GM Nation?', and the review of scientific issues, I asked the Strategy Unit to carry out this study into the overall potential costs and benefits of GM crops.

As I believe people who read this report will discover, the Strategy Unit has drawn on expertise and opinions from a wide spectrum of viewpoints.

The Strategy Unit is making this report to Government. It has sought to provide a comprehensive and impartial analysis of the costs and benefits of different scenarios for the banning or commercial planting of GM crops in the UK. Along with a great deal of other material including the results of the ‘GM Nation?’ debate, the report will help Government decide about the overall direction of its policy towards GM crops. I look forward to receiving views on both the report’s analysis and implications.

Rt. Hon Margaret Beckett MP

Executive Summary

OBJECTIVES OF THE STUDY

The Strategy Unit's study is one strand of a wider public dialogue on GM issues

1. The Government has initiated a dialogue on the issues raised by genetic modification (GM). In Summer 2002, it commissioned three inter-linked strands of work:

- a public debate ("GM Nation?");
- a review of the scientific issues; and
- a study into the overall costs and benefits of GM crops.

2. The aim of all three strands has been to improve the evidence-base, and to create a dialogue between all aspects of opinion on GM. In parallel with this work, the Food Standards Agency (FSA) has carried out its own programme to assess people's views on GM food.

3. The Public Debate, Science Review, FSA work and Strategy Unit (SU) study of costs and benefits will all be taken into account by the Government in developing policy on GM crops.

This report provides an assessment of the costs and benefits of GM crops

4. This report sets out the Strategy Unit's (SU's) analysis of the overall costs and benefits of GM crops. The main objective of this study has been to provide a comprehensive and balanced analysis of the costs and benefits of the possible commercial cultivation, or otherwise, of GM crops in the UK. The study focuses on crops that are currently available, as well as possible developments in the next 10-15 years, and develops scenarios to explore a range of possible futures.

5. The study looks at costs and benefits which may arise in a broad range of areas, and not just at those whose value can be measured in monetary terms.

SETTING THE CONTEXT

GM crops represent just one application of GM technology, and one approach to plant-breeding

6. GM crops are widely grown across the world and have been available for human and animal consumption for almost ten years. However, GM crops represent just one application of GM technology. Genetically Modified Organisms (GMOs) are already in common use for other purposes – such as the use of GM microbes as factories for insulin and for enzymes used in food processing (such as the manufacture of vegetarian cheese). At the same

time, GM crops represent just one approach to plant-breeding, and are in addition to other approaches – such as marker-assisted breeding or radiation-induced mutation.

GM crops need to be considered in context

7. GM crops are not an end in themselves. They therefore need to be considered in the context of the government's objectives in a number of policy areas:

- Agricultural policy and the environment;
- Rural policy;
- Science, innovation and competition policy;
- Policy on food safety and quality;
- International development policy.

8. The analysis in this report has attempted to assess the costs and benefits of GM crops in the light of their impact on these policy objectives. Could GM crops help or hinder achievement of the objectives? What alternatives are available? And how might the situation change over time? Both domestic and international contexts are relevant.

Public attitudes will be important in determining the future of GM crops and foods

9. Surveys over the past few years have generally revealed negative public attitudes towards GM food. However, public attitudes are complex and can evolve. There is also some evidence that attitudes may vary between GM crops and GM foods, and between different types of GM produce and GM traits.

10. Initial focus group work for the Public Debate has helped the process of exploring the complex set of attitudes that lie behind such results. It showed that views on a wide variety of issues frame overall attitudes towards GM crops, including individuals' views on food and health, choice and information, progress and uncertainty, the environment, and ethics. Further complexity arises from the interaction between public attitudes and the activities of other groups and organisations, including NGOs, the media, retailers and Government.

There is a wide-ranging regulatory framework in place

11. Regulatory authorities have already taken steps to tackle potential environment and health issues that could arise from the development of GM crops, and to respond to public concerns. Regulatory policy is largely determined at the level of the European Union (EU), with decisions taken collectively by Member States under a system of supervision which dates back to 1990, and has recently been significantly strengthened. Any new GM crop or food is subject to an approvals process which looks in detail at

potential impacts on the environment and human health, both of the crop and of the food it is used to make.

12. Other elements of the system govern the use of crops and foods after they have been approved, such as rules on the traceability and labelling of GM crops and ongoing monitoring of environmental impacts. Some of these regulations are still being developed.

13. The UK Government has an important role to play in this, both as part of the policy-making process, and in implementing regulatory policy on the ground. Government will need to make some important policy decisions on its approach to GM crops. Key milestones include the upcoming publication of the Farm Scale Evaluation results, and the end of the current voluntary agreement with industry not to grow the crops.

14. Attitudes to risk and regulatory approaches need to be put in context. Non-GM agriculture is not risk-free – indeed there is strong evidence that past changes to agricultural practice have had some negative environmental impacts. The risks associated with GM crops therefore need to be seen alongside the risks involved in any type of agriculture.

This study looks both at the current generation of GM crops, and those which could be brought to market in the next 10-15 years

A relatively narrow range of crops and traits is currently available…

15. Despite rapid take-up during the last few years, GM crops still make up less than 5% of the total global area of crop growing. 66% of the global area of GM crops can be found in the US – other major users are Argentina, Canada and China. Four GM crops dominate. These are cotton, soybeans, maize and oilseed rape. Over 99% of these have one (or both) of two traits: herbicide tolerance and insect resistance. Other crops have been developed, but are not grown widely. Examples include GM sugar beet, and a very limited number of GM fruits.

16. On the basis of decisions made in 1996, the UK already imports some GM products for use here, almost all for non-food uses (mainly cotton), or for animal feed (mainly soya).

17. However, only some of these crops are likely to be relevant for actual cultivation in the UK. Soybeans and cotton are not suitable for the UK climate. The insects targeted by existing insect-resistant GM crops are not currently a significant problem here. Only the herbicide tolerant varieties of crops such as maize, sugar beet and oilseed rape are likely to be of interest.

…although the range could expand significantly over the next 10-15 years

18. Looking ahead, a wider range of GM crops could be developed that are relevant to the UK. Possibilities include:

- the application of GM technology to a wider range of crop types suitable for UK conditions, such as GM wheat and GM potatoes;
- a range of more valuable agronomic traits, such as resistance to common UK pests and plant diseases, or improvements to the efficiency with which crops can absorb nutrients;
- GM foods with consumer benefits, such as longer shelf life, or health benefits, such as improved nutritional content or reduced allergenicity;
- a wide range of non-food crops, which could include crops used as "factories" for a range of goods, such as the production of pharmaceuticals, industrial oils, or renewable materials; as well as crops which could be used directly in the production of energy or fuel.

19. Whilst the rate and success of development of these crops is far from guaranteed, they offer the potential for some valuable new products which could contribute to policy goals in a number of areas. However they may also bring additional uncertainties and risks, which the regulatory system would need to take into account.

Crop developments could also come from conventional and organic techniques

20. Non-GM methods will also continue to produce new developments. Our increased understanding of plant genomics is helping to accelerate many aspects of agricultural research, and conventional methods of plant breeding may deliver some of the benefits which GM approaches are aiming to achieve. The ability of these methods to deliver improvements would depend both on the science, and on the amount of money devoted to such research. It may also be the case that there are some traits – such as those which deliver high levels of biomedical and industrial products – which can only be delivered to a commercial scale using GM.

APPROACH TO THE STUDY

This study has been informed by experts, the public, science, and the best available economic data

21. The study has sought to take on board:

- the views of stakeholders, experts and the wider public – particularly as expressed through the preparatory phase of the Public Debate;
- information on the economic impacts of GM crops where they are already in commercial cultivation in other countries;
- information on the science of GM, partly drawn from the Science Review.

22. Stakeholders and experts have been involved in key aspects of the work, and the Strategy Unit has worked closely with both the Public Debate Steering Board and the Science Review. Interim outputs have also been published for comment.

23. This report goes as far as possible in bringing together the evidence on costs and benefits of GM crops. But it does not draw definitive conclusions or

put forward policy recommendations. This is due to the general nature of the study, as well as to a number of limitations to the evidence base.

There are limitations to the analysis

The study provides a general analysis of the issues

24. Many of the issues to do with GM crops – such as their potential impacts on farming, the environment, human health, and economic activity – are highly specific to individual crops and traits. This is the basis for the current EU regulatory system, which takes a case-by-case approach to regulatory approval.

25. This study recognises that generalisations about the impacts of GM crops are not always possible, and many areas where the analysis differs according to the particular crop variety are highlighted. However, the overall report is at a general level. Its intention is to provide an overview of the issues, and to inform the direction of policy towards GM crops as a whole, rather than to inform individual decisions about specific crops.

The evidence base on the costs and benefits of GM crops is limited – as is the evidence on alternatives

26. There are limitations to the available data:

- although there is a large body of international research on the commercial growing of GM crops, some of this is subject to contradictory interpretations, and its applicability to the UK needs to be treated with caution. It also covers a relatively short time period. As there has been no commercial-scale cultivation of GM crops in the UK, there is also limited domestic evidence of agronomic or environmental impacts;

- there is very little research on the economic and environmental impacts of conventional and organic farming. This makes it hard to establish a baseline against which the impacts of GM crops may be assessed;

- there are also significant uncertainties inherent in looking forward over the 10-15 year time horizon considered in this study. For instance, the UK and international policy environment, public attitudes, and the state of science may well change over this period.

In response to the limitations in the evidence base, and to future uncertainties, the SU has used a scenario analysis to look at different possible futures for the UK with or without GM crops

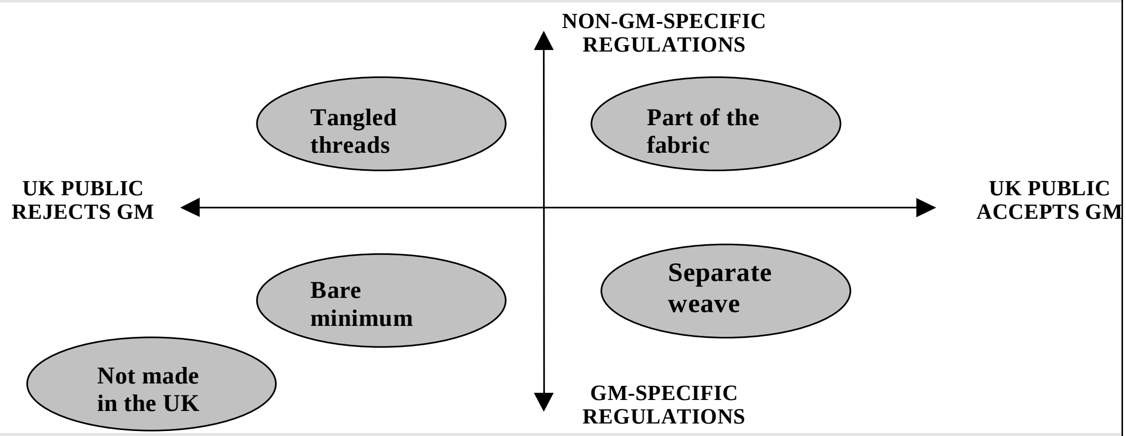
Scenarios allow consideration of a range of possible futures

27. To take into account these areas of uncertainty, the SU has worked with stakeholders to develop a range of scenarios. These cover plausible possible futures with and without commercial cultivation of GM crops in the UK, over a 10-15 year time period.

THE FIVE SCENARIOS

28. The scenarios use different assumptions about possible public attitudes to GM and the nature of the regulatory regime as the main determinants of different futures. The five scenarios, which cover a wide range of possibilities, are summarised in the box below.

The five scenarios



- *Scenario 1: 'Part of the fabric'* – the public largely accepts GM crops and foods, and therefore significant cultivation of GM crops occurs, with the regulatory regime increasingly treating GM crops and foods much like any other novel foodstuff.
- *Scenario 2: 'Separate weave'* – the public increasingly accepts GM crops and foods, and GM crops are gradually introduced under a strict GM-specific regulatory regime including a stringent approvals process, post-market monitoring and labelling.
- *Scenario 3: 'Bare minimum'* – public attitudes are largely against GM crops and foods, and there is a strict regulatory system, leading to very little GM cultivation in the UK in the short-term.
- *Scenario 4: 'Tangled threads'* – there is a breakdown between negative public attitudes and regulations which fail to maintain a separation between GM and non-GM crops grown in the UK.
- *Scenario 5: 'Not made in the UK'* - an explicit decision is made against the commercial cultivation of GM crops in the UK, with the public preferring conventional or organic produce.

29. The scenarios are not predictions, but they are useful in illustrating how costs and benefits may differ in different futures for the UK with or without GM crops.

The report also looks at how unexpected events may throw these scenarios off course

30. The scenario analysis has limitations. In particular, it is hard for such an analysis to look at the possible impact of uncertain-probability, but potentially high-impact, events. The Strategy Unit has therefore analysed how robust the scenarios may be to “shocks and surprises”, which could either support or damage the delivery of particular policy objectives.

31. A range of developments which are, on the surface, unrelated to GM crops may have an impact on how the costs and benefits play out. There are many examples, ranging from elevated concerns about general food safety, through effects of climate change, to changes to the social environment.

32. In addition, GM crops themselves could be associated with unexpected outcomes. These could be positive, such as a surprising breakthrough in GM technology delivering a desirable new crop characteristic. Many people are more concerned, though, about the possibility of a negative shock, such as the discovery of a new allergen associated with a GM crop – particularly if the impact is hard to reverse.

33. The aim of the GM crops regulatory regime is to prevent harm to human health and the environment. Because there are uncertainties associated with any new technology, some risks may be unique to GM crops and food. Others also apply to other methods of plant breeding and agriculture.

34. These shocks and surprises would play out in different ways in different scenarios. In scenarios with a more stringent regulatory framework, for instance, it might be easier to deal with an unexpected negative impact on the environment arising from a GM crop – but it might also be harder to capitalise on any new developments in GM technology. In contrast, a scenario with minimal regulation and significant GM crop growing may deliver a wider range of benefits, but might find it harder to deal with risks.

COSTS AND BENEFITS IN THE SCENARIO ANALYSIS

The SU has carried out a detailed analysis of the potential costs and benefits of GM crops

35. The Strategy Unit’s scenarios are used to analyse the range of possible costs and benefits that may be associated with the cultivation of GM crops.

36. The study identifies the following key areas of cost and benefit:

- *Impacts on the economics of agriculture.* The current generation of GM crops has been designed to offer specific cost or convenience savings to farmers. International evidence suggests that some savings have been realised from the current generation of GM crops, and in some cases these savings have been accompanied by increased yield. However, this evidence needs to be treated with some caution – the regulatory context, market conditions (e.g. consumer demand) and physical characteristics (e.g. farm size) differ between the UK and those countries where GM crops have been grown commercially.

Applying this to the UK context, the study suggests that some farm-level savings might be expected in areas such as spending on pesticides, along with advantages in terms of convenience of farm management and – in some circumstances – increased yields. These would have to be set against the costs associated with commercial cultivation, including the cost to farmers of buying the technology, and some additional costs of compliance with regulations.

The balance of costs and benefits would vary between crops and between types of farm. Some GM crops may only offer advantages to farmers with particularly serious weed problems, for example; others may offer more general benefits, for example GM sugar beet might allow farmers to make significant cuts in herbicide costs. Future crops and traits may offer more valuable benefits than current generations.

Farming practice will also influence the balance of costs and benefits. Farmers' decisions will depend critically on the demand for the GM crop. If the price they received for GM crops was much lower than that for non-GM, then this could easily outweigh any cost savings. Ultimately, farmers would have to make individual decisions on whether to adopt the technology.

- *Practicalities of the supply chain.* Many European consumers continue to demand a choice between GM and non-GM food. Reflecting this, some costs are already incurred in the UK in order to maintain separate non-GM lines of some imported products. These are likely to rise as the range of available GM foods increases, whether or not GM crops are grown in the UK.

  Additional costs may arise if GM crops were cultivated in the UK, particularly in keeping crops separated at the farm level. The nature of any measures which may need to be put in place – and hence their likely cost – is not yet clear. The cost may also vary significantly from crop to crop, depending, for example, on the characteristics of the crops and on the extent to which organic varieties are grown. But the analysis suggests that many of the measures that could be required are consistent with existing farm practice, or could be achieved through co-operation between farmers. This means that these costs could be relatively small as a proportion of the total costs of crop growing. However, the detailed design of any measures will have a significant impact on costs for GM, conventional and organic agriculture.

- *Wider developments in agriculture are likely to be more important in the short-term.* Any cost savings or increased yields offered by GM crops could contribute to improved competitiveness in UK agriculture. However, any economic benefits from the commercial cultivation of current GM crops are likely to be outweighed by other developments, at least in the short-term. UK farmers do not operate in a fully competitive market, and hence their future profitability is more likely to be determined by national and EU policy decisions – for example, on the Common Agricultural Policy

(CAP) – rather than smaller-scale cost savings arising from the use of current GM crops.

- *Wider impacts on the rural economy and communities.* There have been concerns that the introduction of GM crops to the UK might have impacts on rural economies more generally, such as effects on the reputation of rural areas. However, there is little evidence in this area.

- *Agriculture, the environment and human health.* This study has not looked in detail at the scientific evidence on the environmental and human health impacts from GM crops. Some people have concerns about these impacts and the broader uncertainties associated with GM crops. These issues have been dealt with by the Science Review, and are already a key element of the risk assessment procedures applied to all applications for the release of GM crops.

  However, the study does consider how the changes to farm management associated with GM crops could have an impact. The assessment is inevitably preliminary in nature, particularly in advance of the results of the Farm Scale Evaluations (FSEs), which are looking at one aspect of this issue. There is scope for both positive and negative effects, although the exact scale and nature of these are hard to judge, as the relationship between agriculture and the environment is complex and relatively poorly understood. Impacts would also depend on farmer behaviour, which may vary from individual to individual.

  In the short term, the biggest changes could come from the use of herbicide-tolerant crops, and resulting changes in patterns of herbicide use. These changes could have environmentally beneficial effects, for example by replacing persistent or high toxicity herbicides with more benign ones. However there is also scope for costs. Low cost herbicides that can be used with little or no damage to the main crop could lead farmers to increase herbicide use, to the detriment of biodiversity.

  Future GM crops could also directly address environmental or human health objectives, such as the production of renewable materials, or of foods with reduced allergenicity. However, non-GM techniques might achieve some of the same goals – for example, a broccoli with enhanced levels of a cancer-preventing substance has been developed using non-GM techniques. And future developments may also increase risks and uncertainties.

- *Impacts on the science base in the UK.* What happens with GM crops over the next few years will have an important influence over the long-term options available to the UK – for example in affecting the UK's expertise in GM and non-GM technologies, the UK's ability to capitalise on future developments and the signals sent to wider biotechnology and science-based industries.

  Commercial GM crop research in the UK has declined, and is a small component of overall scientific activity, with one multinational crop research facility being based in the UK, and very few small businesses working in the area. The direct economic impacts of GM crop policy that reduced this sector further would therefore be fairly limited in the short term.

However, UK academic crop research is still strong, and the commercial sector has the potential to expand. Significant economic benefits might accrue to companies providing GM crop technologies – and it may be in the UK's interest for these companies to be sited in the UK. There would be a significant opportunity cost if the UK lost its ability to research, develop and bring GM crops to market.

- *International impacts.* UK policy towards GM crops will have international repercussions, and the stance taken by the EU as a whole is likely to have a still greater impact. Differences in approach between the EU and some other countries on GM policy are already causing trade tensions.

  There may also be specific impacts on the UK's policy of ensuring that developing countries should be free to decide for themselves whether to adopt GM crop technology. UK and EU policy towards GM crops may impact on the context in which developing countries make these choices about GM crops.

CONCLUSIONS OF THE STUDY

The scenarios illustrate the trade-offs inherent in any future for the UK, with or without GM crops

37. None of the scenarios are universally good or bad. Instead, they all represent trade-offs between costs in one area and benefits in another. Different individuals will have different views on the desirability of each scenario outcome. Value judgements and "weighting" of different factors will therefore be required to assess how costs and benefits should be traded off against one another.

38. The Government is particularly interested in whether GM crops can help to achieve policy objectives. The analysis shows that different objectives may be supported more or less in different scenarios.

The scenario outcomes could be shifted by interactions between policies and attitudes

39. The scenario outcomes could be shifted by interactions between different factors. Dynamic relationships between, for example, regulatory policy, public attitudes and global developments could affect the overall outcome in any scenario. These interactions are unpredictable and the uncertainty surrounding their potential impacts should be noted when assessing the overall conclusions to this study.

The scenarios show that the nature of the regulatory system will have an important bearing on our ability to deal with any risks to the environment and human health…

40. The current EU regulatory system has been designed to limit adverse effects as far as possible – and as the regulatory system evolves over time, it will continue to retain this aim. But no procedures can be 100% effective, and there will always be the possibility – however small, or disputed – that some unforeseen (and possibly unforeseeable) adverse impacts to the environment or human health may occur, particularly in the longer-term. The potential irreversibility of some of these impacts also has to be taken into account when considering this possibility.

41. In light of this, a key trade-off will be between the costs and burden of regulation, and its effectiveness in anticipating and handling risk. A regulatory system which required large amounts of information, such as many years' worth of testing, might be more effective in anticipating problems or in dealing with unexpected events should they arise. But it could also be expensive and may discourage biotechnology firms from developing potentially valuable new crops in the UK.

*…**as well as on the impact of GM crop cultivation on non-GM and organic farmers***

42. The nature of the rules on the growing of GM crops will determine how effectively they can be kept separate from non-GM crops at the farm level, and to what extent non-GM and organic farmers may have to incur costs themselves in ensuring the integrity of their products. Whether they could pass on any such costs would depend on the relative demand for their goods, which would be higher in scenarios where the public has negative views about GM produce.

They also illustrate the central importance of public attitudes in determining the impacts of GM crops

43. Consumer attitudes are a very important determinant of the impact of GM crops. In scenarios with negative attitudes, there is only a limited market for GM crops, and hence low take-up. Attitudes are complex and heterogeneous, and may vary between different uses of GM crops – the use of crops for industrial purposes or animal feed, for instance, might prove to be more acceptable than their use in food.

In the short term, negative consumer attitudes can be expected to limit the demand for products containing GM foods, and therefore the economic value of the current generation of GM crops

44. Applying this to the current situation in the UK means that if consumer attitudes towards GM foods are negative in the short term, then any net cost and/or convenience savings associated with the current generation of GM crops would be likely to be outweighed by the lack of a market, limiting their

economic value. Interest from farmers may be limited to goods destined for export markets, or for the production of animal feed.

But there is significant potential for benefits from future developments in GM crop technology…

45. The availability of GM crop technology may help in the development of new and potentially beneficial crops in the future, such as those with particularly useful agronomic traits which make agricultural production easier or cheaper. These traits may be important in maintaining competitiveness in internationally-traded commodities. GM crop technology may also help the development of products with health or consumer benefits. And the potential for GM crops to be used in the production of a range of non-food products, such as renewable materials or pharmaceuticals, could provide benefits outside the farming and food industry.

46. However, this potential needs to be balanced against the possibility that new GM crops could introduce new risks. Much would depend on the ability of the regulatory system to keep up with the technology in the future, and to anticipate and manage risks and people's concerns effectively.

…as well as the potential for impacts on wider science and industry

47. GM crop policy may also have wider impacts on UK science and industry. The UK has a leading position in biotechnology in Europe. The UK also has a global reputation for wider scientific excellence, and science-based industries as a whole make an important contribution to national output. This contribution, and its future expansion, is likely to be affected if changes in GM crop policy send signals, either positive or negative, about the UK's attitude to biotechnology, science and industry.

The scenarios demonstrate that international implications could be significant

48. The scenarios show that the global impact of UK or EU GM policy should not be underestimated. The ability of developing countries to choose whether or not to adopt GM crop technology may be affected by considerations about the possible impact on exports to the EU. And taking a significantly different policy direction from other countries could cause serious trade tensions.

NEXT STEPS

49. Your views on the report and on the study as a whole would be welcome, particularly in light of the emerging issues coming out of the "GM Nation?" Public Debate and the Science Review. Please send your comments to:

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to arrive by **Friday, 17th October 2003**.

All responses received before this date will be published by the Strategy Unit and passed on to DEFRA.

Chapter 1: Introduction

Summary

- The Strategy Unit study is one strand of a wider public debate on GM issues.
- The main objective of the study is to provide a comprehensive and balanced analysis of the costs and benefits of the possible commercial cultivation, or otherwise, of GM crops in the UK.
- The report focuses on crops that are currently available, as well as possible developments in the next 10-15 years, and develops scenarios to explore a range of possible futures.
- The SU study does not attempt to provide a single figure for total costs and benefits; neither does it attempt to make policy recommendations or to set out potential implementation strategies.
- The project was carried out by a multi-disciplinary team, including team members with experience in economics, science, policy-making and working in developing countries.

This introductory chapter sets out the context of government initiatives and other studies in which the Strategy Unit GM crops project was conducted (section 1.1). It then describes some key terms used in the report (section 1.2). Section 1.3 outlines some of the significant recent events and policy developments which set the background for any study of GM crops. Details of how the project was conducted and who participated are provided in section 1.4. Section 1.5 describes the scope and limitations of this report, and section 1.6 outlines the way in which the report is structured.

1.1 Project context

The GM dialogue

The Government has decided to instigate a "GM dialogue", with several components

1.1.1 The Secretary of State for the Environment, Food and Rural Affairs, Margaret Beckett, announced on 26th July 2002[1] that she was calling for three inter-linked strands of dialogue on GM[2] issues:

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[1] A press release is available at http://www.defra.gov.uk/environment/gm/debate/index.htm. References in this document relate to material available to the project team up to and including Friday 20th June 2003.

[2] GM is variously used to stand for "genetic modification" or for "genetically modified".

- A public debate;
- A review of the scientific issues; and
- A study into the overall costs and benefits of GM crops.

1.1.2 "**GM Nation? The Public Debate**" has been taken forward by an independent Steering Board.[3] The origins of the Public Debate lie in the Agriculture and Environment Biotechnology Commission's (AEBC) "Crops on Trial" report published in Autumn 2001, and the chair of the AEBC, Professor Malcolm Grant, is also chair of the Public Debate Steering Board. The Steering Board met for the first time in September 2002, and has been asked to report to Government by September 2003. The aim of the Public Debate is to help deepen public understanding and create a dialogue between all aspects of opinion.

1.1.3 The **review of the science of GM** is being led by Professor Sir David King (the Government's Chief Scientific Adviser) working with Professor Howard Dalton (the Chief Scientific Adviser to the Secretary of State for the Environment, Food and Rural Affairs), with independent advice from the Food Standards Agency (FSA).[4] An expert Science Review Panel, chaired by Professor King, has reviewed and summarised the state of scientific knowledge and areas of uncertainty over GM science issues.

1.1.4 The Science Review Panel is due to publish its first report in late July 2003. The Science Review Panel is expected to re-convene in September 2003, to take into account the results of the Public Debate.

1.1.5 The **study into the overall costs and benefits of GM crops** is the subject of this report by the SU.[5] The specific role of the SU study within the overall GM dialogue has been to provide a comprehensive and balanced analysis of the costs and benefits of the possible commercial cultivation, or otherwise, of GM crops in the UK, as a contribution to future decisions about GM crops.

1.1.6 The Public Debate, Science Review, SU study of costs and benefits (and the FSA work described below) will all be taken into account by the Government in developing policy on GM crops. More information about the inter-relationships between the three strands of the overall GM dialogue is provided in Annex D.

There have been other initiatives and studies relating to GM crops

1.1.7 In parallel with the three strands of the GM dialogue, the **Food Standards Agency** has been independently assessing consumer views on the acceptability of GM foods and how these views relate to consumer choice.[6] Activities have included surveys of the attitudes to GM foods of young people and people on low incomes – to ensure that their views are fully represented in the debate – and a Citizen's Jury broadcast live on the internet.

[3] Full details of the Public Debate are available at http://www.gmnation.org.uk.
[4] Full details of the Science Review are available at http://www.gmsciencedebate.org.uk.
[5] An explanation of the origins and role of the Strategy Unit is set out in Annex A.
[6] Full details of the FSA's activities are available at http://www.foodstandards.gov.uk.

The FSA Board has discussed the issues arising from these activities at an open meeting held in May 2003[7].

1.1.8 The **AEBC** is conducting a study on the important issues of co-existence and liability as they relate to GM crops. Their report is expected to be published later in summer 2003.

1.1.9 In addition to the Science Review, an important source of scientific information on four specific GM crops will be the results from the "Farm Scale Evaluations" (FSEs), described in Box 1.1 below. The results are expected to be published in the autumn.

Box 1.1: The Farm Scale Evaluations

The Farm-Scale Evaluations are a three-year programme allowing independent researchers to study the effect, if any, that the management practices associated with Genetically Modified Herbicide Tolerant (GMHT) crops might have on farmland wildlife, when compared with weed control used with non-GM crops. Four crops are involved:

- oilseed rape (spring sown);
- oilseed rape (winter oil seed rape);
- beet (fodder and sugar varieties); and
- maize.

Trial sites have been situated in England, Wales and Scotland, and there have been a total of 60-75 fields of each crop type, over three years. The consortium of research institutions involved in the research is looking at indicators of biodiversity in the GM and non-GM areas of each trial. Comparison of these indicators will form the basis of published results. If the analysis meets appropriate scientific standards, then the FSE results for the three spring sown crops will be made available in autumn 2003. Results for winter oil seed rape, which is a year behind the spring crops, will follow in 2004.

1.2 Definitions of GM crops and GM food

Terminology reflects the many different uses of GM crops

1.2.1 GM crops, like non-GM crops, have a range of current and potential applications: human food, animal feed, textiles (e.g. cotton), and a range of industrial uses (e.g. to make pharmaceuticals or health products). Many crops are used for more than one purpose. Furthermore, GM crops are one application of biotechnology, and in the USA they are often referred to as "biotech crops".

[7] See http://www.food.gov.uk/aboutus/ourboard/boardmeetings/pastmeetings/118783

1.2.2 The overall effect of this situation is the existence of a potentially confusing array of terms. Many of these are described in more detail in Chapter 2. However, some basic terminology is outlined in Box 1.2 below.

Box 1.2: GM definitions

Genetic modification (GM): The technology of altering the genetic material of an organism by the direct introduction or removal of deoxyribonucleic acid (DNA).

Genetically modified organism (GMO): An organism in which the genetic material has been altered by the direct introduction (or removal) of DNA.

GM crops: One type of GMO: crop plants whose genetic material has been altered by the direct introduction or removal of DNA in order to confer particular characteristics on the plant.

GM food: A less well-defined term that applies with different degrees of clarity to a range of foodstuffs. Regulations that will determine how these are classified within the EU are outlined in Chapter 2. GM foods include:

- Any food produced from a GM crop, and in which the altered DNA is still present and detectable. E.g. food containing maize flour from GM maize, or whole foods such as GM tomatoes.
- Foods containing ingredients derived from GM crops but not themselves containing the altered DNA, e.g. sugar from GM sugar beet or oil from GM oil seed rape.

There are also some foodstuffs that are not commonly classed as “GM food” although GMOs have some part in their production. These include:

- meat or dairy products from animals fed with GM crops;
- foodstuffs that use products derived from GM microbes either as ingredients (some riboflavin is produced in GM microbes) or as processing aids (a version of chymosin – the active ingredient in rennet – is derived from GM microbes).

GM seed for sowing or **GM grain** for food use: Although they could grow into GM crops they are not strictly speaking GM crops themselves. They are generally described by the more generic term **“GMO”**. GM crop grain which has been milled into flour, and could not grow into a GM crop, would be classed as GM food.

GM feed: GM crops used to provide animal feed.

GM non-food crops: a subset of GM crops that are not used in food or feed. One significant example is GM cotton.

1.3 Recent events and policy processes

The recent history of GM crop controversies in the UK helps set the project context…

1.3.1 Genetically modified crops – and the issues raised by their possible cultivation and consumption – have attracted considerable controversy and debate. For a short period in February 1999, these issues became front-page news. Some of the events relating to those controversies are outlined in Box 1.3.

> ***Box 1.3: GM food in the late 1990s[8]***
>
> Genetically modified tomato puree was assessed and approved for consumption in the UK in 1995. In February 1996, shortly after this approval was granted, tins of the puree began to appear on the shelves of two British supermarkets – Sainsbury's and Safeway.[9] The puree was the result of over 20 years of research and development on GM tomatoes. It was made from GM tomatoes that contained more solids and less water than conventional varieties[10]. The product was sold between 10% and 15% cheaper than traditional puree.[11]
>
> There was little or no controversy attached to the product launch. The product was clearly labelled, and a non-GM alternative remained available. Early sales were good – at its peak, the GM tomato puree was outselling the conventional tins by two to one.[12]
>
> However, in 1998 the media reported some studies that appeared to show the potential for damaging effects on the environment and human health from GM crops and foods.[13] At the same time, ingredients derived from GM crops began to be used in a multitude of processed foods which were not labelled as 'GM'. The reaction by NGOs, consumers and the media was such that the major retailers and food manufacturers acted to remove GM food from their shelves – including the GM tomato puree that had sold so well.

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8 A more detailed assessment of these events is available in the analysis paper: *GM foods in the late 1990s – an overview of the events and the media reaction* (available on the project website (www.strategy.gov.uk) or on request from the SU).

9 http://members.tripod.com/~ngin/tom.htm

10 Parliamentary Office of Science and Technology (1998), "Genetically Modified Foods – Benefits and Risks, Regulation and Public Acceptance".

11 Harvey M (1999), "Genetic Modification as a bio-socio-economic process: One Case of Tomato Puree" CRIC Discussion Paper No 31.

12 Coombs T (1997), "Marketing Genetically Modified Foods", Lecture to 'Future Foods '97', Auckland, New Zealand.

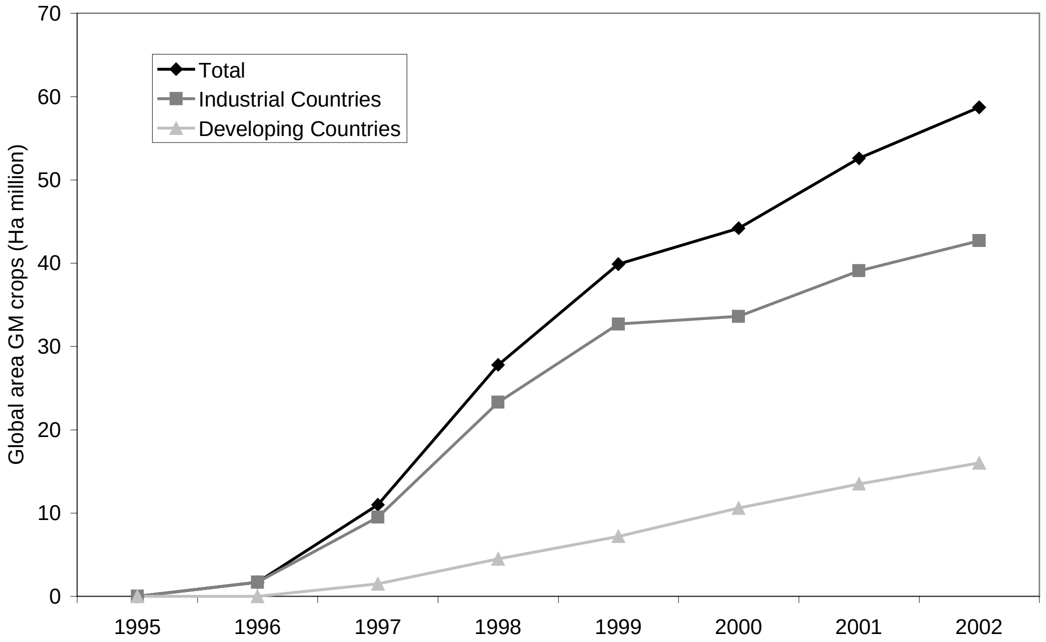
13 Since then, there have been a variety of other reports, which have made similar claims. All of these issues are being dealt with in the Science Review, but will not be addressed here.

…as does the rapid take-up of GM crops in other countries

1.3.2 Whilst GM crops and food have been particularly controversial in Europe, their take-up in other parts of the world has been rising rapidly. The total area planted with GM crops has grown by more than 10% every year since their commercialisation in 1996 (see Figure 1.1 below). Between 2001 and 2002, the increase was 12%. Over 99% of the GM crops grown are varieties of maize, soybeans, cotton and oil seed rape. Over 99% of these GM varieties are herbicide tolerant and/or insect resistant.[14]

1.3.3 Sixteen countries worldwide currently grow GM crops commercially. 66% of the global area of GM crops can be found in the US. Nine developing countries[15] also have commercial GM crops: Argentina, China, South Africa, India, Uruguay, Mexico, Indonesia, Colombia and Honduras. Of the area of crops grown in developing countries, Argentina dominates with over 80% of the growing area. China is next with about 13%, followed by South Africa with about 2%. The other countries (plus Romania and Bulgaria) all have less than 100,000 hectares.

Figure 1.1 Global Area of GM crops from 1996 to 2002.[16]



Developments in policies and policy processes are highly significant to the project context

1.3.4 Although the SU study has looked ahead to a 10-15 year time horizon, current policy developments and processes play an important role. The wider

[14] International Service for the Acquisition of Agri-Biotech Applications (ISAAA), "GM Crop Update 2002", http://www.isaaa.org/.
[15] Based on the OECD list of those countries in receipt of aid. See DfID (2002) "Statistics on International Development".
[16] ISAAA (2002) op cit.

policy context is described in Chapter 2, but some recent events and trends are worth highlighting here, in order to put the study into perspective:

- Since 1998, a number of European Union (EU) Member States (not including the UK) have pursued a moratorium effectively blocking approvals for new applications for marketing consents for genetically modified organisms (GMOs). This includes consents for the commercial cultivation of GM crops. The regulatory framework has recently been strengthened with the entry into force of Directive 2001/18/EC. However, some Member States consider that additional traceability and labelling rules need to be in place before any decisions on marketing of further GM products in the EU can be taken under this framework.

  In May 2003 the US, Canada and Argentina announced their intention to file a complaint at the World Trade Organisation (WTO), on the grounds that the failure of the EU to implement its approvals legislation constitutes a barrier to trade.

- In 1998, the UK Government reached a voluntary agreement with the agricultural biotechnology industry that no GM crops would be grown commercially in the UK until the results of the FSE trials had been assessed.[17] Irrespective of the uncertainty surrounding the EU approval process, one of the crops in the FSE trials (herbicide-tolerant maize) already has a marketing consent for commercial cultivation anywhere in the EU. Apart from the voluntary agreement, and subject to the FSE results, the only remaining legal obstacles to commercial cultivation of this GM herbicide tolerant maize in the UK are the need to secure approval under seeds legislation and under pesticides legislation (for the associated herbicide use).

1.4 Project participants and process

Composition of the Strategy Unit team

1.4.1 The study was carried out by a multi-disciplinary team, including team members with experience in economics, science, policy-making and working in developing countries.[18] None of the team had previously worked for organisations with a financial interest in GM crops or GM foods, neither had they been associated with campaigning activities on GM issues.

Links with other Government activities and external groups

1.4.2 Throughout the study, the team has worked closely with the Public Debate Steering Board, and has reported regularly to the Board – often in some depth – on work in progress. The team has also been in regular contact

[17] Voluntary agreement with the Supply Chain Initiative on Modified Crops (SCIMAC), November 1999

[18] Membership of the project team, and more detailed information on working processes, is given in Annex B

with the secretariat of the Science Review, and has attended meetings of the Science Review Panel. In addition, the SU appointed Expert Advisory Groups to assist with different aspects of its analysis.[19] Although the input and assistance of the Public Debate Steering Board, the Science Review Panel and the Expert Advisory Groups have played a crucial part in the project, because their role has been advisory, this report does not necessarily reflect their views.

1.4.3 The team has held a number of meetings and discussions with a wide range of stakeholders and experts from among NGOs, industry, farmers, academia and elsewhere.[20] The team has also had regular contact with representatives from the key government departments with an interest in this area, as well as with representatives from the Devolved Administrations. In addition to contact with officials, the team has had regular meetings with the study's Sponsor Minister, Margaret Beckett (Secretary of State for the Environment, Food and Rural Affairs).

The Strategy Unit study had three phases

1.4.4 The study had three main phases, outlined below.

1. An extended period to determine the scope of the project. During this phase the SU published a scoping note for comment (25 September 2002) and met a number of stakeholders and experts from inside and outside Government. The SU received over 150 responses to its scoping note, from a wide range of organisations and individuals. These responses were published on the website, along with a summary of the issues raised.[21]

2. An interim phase, during which the SU undertook an assessment of the issues that it would need to address in its analysis, and developed a methodology by which it could take these issues into account. The SU made extensive use of its Expert Advisory Groups and discussions with stakeholders, as well as holding a discussion with experts on "risk and uncertainty".

   These discussions highlighted the need for the SU project to be able to (i) take into account a range of different potential futures for GM crops; (ii) draw together the many disparate types of cost and benefit that might arise; and (iii) explicitly take account of uncertainty in the analysis. Scenarios provided one way to address these needs, and a workshop with stakeholders and experts was held to develop a range of different scenarios for the SU project. A brief description of the scenarios is given in box 1.4 below; they are described in detail in chapter 4.

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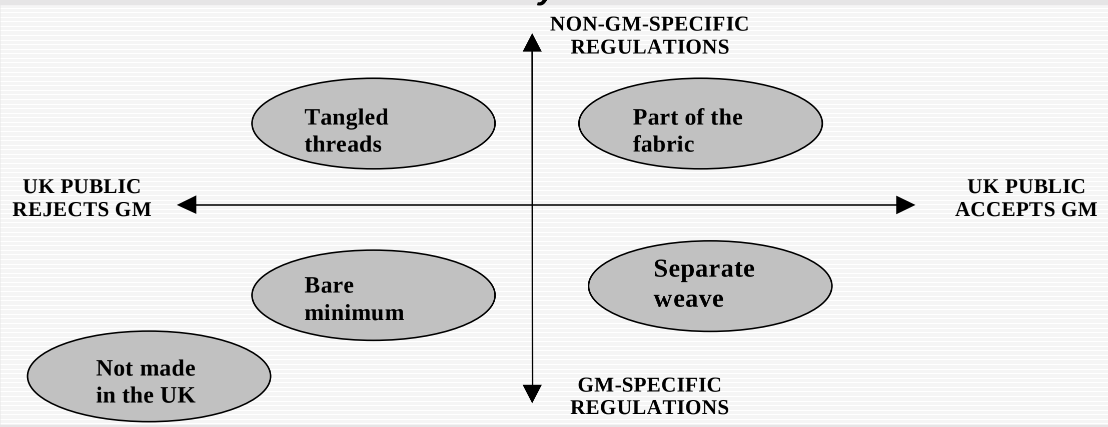
[19] The function and membership of the Expert Groups is described in Annex B.
[20] Annex C contains details of organisations consulted during the course of the whole study (August 2002 – June 2003).
[21] The scoping note, responses and summary of responses are available on the project website.

On 30 January 2003, the SU published an overview methodology paper and a series of working papers. Over 60 responses were received, and these have been published on the project website.[22]

3. A final, analytical phase, in which the SU put its methodology into practice in analysing the costs and benefits that could arise under the different scenarios. This report, together with the analysis papers available on the project website, was produced at the end of this analytical phase. Meetings and correspondence with stakeholders and experts remained important during this phase of the study, and the SU also held a seminar on 3 April 2003 in which stakeholders and experts debated possible "shocks and surprises" that could disrupt the scenarios.[23] The shocks and surprises are described in detail in chapter 4.

Box 1.4: Scenarios used in SU study



- **Scenario 1**: *'Part of the fabric'* – the public largely accepts GM crops and foods, and therefore significant cultivation of GM crops occurs, with the regulatory regime increasingly treating GM crops and foods much like any other novel foodstuff;
- **Scenario 2***: 'Separate weave'* – the public increasingly accepts GM crops and foods, and GM crops are gradually introduced under a strict GM-specific regulatory regime including a stringent approvals process, post-market monitoring and labelling;
- **Scenario 3**: *'Bare minimum'* – public attitudes are largely opposed to GM crops and foods, and there is a strict regulatory system, leading to very little GM cultivation in the UK;
- **Scenario 4**: *'Tangled threads'* – there is a breakdown between negative public attitudes and regulations which fail to maintain a separation between GM and non-GM crops grown in the UK;
- **Scenario 5**: *'Not made in the UK'* – an explicit decision is made against the commercial cultivation of GM crops in the UK, with the public preferring conventional or organic produce.

[22] The overview methodology paper, working papers and responses are available on the project website, along with a note of the scenarios workshop.
[23] A note of the "shocks and surprises" seminar is available on the project website.

1.5 Scope and limitations of this report

Scope of the Strategy Unit project

1.5.1 In its assessment of the overall costs and benefits of GM crops, the SU study has focused on a 10-15 year time horizon, though data availability has meant that much of the analysis has centred on the types of GM crop that may be available over the next few years.

1.5.2 The SU study has recognised that there are uncertainties in many areas relevant to the costs and benefits of GM crops. The incorporation of scenarios and "shocks and surprises" into the project has played an important role in helping the SU to explore and take into account different types of uncertainty. The scenarios allowed the SU to consider some of the uncertainties that are involved in looking forward 10-15 years – uncertainties that arise from the interactions between a range of currently-identified variables. "Shocks and surprises" allowed the SU to think how different potential futures might be disrupted - not by predictable changes to identified variables, but by events that are currently unforeseen.

1.5.3 There are also uncertainties that arise from absences in data availability or from disputed interpretations of existing information. The Science Review has played an important role in seeking to clarify some of the scientific uncertainties. But numerous other uncertainties remain, and these are reflected in the many qualitative – as well as quantitative – elements to the study. Some of the key areas are outlined below.

- Although there is a large body of international research on the commercial growing of GM crops, some of this is subject to contradictory interpretations, and its applicability to the UK needs to be treated with caution. It also covers a relatively short time period. As there has been no commercial-scale cultivation of GM crops in the UK, there is also limited domestic evidence of agronomic[24] or environmental impacts.

- There is very little research on the economic and environmental impacts of conventional and organic farming. This makes it hard to establish an analytical baseline against which the economic and environmental impacts of GM crops may be assessed.

- There are also significant uncertainties inherent in looking forward over the 10-15 year time horizon considered in this study. For instance, the UK and international policy environment, public attitudes, and the state of science may well change over this time period.

1.5.4 In this context, it is important to be clear exactly what the SU study has <u>not</u> done:

[24] i.e. relating to soil management or crop production.

There is no attempt to provide a single "net present value" of total costs and benefits; neither has the study attempted to make policy recommendations.

This report is general, not specific, in nature

1.5.5 Many of the issues that relate to GM crops – their potential impacts on farming, the environment, human health, and economic activity – are highly specific to individual crops and traits. In some cases, the potential for differences are obvious: the potential impacts of a GM herbicide tolerant oil seed rape variety for use in cooking oil will be different from those of a GM potato containing starch for use in industrial manufacturing. In other cases, superficially similar GM crops may have very different impacts: a GM herbicide tolerant sugar beet variety could have different impacts from a GM herbicide tolerant wheat variety.

1.5.6 Consequently, many analyses of GM crops need to be highly specific. This is the basis for the current EU regulatory approach, where individual GM crops are assessed on a case-by-case basis.

1.5.7 The SU analysis has recognised that generalisations about the impacts of GM crops are not always possible, and many areas where the analysis differs according to the particular crop variety have been highlighted. However, the overall report is positioned as far as possible at a general level. Its purpose is to look forward over a 10-15 year timescale and to inform the overall direction of policy towards GM crops as a whole. This in turn dictates the level of assessment in the report, and the focus (in the main) on broad trends and qualitative descriptions, rather than on quantitative data.

1.5.8 The report should thus be seen as a complement to – not a substitute for – more specific analysis of individual issues and decisions.

The analysis presented in this report cannot be regarded as definitive

1.5.9 This report is presented not as a statement of Government policy or thinking, but as a contribution to future policy decisions on GM crops and food.

1.5.10 It will be for Government to take a view on policy implications after it has received the full suite of outputs from the GM dialogue – including the report presented by the Public Debate Steering Board, the final assessment of the Science Review, the results of the FSEs and the work carried out by the FSA.

1.5.11 This report should be seen as a first attempt to take an overview of the costs and benefits associated with GM crops. There appears to be scope for and value in continuing the kind of analysis contained within this report. An overall understanding of the economic impacts of the UK's approach to GM crops is a valuable resource for decision-making. As technology develops, some knowledge gaps are filled in, and new methodologies for assessing costs and benefits are invented, improved understanding of these impacts will become possible. However, there are some inevitable limits to a costs and benefits approach – economics is unlikely to capture the ethical and social issues which GM crops will raise.

But decisions can and must be made

1.5.12 Although more clarity is expected to emerge over time, this does not mean that decisions affecting the UK's approach to GM crops cannot be taken now. Combined with the results from other strands of the GM dialogue, the FSE results and other relevant information, the analysis presented here – including the identification of areas of uncertainty – should provide sufficient basis for such decisions.

1.6 Structure of the report

1.6.1 The remaining chapters of this report cover the following:

- Chapter 2 sets out the broad backdrop of science, regulations, public attitudes and wider policy objectives within which GM crops have relevance;
- Chapter 3 summarises the most important costs and benefits identified in the Strategy Unit's analysis;
- Chapter 4 compares costs and benefits in a range of different scenarios; it also considers shocks and surprises and makes an overall assessment of the results of the analysis; and
- Chapter 5 explains what happens next.

1.6.2 Annexes provide further details on the processes behind the preparation of this report. They cover:

- the role of the SU;
- the Project Team, Sponsor Minister, Expert Advisory Groups;
- organisations consulted and submissions received; and
- the GM Dialogue: links with the Public Debate and the Science Review.

1.6.3 There are also a number of analysis papers available on the SU web site[25] which expand on the analysis set out in this report - along with the working papers published part-way through the project.

[25] Paper copies of the analysis papers are also available on request from the SU

Chapter 2: The backdrop for GM crops: science, regulations, public attitudes and wider policy

Summary

- Biotechnology has a wide range of current and future applications. Genetic Modification is one technique used in wider biotechnology. GM crops are one type of GMO and one aspect of agricultural biotechnology.

- There is a wide-ranging regulatory framework in place. Regulatory authorities have already taken steps to tackle potential environment and health issues that could arise from the development of GM crops.

- Public attitudes will be important in determining the future of GM crops and foods in the UK. Surveys on GM foods over the past few years have generally revealed a negative public attitude towards GM food. There are complex sets of issues that lie behind such results.

- GM crops are not an end in themselves, they need to be considered in the context of the Government's objectives in a number of policy areas. They also need to be considered alongside alternative approaches.

- The wider policy context for GM crops includes agricultural and environmental policy; rural policy; science, innovation and competitiveness policy; policy on food safety and quality; and international development policy.

This chapter explains the general backdrop against which any assessment of GM crops needs to be made. It starts by explaining how GM crops fit within the wider context of biotechnology, and considers the different types of uses to which GM crops – and their alternatives – may be put (section 2.1). The regulatory regime that governs GM crops is then described (section 2.2), and this leads to a discussion of public attitudes to GM (section 2.3).

The chapter then goes on to point out that GM crops and foods – and the non-GM alternatives – need to be assessed in terms of their contribution to a range of environmental, social and economic objectives – they are not an end in themselves. In view of this, the chapter then explains the key objectives relating to rural policy, agricultural policy, science policy and policy on food safety (section 2.4) against which any impacts of GM crops need to be assessed.

2.1 GM crops in their scientific context

GM crops and wider biotechnology

2.1.1 Biotechnology is a rapidly-expanding area of activity. It is a general term that encompasses many different aspects of scientific research and industrial applications. In many cases, the applications have more importance in terms of their future potential than in their current contribution.

2.1.2 GM crops are only one set of biotechnology applications. In order to describe GM crops in their wider context of related biotechnology activities, the following sub-sections outline biotechnology at its most general, and how genetic modification is used in biotechnology, before turning to look specifically at GM crops, and how they fit into this overall picture.

Biotechnology has a wide range of current and future applications

2.1.3 Biotechnology can be defined as the application of knowledge about living organisms, and their components, to make new products and develop new industrial processes.[26] The term covers a diffuse range of techniques, many of which relate to recent advances in genetics research, and a wide range of applications.

2.1.4 The principal areas where biotechnology has been applied to date include medicine and health care (sometimes referred to as “red” biotechnology) and agriculture (“green” biotechnology). The use of biotechnology in industrial production - e.g. using enzymes in pulp, paper and food processing - (“white” biotechnology) is also significant[27].

2.1.5 The European Commission has described biotechnology as “the next wave of the knowledge-based economy” to follow information technology. Biotechnology has the potential to generate skilled jobs[28] and significant sources of revenue, as well as delivering social objectives, by offering “opportunities to address many of the global needs relating to health, ageing, food and the environment, and to sustainable development”.[29] Some indication of the economic significance of biotechnology is provided in box 2.1 below.

[26] DTI (1999) “Genome Valley”, a report on the economic potential and strategic importance of biotechnology in the UK.
[27] Europabio (2003), “White biotechnology: Gateway to a More Sustainable Future”.
[28] Tait, J et al (2001), “Policy Influences on Technology for Agriculture – Final Report”. European Commission DG XII Project No. PL 97/1280
[29] COM (2002) 27, op cit.

Box 2.1: The economic significance of biotechnology.

Biotechnology lacks an agreed definition of its scope and boundaries that can be used with industry classifications of national statistics[30]. The main reason for this is that biotechnology is an enabling technology not an end in itself – biotechnology is applied in many different sectors, from agriculture to pharmaceuticals.

There are some companies (primarily small and medium-sized enterprises (SMEs)) whose business can fairly be described as entirely biotechnology-based. 2001 survey data indicate that the UK has almost 400 such firms, employing more than 18,700 people, with revenues of over £1.8 billion[31].

However, biotechnology SMEs comprise a relatively small amount of activity compared to large businesses and broad sectors of the economy where biotechnology could find some uses. In 1999, the DTI stated that "the industrial sectors which stand to benefit from biotechnology….employ over 1.75 million people in the UK and account for over 10% of UK GDP (i.e. £90 billion in 1999)".

The European Commission has estimated that by 2010, global markets for sectors where biotechnology is likely to constitute a major portion of new technology applied (excluding agriculture) could be worth over €2000 billion (£1300 billion).[32]

The USA is the world leader in biotechnology, but the UK is also well positioned: it vies with Germany as the leader in the EU[33]. The UK leads Europe in terms of the market capitalisation of its biotechnology companies, in terms of revenues generated, and in terms of the amount of venture capital financing of the sector[34].

Genetic Modification is one technique used in wider biotechnology

2.1.6 The rapid expansion of biotechnology in recent decades has resulted mainly from advances in the understanding of genes and how they function. Some information about genes and genetic modification is given in box 2.2 below.

Box 2.2: Genes and Genetic Modification

All plants and animals contain **genes** – humans, for example, contain about 30,000 genes. Genes are lengths of **DNA**. They work by controlling the production of **proteins**, which in turn determine the physical characteristics of an organism and many of its responses to environmental stimuli.

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30 M. Nawaz (2003) "Capturing the Economic Potential of all GM crops for UK plc".
31 DTI data; see http://www.wired-gov.net/WGLaunch.asp?ARTCL=15984
32 Life sciences and biotechnology – A Strategy for Europe COM (2002) 27.
33 Allansdottir, A et al (2002), "Innovation and competitiveness in European biotechnology", Enterprise Directorate-General, European Commission Paper No. 7.
34 Ernst and Young (2003), "Endurance – the European Biotechnology Report".

Although the cells in an organism contain the same DNA, not all genes are active in all the cells – allowing parts of an organism to differ from one another. For example, cells in the liver express different genes to cells in the brain. In addition, genes need other sequences of DNA (called **promoters**) to switch them on, and it is these promoters that determine where in the organism (and when in its life cycle) particular genes are active. The complete set of DNA in an organism forms that organism's **genome**. Research to understand the structure, function and evolution of genes is called **genomics**.

Knowledge of how DNA operates on a molecular level, and in particular how its chemical sub-units can link, split and re-unite (known as **recombinant DNA technology**) enables scientists to chop and splice DNA and to manipulate individual genes. Any organism that has been manipulated in this way is called a **GMO**. For the purposes of this report, **genetic modification** is defined as altering the genetic material of an organism by the direct introduction or removal of DNA.

2.1.7 One of the key ways that GM fits into wider biotechnology is as a tool in fundamental research. GM enables scientists to make controlled changes in genetic structures and so to test what each gene does. GM microbes, plants, fish, insects, amphibians and mammals have all been created for research purposes to understand gene function. GM animals (especially GM mice) have been developed as models for humans in medical research.

2.1.8 Without the ability to genetically modify different organisms it would be very difficult to interpret the mass of DNA sequence data (including human genome data) that is being generated in laboratories around the world. Genome sequence data itself is of little interest, but once the functions of different genes and combinations of genes are identified, the relationships between genetics and (for example) the causes of and susceptibility to disease, or the productive yield of an agricultural crop, can start to be explored.

2.1.9 Another important relationship between GM and wider biotechnology comes from creating specific GMOs with marketable characteristics – this is one way to generate commercial applications of biotechnology. Such GMOs include:

- GM microbes, GM crops and GM animals that act as "factories", producing pharmaceutically-active proteins;
- GM microbes that act as factories to produce enzymes for food processing;
- GM crops with modified agronomic or food quality traits; and
- GM fish to increase growth rate in aquaculture.[35]

[35] GM microbes producing pharmaceuticals and enzymes etc. are in widespread commercial use. The products from GM microbes currently used in food include chymosin for cheese production and riboflavin (vitamin B2). See Consumers' Association (2002) "GM Dilemmas".

2.1.10 However, it is important to stress that applications of biotechnology are not limited to the use of GMOs. Much of the knowledge that genetics and other biological research has generated about living organisms can be applied in other ways. For example, understanding how microbes can take up and process pollutants has led to a number of uses for non-GM microbes in cleaning up polluted soil.[36] Within agriculture, biotechnology is also used to develop diagnostic techniques to improve targeting of pesticide applications. Fungicides based on biodegradable products have also been developed using biotechnology.

GM crops are one type of GMO and one aspect of agricultural biotechnology

2.1.11 Thus there are two contexts that relate GM crops to wider biotechnology. First, GM crops are one type of genetically modified organism, and have potential uses in common with other GMOs e.g. as research tools and as potential producers of specific valuable biomolecules. When assessing costs and benefits of GM crops in this context, it makes sense to compare GM crops with other GMOs or with alternative technological methods of producing new materials or synthesising complex molecules.[37]

2.1.12 Second, GM crops are one of the ways that advances in biotechnology can be applied to agriculture – that is, they are one element of agricultural ("green") biotechnology. To be more specific, they represent one way that biotechnology can be used to support the development of new crop varieties. When assessing costs and benefits of GM crops in this context, it makes sense to compare GM crops with other types of crop rather than other GMOs. Box 2.3 sets out a number of techniques of producing new crop varieties, including genetic modification.

Box 2.3: GM and other methods of plant breeding

There is a wide range of methods through which genes conferring desirable characteristics can be introduced into crop varieties; traditional plant breeding is at one end, GM is at the other.

- Traditional plant breeding, whereby different varieties of crops are cross-bred to create a number of different offspring. Those that possess desirable characteristics are selected and multiplied up.
- Marker-assisted breeding, whereby offspring from crossing experiments are screened to see if they contain desired genes at an early stage in the breeding programme.

GM crops with agronomic and food quality traits have been commercialised in a number of countries around the world. GM crops and animals for pharmaceutical production, and GM fish in aquaculture, are at the research and development stage and are yet to be commercialised.

[36] All commercial uses of bio-remediation in the USA use naturally-occurring micro-organisms. Biotechnology Indicators and Public Policy, OECD Directorate for Science, Technology and Industry May 2002, DSTI/EAS/STP/NESTI(2002)8.

[37] Some examples of such comparisons are provided in the analysis paper: *Analysis of the Costs and Benefits of GM crops to Industry and Science* (available on the project website or on request from the SU).

- Induced mutation, whereby doses of radiation or mutagenic chemicals are used to make random changes to the DNA within plant cells. The alterations in the DNA can confer novel characteristics on the plants. Plants with new, valuable characteristics can be used in traditional plant breeding programmes.
- Protoplast fusion, whereby individual cells with their outer walls removed are fused, and the resulting single cell grown in a culture medium.
- Embryo rescue, whereby plant embryos created from cross-fertilisation are removed and grown outside the parent, allowing the creation of offspring from crosses that might otherwise fail to produce viable seed.
- Tissue culture selection, whereby a nutrient medium is used to grow many millions of individual plant cells, which are then exposed to damaging conditions or chemicals (e.g. herbicides) – only cells which happen to possess elevated levels of resistance to the hazard will survive.
- Genetic modification, whereby specific genes are inserted or removed into / from the plant genome in order to confer desirable characteristics on the plant. Inserted genes can come from any species.

Developments in new techniques may increasingly mean that the boundary between GM and non-GM crops will be blurred. Genetic modification already shares some similarities with other techniques – for example, marker-assisted breeding – which are based on genomics.

GM crops and alternative approaches

GM crops are currently limited to a small number of crop and traits

2.1.13 Although some of the first GM crops to be sold were GM tomatoes, there have been very few GM fruits or vegetables brought to commercial cultivation. Most GM crops are broad acreage commodity crops. To date there have been just two main traits expressed in the vast majority of commercially cultivated GM crops:

- **Herbicide tolerance**: this trait renders the crop tolerant to a particular herbicide, and means that a field can be sprayed with that herbicide without risk of damage to the crop.[38]

- **Insect resistance**: this trait renders the crop resistant to certain types of insect that would otherwise damage the crop.

2.1.14 This study has looked closely at the current generation of herbicide tolerant and insect resistant crops – especially those that are likely to be relevant to the UK. Because these crops have been commercially cultivated elsewhere, there is a body of evidence about them which is readily available. However, because this study has considered a 10-15 year timescale, it has

[38] Herbicides are a form of pesticide that is used to kill weeds. The term “pesticides” is used generically to cover all chemical treatments aimed at the destruction of living organisms that would otherwise damage crops (or animals or people). As well as herbicides, this includes fungicides (used to kill fungal diseases) and insecticides (used to kill insects).

been important to consider also the potential future generations of GM crops that may be suitable for commercial cultivation in the UK.

A wider set of crops and traits may become available in the future[39]

2.1.15 Looking ahead, a wider range of GM crops could be developed that are relevant to the UK. Possibilities include:

- the application of GM technology to a wider range of crop types suitable for UK conditions, such as GM wheat and GM potatoes;
- a range of more valuable agronomic traits, such as resistance to common UK pests and plant diseases, or improvements to the efficiency with which crops can absorb nutrients;
- GM foods with consumer benefits, such as longer shelf life, or health benefits, such as improved nutritional content or reduced allergenicity; and
- a wide range of non-food crops, which could include crops used as "factories" for a range of goods, such as pharmaceuticals, industrial oils, or renewable materials; as well as crops which could be used directly in the production of energy or fuel.

2.1.16 Any benefits or costs from these crops could in principle accrue to a wide set of interests, including food manufacturers, retailers, consumers and – especially for non-food applications - a diverse range of industrial sectors.

GM may have a unique role in some circumstances, but alternative approaches could deliver similar traits and outcomes

2.1.17 GM techniques are not the only means by which desirable traits for crops can be developed. Non-GM breeding techniques have already delivered crops that are tolerant to broad spectrum herbicides.[40] Such crop varieties are not subject to the controls imposed by the GMO legislation.[41] However, GM may sometimes be the only way of breeding a particular characteristic. This is most likely to be the case with characteristics that are governed by a small number of genes, particularly in circumstances where:

- the required genes are not found in the gene pool of related plants. For example, crop plants developed to produce commercially viable amounts of novel high value industrial chemicals will often need to be GM;[42] or

[39] A list of traits – and the crops to which they may be applied – was included in the Strategy Unit's "Background Working Paper for the Analysis of the Costs and Benefits of Industry and Science", available on the project website.
[40] For example, oil seed rape tolerant to sulphonylurea herbicides.
[41] However, the Government's Advisory Committee on Releases to the Environment, ACRE, has said that, "We have no reason to believe that conventionally bred crops with novel traits such as tolerance to broad-spectrum herbicides would not pose similar risks as those produced via genetic modification techniques." (ACRE (1999) "The Commercial Use of Genetically Modified Crops in the United Kingdom: the Potential Wider Impact on Farmland Wildlife", available at http://www.defra.gov.uk/environment/gm/wildlife/index.htm.)
[42] DEFRA (2002) Annual report of the Government-Industry Forum on Non-Food Crops.

- the required genes need to be rapidly introduced into elite crop varieties. For example, genes conferring resistance to rapidly-evolving pests might be present in old cultivars but cross-breeding these might result in the elite variety losing many of its other desirable characteristics.

2.1.18 GM may be less helpful in enhancing quantitative traits that depend on the action of many genes, each of which has a relatively small impact on the trait. Examples include complex phenomena such as the dependence of crop yield on environmental conditions.[43]

2.1.19 Different approaches to farming are also relevant. Organic farming aims to produce food of good nutritional quality by using management practices which aim to avoid the use of agrochemical inputs and to minimise damage to the environment and wildlife.[44] While there are some pesticides approved for use in these systems, organic farmers seek to use non-chemical alternatives – for example, natural predators to kill damaging insects; crop rotations to maintain soil fertility; or companion planting to avoid build-up of pests.

2.1.20 A related approach – though without the same underlying ethos and principles of organic farming – is integrated pest management (IPM). IPM involves a combination of methods to achieve effective pest control whilst minimising pesticide use and adverse effects on non-target species. GM crops could form part of IPM approaches. The use of IPM is being encouraged as best practice in farming through initiatives such as LEAF – Linking Environment And Farming.[45]

The agronomic utility of GM crops and their alternatives is only a small part of the story

2.1.21 GM crops raise many more issues than simply how to introduce a particular trait into a particular crop variety. Like any new technology, applications of biotechnology and genetic modification, including GM crops, could possibly cause some unwanted effects. Attempting to avoid the potential "downside" of any new technology is (in part) the job of government regulatory regimes. The regulations that cover GM crops (often part of regulations governing all GMOs) are described in the following section.

[43] See the Industry and Science Analysis Paper, available on the project website.
[44] See, for example, http://www.defra.gov.uk/farm/organic/default.htm for more details.
[45] See http://www.leafuk.org/leaf/

2.2 The fundamentals of GM crop regulatory policy[46]

The regulation of genetic modification reflects concerns about a number of potential adverse effects

2.2.1 Regulations governing research and uses of genetic and reproductive science were developed because of concerns about the increasing ability to change the genetics of living creatures. In broad terms, these concerns reflect three areas of adverse effects that could arise as a result of genetic modification:

- effects on biodiversity as a result of releasing GMOs into the environment;
- human health effects of GMOs; and
- ethical issues raised by the kinds of changes scientists could make – particularly in respect of humans and higher mammals.

2.2.2 Regulations are required because the costs of harm would generally not be borne by those causing the damage.

2.2.3 Apart from general support to overcome barriers to R&D, there is no direct regulatory intervention to promote GMOs with desirable traits or characteristics – the presumption is that the market will be willing to pay the going rate for these innovations.

There is a framework of EU and international regulations

2.2.4 The import and cultivation of GM crops has been regulated at EU level since 1990. Overall, current EU regulatory policy for GM crops seeks to ensure that they:

- present no unacceptable adverse risks to human health and the environment; and
- can circulate freely as products on the EU single market, provided all appropriate measures are taken to avoid adverse effects.

2.2.5 The basis for the regulation for GM crops is Directive 2001/18/EC on the deliberate release into the environment of genetically modified organisms, described in Box 2.4 below.

[46] An overview of the regulatory context pertaining to GM crops is available - see the analysis paper *Regulations and GM crops: Key Questions answered* (available on the project web site or on request from the SU).

Box 2.4: EU regulations on the release of GMOs into the environment

Directive 2001/18/EC on the deliberate release into the environment of genetically modified organisms was adopted by the Council of Ministers in February 2001.[47] It aims to strengthen the safety assessment of GMOs, and to improve transparency and public consultation. The new regime applies to applications for commercial releases of GMOs, including cultivation within the EU as well as imports of commodities produced outside the EU, and to research trial releases.

As with the previous Directive, decisions to approve GM crops are taken on a case-by-case basis, following a scientific assessment of any risks to human health and the environment. Ethical and socio-economic issues are not directly taken into account in assessing individual consent applications, but the Directive contains provision for these issues to be considered at a general level. The regulations also require a plan for post-market monitoring to be put in place.

Following the entry into force of Directive 2001/18/EC, a number of new applications have been made for the commercial importation and cultivation of GMOs within the EU. These applications have entered into a formal process of assessment by Member States, as laid down in the Directive, which sets out procedures and deadlines for decisions to be taken by Member States and the European Commission. If a consensus on any application can not be reached, decisions can be made by qualified majority voting.

2.2.6 EU and UK decisions about GM regulations are influenced by international agreements. Regulations need to be consistent with broader multilateral obligations embodied in a number of key agreements summarised in table 2.1.

Table 2.1: Multilateral Agreements Relevant to UK and EU Decisions on GM Crops

Policy	Description
The role of the World Trade Organisation (WTO)	• WTO agreements cover goods, services, intellectual property, dispute settlement and policy review; • Countries bring disputes to the WTO if they think their rights under the agreements are being infringed; • No trade dispute over GMOs has yet been examined by a WTO panel but one has been recently filed and is in the consultation stage[48].
The Cartagena Protocol on Biosafety	• The Cartagena Protocol on Biosafety is a multilateral environmental agreement focussing on the transboundary movements of GMOs; • The key provisions of the Protocol set out internationally-agreed operative procedures under which countries can decide whether to allow imports of GMOs that may affect biodiversity. • 103 countries have signed the Protocol, and over 50 countries have

[47] It was transposed into national legislation in England in October 2002, in Scotland and Wales in December 2002 and in Northern Ireland in April 2003.
[48] References in this document relate to information available to the project team up to and including 20th June 2003.
[49] http://www.biodiv.org/biosafety/

	now ratified it. It will enter into force on 11 September 2003[49]. The UK will complete ratification during 2003 once the relevant implementing EU measures are in place.
Codex Alimentarius	• Codex Alimentarius is a set of international codes of practice, guidelines and recommendations pertaining to food safety and quality – it includes principles (currently in draft) for risk analysis of GM foods and related guidelines for the safety assessment of foods from GM plants.

Overall, there are a wide range of regulations that affect GM crops in the UK

2.2.7 Specific regulations for GM crops in the UK apply at a number of different levels, related to different types of use. The following list indicates the main types of use, all of which are regulated under EU directives.

- **Contained use**, i.e. GM crops being researched inside laboratories, industrial production plants or greenhouses. As with all contained use of GMOs, this is regulated by the Health and Safety Executive (HSE) under the Genetically Modified Organisms (Contained Use) Regulations (2000).

- **Field trials**, i.e. GM crops that are being grown in small-scale non-commercial research trials in the field. These must be approved under Directive 2001/18/EC. Release of GMOs into the environment is regulated by DEFRA and by the Devolved Administrations, with guidance from the Advisory Committee on Releases to the Environment (ACRE).

- **Market release**, i.e. GM crops that are intended for commercial release onto the EU market. These are also governed by Directive 2001/18/EC, and approval is required for crops that are going to be imported into the EU, cultivated in the EU and / or processed in the EU. Approvals are again based on a risk assessment, but apply across the whole of the EU.

- **Food and food ingredients**. In addition to gaining approval under Directive 2001/18/EC, any GM crop that is intended for use as human food or as a food ingredient must meet Novel Food regulatory requirements. The focus of the assessment is on differences compared with existing foods that are otherwise “substantially equivalent”. The FSA is the competent authority, advised by the Advisory Committee on Novel Foods and Processes (ACNFP).

- **Seeds and varieties**. New varieties – whether GM or conventional – can only be marketed to farmers if they are shown to be distinct, uniform and stable and have been added to the UK National List or the EU Common Catalogue (an amalgam of the National Lists of Member States).

- **Pesticides**. Pesticide approvals are limited to uses with specific crops for specific purposes at specific times of the year. Any new pesticide/crop combination needs to be approved by the Advisory Committee on Pesticides. Such approvals would be needed for many new crops, including some herbicide tolerant GM crops.

2.2.8 Looking to the future, there are a number of new regulations currently in negotiation:

- **Regulation on Food and Feed**. This would replace the existing approvals procedures for GM foods and introduce new rules for the approval of GM animal feed. Its main impact will be to take the approvals process into a "one stop shop", operated by a new European Food Safety Authority. It would also introduce new authorisation requirements for products derived from GMOs, but containing no GM material, and specify stricter labelling requirements for food and feed.

- **Regulation on Traceability and Labelling**. This would extend the rules currently set out in Directive 2001/18/EC, by seeking further harmonisation of systems to trace and label GMOs. It also contains requirements for identification of bulk shipments of GM commodities. Like the food and feed measure, it would for the first time apply requirements to GM-derived products.

- **Commission Proposals on Adventitious Presence**.[50] These would tighten the rules for the extent to which a product or seed may still be classed as "non-GM", even if it contains some adventitious presence of an approved or non-approved GMO. These rules would be introduced under the two measures above and under existing seeds directives.[51]

- **Regulation on Transboundary Movements of GMOs**. This would complete EU implementation of the Cartegena Protocol on Biosafety, mainly by supplementing the existing rules on imports of GMOs under Directive 2001/18/EC with new rules on exports of GMOs to third countries.

There are different national approaches to GM crop regulation around the world

2.2.9 All existing regulatory systems governing the uses of GM techniques in food and agriculture are based broadly on assessments of safety for human health and the environment. There is general agreement that such systems "need to be science-based, transparent and involve community participation, and that safety assessments should be undertaken on a case-by-case basis".[52]

2.2.10 Within such overall agreement, two distinct approaches have emerged: regulations based on the safety of the *product*, versus regulations based on the *process* by which the product is produced. Essentially, this splits regulations into ones which assess GMOs and their products because they are novel (USA, Argentina, Canada, China, Japan) and those that assess GMOs and their products because they have been created using genetic

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[50] Adventitious (or accidental) presence of GMOs occurs when GMOs are found to be in what is ostensibly a non-GM product or seed.
[51] See the Regulations Analysis Paper, available on the project website, for further details.
[52] International Council for Science (2003) "New Genetics, Food and Agriculture: Scientific Discoveries – Societal Dilemmas".

modification (EU, Australia).[53] In addition, the interpretation of risk assessment and management differs amongst countries and regions.[54]

2.2.11 Within each major grouping there are different mechanisms through which the assessments are made. In the USA it was decided that no new and specific biotechnology regulation system was required, and existing assessments of food and agriculture could be applied to GM crops. In Canada, a new regulatory framework for biotechnology was developed, but this assesses all plants or products with new traits or attributes, irrespective of whether these were developed using GM or more traditional plant breeding methods. In China, product-based assessments also contain explicit consideration of "the economic interest" of the GM crop.[55]

2.2.12 Regulations based on *process* also vary. The EU approach is outlined in 2.2.6 and 2.2.7 above. Australia passed a Gene Technology Act in 2001 to regulate research, manufacture, production and importation of all organisms that have been genetically modified. The Act created a new Office of the Gene Technology Regulator to oversee and enforce all regulations relating to the use of GMOs.[56]

Not all relevant regulations relate directly to GM Crops

2.2.13 Another set of regulations that is important for GM crops – and for biotechnology more generally – is the regulatory regime governing patents and Plant Breeders' Rights. These different forms of intellectual property protection affect the ability of those involved in developing new crop varieties to derive financial returns from their research, and help shape the kinds of research that is conducted. They are described in Box 2.5.

Box 2.5: Patents and Plant Breeders' Rights

Patents are "an exclusive right given to an inventor to exclude all others from making, using and/or selling the invention".[57] The exact right afforded depends on which country issued the patent. Patents can be given for products and processes. They are limited to a fixed period – at least 20 years under the TRIPS agreement[58] – after which the invention moves into the public domain and can be exploited by anyone.

It is not possible to patent a plant variety in its own right. However, it is possible to patent the use of an invention within a plant – such as a GM plant.

[53] J-P Nap et al (2003) The release of genetically modified organisms into the environment. Part 1. Overview of current status and regulations. The Plant Journal, Vol. 33, pp1-18.
[54] International Council for Science (2003) op cit.
[55] J-P Nap et al (2003) op cit.
[56] J-P Nap et al (2003) op cit.
[57] Taken from entry on "Patent(s)" in Table 1 of Kowalski, Stanley P., Ebora, Reynaldo V., Kryder, David R. and Potter, Robert H. (2002) "Transgenic crops, biotechnology and ownership rights: what scientists need to know", The Plant Journal 31(4), pp 407-421.
[58] The TRIPS (Trade-Related aspects of Intellectual Property Rights) Agreement is one of three pillars of the World Trade Organisation (WTO), alongside trade in goods and trade in services. All parties to the WTO are required to comply with TRIPS – though some (developing) countries have a derogation until 2006.

For example, a patent could be granted on a gene for frost resistance. The patent might cover the gene in its isolated form, and the gene when in a plant variety.[59]

Plant Breeders' Rights (also known as Plant Variety Rights, PVRs) are a form of intellectual property designed to protect new varieties of plants. Once protection has been granted, it lasts for 25 years (30 years for trees, vines and potatoes). As with patents, the owner's consent is required for most uses of the propagating material of the plant variety (usually granted in return for royalties on seed sales).

There are some important differences between patents and PVRs. For example, there are no restrictions on the use of PVR-protected plants for breeding programmes, nor for private or experimental purposes. There is also an exemption that allows farmers to save seed from many PVR-protected varieties in return for reduced payments.

2.3 Public attitudes

2.3.1 This report (see paragraph 2.2.1) has already observed the way in which regulations have been driven by a set of concerns emerging from the development of GM technology. Many of these concerns are at the root of public attitudes to GM. Public attitudes are particularly important- and particularly complex – in the context of GM crops.

Opinion poll evidence reveals that public attitudes are complex

2.3.2 There have been a number of opinion poll surveys of public attitudes to GM crops and food in the past few years (Box 2.6). Whilst such surveys are widely referred to and provide important snapshots of how people regard the issues, they must also be interpreted with care – outcomes can be influenced by factors such as the size of sample, level of interaction with survey participants, and the design and phrasing of the questions.[60]

Box 2.6: Recent evidence from opinion polls on GM

A wide variety of organisations have published opinion poll data on the public's attitudes to GM.

- MORI Environment Research (2003) found that 56% of people in the UK are opposed to the introduction of GM food – more people than are opposed to nuclear power or congestion charging. 14% support their introduction, and 25% neither support nor oppose their introduction.

- The Food Standards Agency (2003) have found that consumer concerns about GM food fell from 43% to 36% between 2000 and 2002. In discussion

[59] Source: UK Patent Office.
[60] See, for example House of Lords Science and Technology Committee (2000) "Science and Society" 3rd Report Session 2000-1.

groups with young people and people on low incomes, a minority held firm views either way – most were relatively neutral.

- The Consumers' Association (2002) found that 32% of consumers were in favour of growing GM crops for commercial purposes in the UK at the present time. In contrast, 58% were against, and cited lack of information as the primary reason. 50% thought that GM could offer benefits for food production – but at the moment, these benefits are seen to be going to those developing the technology, not to consumers. 57% had concerns about the use of GM in food production, these concerns relating mainly to not knowing enough about GM, or to fears of tampering with nature.

- Eurobarometer (2002) found that support for GM food and crops had stabilised across Europe between 1999 and 2002. Support by the UK public had grown in that time, with the position now one of "weak support" for GM crops and "weak opposition" to GM food.

2.3.3 The main message coming from the opinion poll data is that public attitudes are complex, though there does seem to be some evidence that attitudes towards GM crops and foods are generally negative. In addition, there appears to be some evidence that attitudes may vary between GM crops and GM foods, and between different types of GM produce (food, feed and non-food) and GM traits (agronomic benefits, environmental benefits, etc.).

The public will "frame" GM issues in different ways

2.3.4 One reason for this complexity is the fact that the public will "frame" GM issues in different ways, depending on their primary point of contact with GM technology. For example, any one individual could view GM crops and foods from the point of view of a consumer, a parent, a tax-payer, an environmentalist or an employee. The GM Public Debate has been designed in part to clarify public concerns and to inform government about them. Results from early work commissioned by the Debate indicate some of the key frames (Box 2.7).

Box 2.7: How the public frames issues relating to GM

One of the aims of the Public Debate's "Foundation Discussion Workshops" – held during November 2002 – was "to allow the public to frame the issues" that would be used in the main part of the Debate. The organisers of the workshops (Corr Wilbourn) suggested the following headings as representative of the way in which the public frames GM issues:

- Food – including health issues, aesthetics, product characteristics, economics, political issues and impacts on production processes.
- Choice – including the extent to which a choice exists, issues of timing, labelling and impacts on organic farming.
- Information needs – including information on GM and on those with a stake in GM.

- Progress – including science, technology, medicine, economics, ideology and the way in which these fit with the trajectory of GM.
- Uncertainty – including the potential for catastrophe, liability and potential mis-use.
- Targets – including plants, animals, humans and micro-organisms.
- Ethics – including questions of why GM is happening at all, and how / by whom it is being controlled.

2.3.5 Another complexity in public attitudes arises from their inter-dependency with the views, policies and campaigns of other groups and organisations, including the Government. The events surrounding the introduction and subsequent withdrawal of GM foods in the late 1990s provide a good example.[61] The retailers and food manufacturers took steps to engage with and inform their consumers and the media before introducing GM tomato paste in the UK. However, they were in turn heavily influenced by subsequent "anti-GM" campaigns by Non-Governmental Organisations (NGOs) and the media, which also helped to shape consumer attitudes.

2.3.6 Members of the British Retail Consortium (BRC), including all the major UK supermarket chains, currently have a policy of not stocking foods sourced from GM materials and ingredients.[62] The BRC highlights the importance of consumer attitudes in determining how this policy may evolve in the future. In its policy statement of October 2002, it states that "Retailers will consider the sale of GM foods or foods containing GM ingredients, provided they have approval from the regulatory authorities and where they have confirmed a clear consumer demand."

2.4 The wider policy context

GM crops are not an end in themselves

2.4.1 Neither GM crops, nor the alternatives to GM crops, can be considered as ends in themselves. GM crops are useful only if they are able to play a role in meeting desirable objectives – environmental, social and economic – without imposing unacceptable costs. Hence the analysis of costs and benefits associated with GM crops makes sense only in the context of those wider objectives, particularly as reflected in Government policy. That is why this report's analysis is focused on addressing the following questions, across a range of different scenarios:

- How will GM crops impact on the Government's policy objectives?

- Are GM crops likely to have a positive role to play, perhaps as part of the solution to current problems?

- Are GM crops likely to exacerbate current problems or create new ones?

[61] These events are discussed in Box 1.3 and in the GM Foods in the late 1990s Analysis Paper.
[62] "New food products and processes", BRC Food Briefing (October 2002)

- Or are GM crops irrelevant to meeting the main objectives in each policy area?

- What are the alternatives to GM crops, and how do they compare in their ability to deliver on objectives?

- How might the answers to these questions change over time?

2.4.2 The remainder of this section sets out which of the Government's wider policy objectives may be affected by GM crops.

Agricultural policy and the environment

UK agriculture is strongly influenced by international developments

2.4.3 In the mid-part of the 20th Century, the focus of farming in the UK was on delivering some degree of self-sufficiency in food production. But during the latter part of the century, with the introduction of the Single Market and the creation of the WTO (and its fore-runners "GATT" and "GATS"), imports became much more readily available, often at a lower cost than domestic agriculture could deliver.

2.4.4 The latter part of the 20th Century also saw the establishment of the Common Agricultural Policy (CAP), and the associated system of subsidies and quotas. Notwithstanding the reduction in price support that has been seen in the ongoing reforms of CAP, it is important to be clear that UK farmers do not operate in a fully competitive market: in 2001, gross output from farming in the UK was £15 billion; CAP funding to the UK was £3 billion.[63]

2.4.5 CAP has established a complex set of incentives, and this means that the impact of a new development such as GM crops is not easy to predict. The difficulties of making firm predictions are exacerbated by the fact that CAP is in the middle of a mid-term review, and also by the expected accession of ten new Member States in 2004[64] – most of which have large agricultural sectors and could have a major impact on farming across the EU.

2.4.6 Market reform and trade liberalisation are key elements of the UK Government's position on CAP reform.[65] They also form part of the PSA target to promote trade opportunities for the UK and developing countries.[66]

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[63] DEFRA/ONS Summary of UK food and farming and http://www.defra.gov.uk/farm/capreform/indetx.htm

[64] Bulgaria and Romania to follow in 2006 or 2007.

[65] DEFRA (December 2002) "Strategy for Sustainable Farming and Food - Facing the Future", available at http://www.defra.gov.uk/farm/sustain/newstrategy/index.htm

[66] DTI/DfID/FCO joint Public Service Agreement target to "Secure agreement by 2005 to a significant reduction in trade barriers leading to improved trading opportunities for the UK and developing countries". See http://www.hm-treasury.gov.uk/spending_review/spend_sr02/psa/spend_sr02_psaindex.cfm

The economic significance of agriculture has diminished

2.4.7 Despite some limited recovery in the last two years, farm incomes have fallen very substantially since 1995. This has been due to a number of difficulties:

- Exchange rate changes, which affect subsidy payments and value of farming outputs;
- Weak world commodity prices;
- One-off crises, such as BSE and the 2001 outbreak of Foot and Mouth Disease (FMD).

2.4.8 However, the food chain as a whole (including agriculture) remains economically significant in the UK. Some statistics outlining the UK agricultural and food sector are shown in Box 2.8 below.

Box 2.8: Economic Significance of UK Agriculture and Food

There has been a long-term decline in the contribution of the agricultural industry to the UK economy. Agriculture currently accounts for less than 1% of GDP, down from a level of 2.1% in 1983.[67] Agriculture's share of total economic gross value added is at its lowest in England at 0.6% and highest in Northern Ireland at 2.9%.

Agriculture's share of the total workforce is falling, having experienced a drop of 20% over the last 10 years to its current level of 2% of the labour force.[68] Its share of total regional employment varies considerably throughout the UK, with the lowest proportion of 1.9% in England and the highest of 7.6% in Northern Ireland.

Downward trends in employment and contribution to GDP are common to most developed countries, and are more pronounced in most other EU countries.[69]

The UK currently has the fastest growing organic market in Europe. Organic produce make up 1.4% of the total value of sales of food and drink in the UK and in 2002, 4.3% of the total agricultural land area in the UK was managed organically.[70]

The UK is a world leader in added value food and drink production and marketing.[71] The UK food chain of agriculture, horticulture, food and drink manufacturing, food and drink wholesaling, food and drink retailing and

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[67] DEFRA (2001), op cit.
[68] DEFRA (2001), op cit.
[69] DEFRA (2002) "Farming and Food's Contribution to Sustainable Development: The Current Situation and Future Prospects".
[70] See background working paper for the analysis of the costs and benefits in the product chain.
[71] See http://www.dti.gov.uk/sectors_food.html

catering industries provides 12.5 % of total employment and exports goods worth £9 billion (some 3 % of total exports).[72]

The food chain accounts for nearly 8 % of UK GDP[73] (i.e. about £65 billion). The largest contribution is from manufacturers (£19.4bn), followed by retailers (£16.6bn)[74]. The UK retail sector is characterised by a certain degree of concentration: five supermarket chains account for about 70% of grocery sales in the UK. This has given rise to concerns about the imbalance of power between large retailers and their smaller suppliers.[75] Few producers supply supermarkets directly, but there are similar concerns about the balance of power further down the chain.

2.4.9 A further concern for UK agriculture is the rate and efficiency with which new knowledge and technology is applied. This is an important component in explaining the sector's slow productivity growth.[76]

Links between agriculture and the environment are seen as increasingly important

2.4.10 Agriculture has had a significant effect on the environment for many hundreds of years. In the UK, impacts range from the ancient (e.g. downland from sheep farming), through the historical (e.g. patchwork field patterns dating back several centuries) to the relatively recent (e.g. the bright yellow fields of oil-seed rape). 75% of the UK land area is currently managed by farmers[77], and in recent years there have been a number of important trends (good and bad) in agriculture's impact on the environment, shown in Box 2.9 below.

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[72] DEFRA (2002) "Farming and Food's Contribution to Sustainable Development: The Current Situation and Future Prospects".
[73] DEFRA (2002) op cit. GDP figures based on 2000 data.
[74] DEFRA (2002) op cit. See also background working paper for the analysis of the costs and benefits in the product chain.
[75] This has been a recurrent theme in the Strategy Unit's meetings with stakeholders involved in farming and food production. The subject was addressed in a report by the Competition Commission, following which the Office of Fair Trading has drawn up a code of practice which defines the principles and practices that apply in order to achieve fair and balanced trading relationships between the largest supermarkets and their suppliers. See DEFRA (2002) op cit.
[76] DEFRA (December 2002) "Strategy for Sustainable Farming and Food - Facing the Future".
[77] DEFRA (2001), "Agriculture in the United Kingdom – 2001", online at http://www.defra.gov.uk/esg/work_htm/publications/cf/auk/current/auk_pdf.htm

Box 2.9: *Trends in environmental impacts of agriculture*[78]

Pesticide residues in water have fallen: the number of monitoring sites where the Environmental Quality Standard was not met fell from 10 in 1995 to 4 in 1997 in England, Wales and Northern Ireland.

Farmland bird numbers have fallen sharply: farmland and woodland birds have generally been declining from the mid-1970s to 1998. Populations of some farmland birds such as the skylark and corn bunting, and of woodland birds such as the song thrush and bullfinch, have fallen by more than half in that time.

Vegetation groups associated with agriculture have decreased: the average number of species in fields, woods, moorland, hedges and streamsides, especially in lowland landscapes has fallen. The changes in the different types of plants suggest that the decline reflects an overall shift towards more intensively-managed and nutrient-rich vegetation.

Characteristic countryside features have deteriorated: hedges, walls and ponds have been in decline through the 1980s and early 1990s, mainly due to lack of appropriate management. Now more hedges are being planted than uprooted, but the problem of maintenance remains. In England and Wales, the length of managed hedgerows decreased by nearly a third between 1984 and 1993.

2.4.11 In addition, concerns have been expressed about the future impacts of climate change on the relationship between agriculture and the environment in the UK.

Policy-makers have taken the changing situation into account

2.4.12 The UK Government's priority reflects environmental and economic concerns:

> "*to secure an environment in which a competitive and sustainable agricultural industry with a strong market orientation can flourish*".[79]

2.4.13 That priority is mirrored in the European Commission's mid-term review of CAP, which recognises that:

[78] See http://www.sustainable-development.gov.uk/sustainable/quality99/package/agricult.htm
[79] http://www.defra.gov.uk/farm/ag2000.htm

"besides supporting farming incomes, [CAP] must yield more in return regarding food quality, the preservation of the environment and animal welfare, landscapes, cultural heritage, or enhancing social balance and equity."[80]

Changing pressures and priorities require changes in the farming sector

2.4.14 Within England, the "Curry report" (published in January 2002) set out a vision for the future of food and farming.[81] The report described its central theme as "reconnection", and made over 100 policy recommendations aimed at:

- Reconnecting farmers with their market and the rest of the food chain.
- Reconnecting the food chain with a healthy and attractive countryside.
- Reconnecting consumers with what they eat and where it has come from.

2.4.15 The Government has now published its response to the Curry report.[82] The key element of the policy response is the publication of a "strategy for sustainable farming and food" in England.[83] In parallel, the UK Government has put together an action plan to develop organic food and farming in England.

2.4.16 The strategy makes clear that the success of the industry ultimately lies in its own hands. The overarching aims provide "a framework for the future", not "a single blueprint – a master plan – for all to follow"[84]. Individual farmers and other companies in the food product chain will continue to have a range of options for developing their businesses.

2.4.17 The devolved administrations have their own agriculture and food strategies, each reflecting the particular circumstances of agriculture (conventional and organic) in those administrations.[85]

[80] http://www.europa.eu.int/comm/agriculture/mtr/index_en.htm

[81] The "Curry report" is the common term used for the report of the Policy Commission on the Future of Farming and Food, chaired by Sir Donald Curry. Details are available at http://www.defra.gov.uk/farm/sustain/default.htm.

[82] DEFRA (December 2002) "Response to the Report of the Policy Commission on the Future of Farming and Food by HM Government", (CM 5709) available from http://www.defra.gov.uk/farm/sustain/newstrategy/index.htm.

[83] DEFRA (December 2002) "Strategy for Sustainable Farming and Food - Facing the Future".

[84] DEFRA (2002) "Strategy for Sustainable Farming and Food - Facing the Future".

[85] In Scotland, the Scottish Executive has published "A Forward Strategy for Scottish Agriculture" (2001), available from http://www.scotland.gov.uk. The Scottish Executive Organic Action Plan is at http://www.scotland.gov.uk/library5/agri/orap-00.asp. In Wales, agriculture is a key element of the "Rural Development Plan for Wales 2000-2006" (2001), op cit. Organic farming is covered in http://www.wales.gov.uk/keypubassemcomagriandrural/content/organicfarming/English%20Text%20&%20Cover.pdf.
In Northern Ireland, a vision for the future of the agri-food sector is described at http://www.dardni.gov.uk/.

Increasing provision of environmental goods from agriculture is a major theme

2.4.18 Efforts have been made to minimise any adverse environmental impacts from agriculture through the introduction of agri-environment schemes, which offer financial rewards for farmers observing good environmental practice. The main government-led schemes in England are currently the Countryside Stewardship Scheme and the Environmentally Sensitive Areas scheme. Similar measures are in place in Scotland, Wales and Northern Ireland.

The role of GM crops in the future of farming is not yet clear

2.4.19 New technologies, such as increased mechanisation, have played an important role in promoting agricultural productivity. The potential role of GM technology, however, is not yet clear.

2.4.20 The Government's Strategy for Sustainable Food and Farming states that

> "*The techniques of genetic modification, if applied safely and responsibly, have the potential to contribute to sustainable food and farming. But genetically modified organisms (GMOs) may, as well as bringing benefits, pose an as yet unknown risk – not to human health – but to other biodiversity*."[86]

2.4.21 Chapter 3 attempts to assess the potential costs and benefits that GM crops might bring in relation to the objectives for agriculture in the UK. It also considers the interaction between GM crops and other approaches, for some of which – for example, organic farming – there is already rather more clarity in the role they are expected to play.

Rural policy

2.4.22 Impacts of GM crops on agriculture and the environment may affect rural areas of the UK. Such impacts would need to be seen against the backdrop of overall rural policy, and some statistics outlining UK rural economies and communities are shown in Box 2.10 below.

[86] DEFRA (2002), op cit, p35.

Box 2.10 Rural economies and communities

The past 20-30 years have seen significant economic changes in rural economies. Some key trends have been:[87]

- A decline in agricultural employment in rural areas from 6% to 4% of total rural employment, and an increase in employment in the service sectors from 60% to 71% (between 1981 and 1996);

- An increase of 24% in the population of rural England between 1971 and 1996, compared to 6% across England as a whole;

Rural tourism is worth nearly £14 billion a year and supports 380,000 jobs[88].

Rural policy is an important issue in England and in the devolved administrations

2.4.23 The challenges facing rural policy in England were highlighted in the Performance and Innovation Unit report on "Rural Economies",[89] the themes of which were taken up in a White Paper setting out the Government's policies for rural England.[90] The vision for rural England, set out in that paper, is of:

- a living countryside, with thriving rural communities and access to high quality public services;

- a working countryside, with a prosperous and diverse economy, giving high and stable levels of employment;

- a protected countryside, in which the environment is sustained and enhanced, and which all can enjoy; and

- a vibrant countryside which can shape its own future and whose voice is heard by government at all levels.

2.4.24 A number of policy initiatives are in place to seek to achieve this. A central element is the England Rural Development Programme (ERDP).[91] Under this programme, £1.6bn is being made available to farmers over seven years, for environmental protection and improvement and rural development. In England, a further £48 million has been made available over three years through the Countryside Agency's Vital Villages scheme.[92]

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[87] Performance and Innovation Unit (December 1999) "Rural Economies", available from http://www.strategy.gov.uk.
[88] Countryside Agency (2002) "State of the Countryside Report"
[89] Performance and Innovation Unit (1999) op cit.
[90] DEFRA (November 2000), "Our Countryside: The Future – A Fair Deal for Rural England", available at http://www.defra.gov.uk/wildlife-countryside/ruralwp/index.htm.
[91] Details are available at http://www.defra.gov.uk/erdp/erdphome.htm.
[92] http://www.countryside.gov.uk/vitalvillages/

2.4.25 Rural policy is just as important in the devolved administrations.[93] As in England, both Wales and Scotland attach special importance to their "clean, green" image, which impacts on the marketability of their food produce and the attractions of their countryside environments. For the whole of the UK, GM crops – and the alternatives to GM – could potentially have important implications for rural economies, rural communities and rural employment.

Science, innovation and competitiveness policy

Science and technology are important for future UK productivity and competitiveness

2.4.26 Many of the policies relating to science and innovation seek to address the wider issue of UK productivity and competitiveness, summarised by the Treasury[94] as follows:

> *"The UK's productivity performance has been poor for a long time in comparison to other major economies. As a result, the UK now has a productivity gap, measured in output per worker, that is substantial on all measures in comparison to the US, Germany and France….At the national level, the UK has a shortfall against its major competitors in terms of investment in physical and human capital and in terms of technological progress."*

2.4.27 Whilst there are many macro-economic and micro-economic factors involved in overall productivity and competitiveness, science and technology is highlighted as one of the main areas out of which improvements could arise.

The UK is aiming to build on its science policy successes

2.4.28 Science-based industries linked to biotechnology, information technology and nanotechnology are expected to be at the forefront of future economic growth. This makes it important that the UK is involved in these industries and the associated science – particularly in the context of a competitive international environment in which other countries are also seeking to support scientific research in order to deliver future prosperity.

2.4.29 The UK has a good track record in some important areas:[95]

- attracting investment from multi-national companies working in science-based industries;

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[93] The vision for rural policy in Scotland was set out in "Rural Scotland: A New Approach" (May 2000), available from http://www.scotland.gov.uk. In Wales, the key document is the "Rural Development Plan for Wales 2000-2006" (2001), available from http://www.wales.gov.uk. In Northern Ireland, the Rural Development programme strategy 2001-2006 was published in 2001.
[94] HMT (2000) Productivity in the UK: The Evidence and the Government's Approach
[95] DTI (1999) Genome Valley, a report on the economic potential and strategic importance of biotechnology in the UK.

- generating clusters of small businesses and start-ups working at the cutting-edge of these new industries;
- public research institutions and universities that are respected the world over.

2.4.30 It is important that the UK continues to build on these strengths – and that it also seeks to improve performance in areas where it has historically not done so well, such as bringing new products to market and hence enjoying the "early-mover advantages".

2.4.31 One area of concern is the UK's lower-than-average expenditure on R&D. The Government's strategy for science, engineering and technology *Investing in Innovation*[96] highlighted the fact that between 1981 and 1999 "the UK is the only country to experience a significant decline in total R&D spending as a share of GDP compared with its competitors". The UK currently spends 1.83% of its GDP on R&D (£17.5 billion: one-third public sector, two-thirds private sector). This compares to a G7 average of 2.10% GDP[97].

2.4.32 The recent government spending review reflects the priority given to science: planned expenditure on science is set to increase by £1.25 billion between 2002/3 and 2005/6, with the DTI budget for science increasing by 10% in real terms year on year. This additional funding has been provided in the expectation that it will lead to economic gain - the associated public service agreement (PSA) target is to:

> "*improve the relative international performance of the UK's science and engineering base, exploitation of the science base, and the overall innovation of the UK economy*".[98]

2.4.33 In addition to measures aimed at improving the science base and creating better links between academia and business, the recent Government White Paper on science policy, "Excellence and Opportunity",[99] emphasises the key role of consumers and the public:

> "*an innovation will only succeed if it is desired and accepted by consumers and members of the public … Science and innovation need a stable and transparent framework of public support within which they can develop*".

2.4.34 This introduces a further aspect of science policy related to the relationship between scientists and wider society. The scientific community has been placed under increasing scrutiny as scientific developments have become more visible and more pervasive. Government policies aim to achieve greater public involvement in debates about the place of science in society[100].

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[96] HM Treasury (July 2002).
[97] From SET Statistics 2003 on www.ost.gov.uk.
[98] See the Industry and Science Analysis Paper, available on the project website.
[99] Cm 4184
[100] http://www.ost.gov.uk/society/index.htm

GM crops could be an important test case

2.4.35 Multinational companies, small and medium sized enterprises (SMEs) and academic researchers have all contributed to the development of GM crops. Thus GM crops cut across many of the Governments' priority issues for science – the ability of UK to attract inward investment in high-technology industries; the ability of the UK to generate and support new technology-based SMEs; and the ability of the academic community to generate valuable intellectual property and work closely with commercial organisations.

2.4.36 Some commentators see GM crops as an important test case for decision-making about science-based industries in the UK in general. Furthermore, the issues relating to GM crops and food have been, and seem set to continue to be, an important "testing-ground" for the relationship between science and society.

2.4.37 GM crop development is a small activity both in the context of UK scientific activity, and in the context of the global industry. Some figures are shown in Box 2.11 below. Whilst the UK has maintained a number of centres of excellence in the public sector,[101] commercial research has been cut or passed into foreign ownership in the past two decades, with the greatest reductions between 1999 and 2001.[102]

2.11: UK activity in agricultural biotechnology and GM crop development.[103]

Data on the extent of GM crop R&D in the UK are not precise nor especially complete. The boundaries of the various scientific activities involved are not clear cut, and there is a range of activity in both the public and private sector. Many of the figures available look at the agricultural biotechnology sector. This sector includes, but goes wider than, GM crops.

The commercial agricultural biotechnology industry in the UK employs just under 1,300 people in R&D.[104] This is just under 1% of the total commercial R&D employment in the UK (153,000).[105]

Syngenta – the only multinational agricultural biotechnology company with a major research station in the UK – spends about £120 million in the UK on R&D[106]. The main public sector sponsor of GM crop development, the BBSRC[107], invests about £55 million on agricultural biotechnology research,

[101] See background working paper on industry and science on the project website.
[102] See the Industry and Science Analysis Paper, available on the project website.
[103] See the Industry and Science Analysis Paper, available on the project website.
[104] Poole NJ (2001) *The competitiveness of R&D in the UK – the agrochemical and biotechnology sector*
[105] www.ost.gov.uk/setstats
[106] Expenditure figures in Box 2.11 are *per annum*.
[107] Biotechnology and Biological Sciences Research Council.

of which nearly £18 million is in GM crop research.[108] Total UK spending on all R&D is £17.5 billion; one-third public, two-thirds private sector.[109]

Estimates of global GM crop R&D are about $4.4 billion (£2.7 billion), composed of roughly 3/4 private and 1/4 public sector research.[110] It is difficult to split this into national contributions, but one indicator of R&D activity in GM crops is the number of field trials. There were 11 GM field trial notifications and permits in issued in the UK in 2001, compared to 61 across the whole EU, and 1189 in the USA.[111]

2.4.38 Chapter 3 considers the potential impact of GM crops on future development of the UK science base, and also considers what might happen to the other scientific approaches that might offer alternatives to GM crops.

Policy on food safety and quality

Recent scares and controversies have focused attention on food labelling

2.4.39 Food safety and quality has been a major issue over recent years, due to a number of high-profile scares and controversies, including:

- The links between Bovine Spongiform Encephalopathy (BSE) – more commonly known as "mad cow disease" – and variant Creutzfeldt-Jakob Disease (vCJD).
- Outbreaks of *E. coli* food poisoning traced to a number of different food manufacturers and retailers.
- Concerns about levels of pesticide residues on fresh fruit and vegetables.[112]
- Allergenicity linked to various foods, such as nuts and kiwi fruit.

2.4.40 These have led consumers to pay much more attention to the food they eat, including what it contains and how it is produced. An important result has been the increased focus on labelling. In addition to basic informational labelling, this comes in two main forms:

- "Negative" labelling, which conveys a warning, such as "may contain nuts".

[108] See the Industry and Science background working paper, available on the project website.
[109] www.ost.gov.uk/setstats
[110] James C (2002) *Global review of transgenic crops: 2001 feature: Bt cotton*. ISAAA Briefs No 26, Ithaca, NY
[111] Data from JRC (http://www.jrc.es/home/index.html) and USDA (http://www.usda.gov/). Note that US regulations require repeat notifications each year; EU regulations require one notification only for trials lasting more than one year – average is 2.6 years
[112] About 30% of the food we eat contains detectable pesticide residues (2000 data). However, the vast majority (98%) of samples tested since 1998 do not contain residues above legal limits and do not contain non-approved pesticide residues. In almost all cases where a legal limit was exceeded or non-approved use was found, no risk to health was presented.

- “Positive” labelling, which conveys a sense of quality – such as “farm-assured”, “premium” or “organic”.

2.4.41 One other area that has come under attention is the nutritional value of processed foods, and concerns about potential links to obesity and poor health, especially among children. Some data on UK food and nutrition are given in box 2.12 below.

Box 2.12: UK food and nutritional data[113]

Although people are eating more fruit and vegetables than they were 15 years ago, the FSA’s recommendation to consume at least five portions of fruit and vegetables each day is met by only 14% of the population. 35% of the population take dietary supplements of multivitamins and multiminerals.[114]

Levels of obesity have tripled since 1980 in England, and there is no sign of the upward trend stopping. Currently, over 1/2 of women, and about 2/3 of men are either overweight or obese. Deaths linked to obesity shorten life by 9 years on average.

About 20 to 30% of people in the UK believe they are intolerant to one or more foods. However, tests show that only about 5 to 8% of children and 1 to 2% of adults actually have a food intolerance. It is estimated that 10 deaths a year in the UK are caused by food allergy.

The Food Standards Agency (FSA) plays the key role in promoting food safety and quality

2.4.42 Collectively, concerns such as these were an important factor in the creation of the FSA. The FSA was established by an Act of Parliament in 2000, and its purpose is to protect the public’s health and consumer interests in relation to food. The objectives of the FSA reflect Government’s policy objectives for food safety and quality.[115] They include: reducing foodborne illness by 20%; helping people to eat more healthily; and promoting honest and informative labelling to help consumers.

GM foods will impact on food quality and safety

2.4.43 A wide range of different technical, commercial and social changes will affect all these objectives. There can be no doubt that GM foods have the potential to effect some of them, and Chapter 3 considers the potential impacts GM crops might have. It also assesses the contribution of GM crops alongside other approaches – for example “quality assured” schemes, and organic produce.

[113] Data from Food Standards Agency unless stated otherwise. See www.food.gov.uk.
[114] National Diet and Nutrition Survey (2002).
[115] FSA aims for 2001 to 2006, taken from http://www.food.gov.uk/aboutus/.

International Development Policy

International development policy focuses on the UN Millennium Development Goals

2.4.44 The UK Government's international development policy is based on the 1997 and 2000 White Papers on International Development. There is an overarching commitment to promote sustainable development and eliminate world poverty.

2.4.45 The specific focus for Government policy is a commitment to the internationally agreed Millennium Development Goals. These Goals, to be achieved by 2015, were adopted by the United Nations at the 2000 General Assembly. They seek to:

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV/AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

There is considerable controversy about the role of GM crops in developing countries

2.4.46 The role of GM crops in developing countries is subject to many competing claims. On the one hand, GM crops are argued to be a major solution for world hunger – for example, through their potential ability to help developing countries grow crops in poor conditions (such as drought or salinity); through their potential to increase yields; or through other potential benefits such as improved nutritional value. On the other hand, it is argued that GM crops do not meet the needs of the poorest farmers in developing countries for a number of reasons. These include the cost of the technology, challenges to risk management and control over the food chain.

Government policy emphasises the potential benefits but stresses that developing countries should make their own decisions

2.4.47 GM crops have not so far been a major focus of Government policy in this area. The policy on GM crops in developing countries states that:

> *"GM technologies have the potential to provide significant benefits for poor farmers if applied safely and responsibly to the crops they rely on."*

> *"Developing countries need to be able to make their own informed choices about whether to adopt GM technologies or*

not and build the capacity to manage their safe development and use."[116]

2.4.48 The extent to which GM crops could increase in importance in this policy area depends whether current and, in particular, future GM crops are relevant to the needs of poor farmers in developing countries; and whether they are available to them.

2.5 Summary

2.5.1 Even a narrow description of the current state of play regarding GM crops involves a range of background technical information and intricate regulatory detail. Any forward projection needs to consider that GM crops and their alternatives could touch on a number of major policy areas – agriculture, environment, rural communities, science, food safety, and international development – each of which could have consequences for many other aspects of policy.

2.5.2 By affecting so many areas of activity, a wide range of stakeholders will be affected in turn. There are many different ways in which these stakeholders might respond to developments in GM crop technology or changes in GM crop regulations, and many ways in which costs and benefits might arise. These are analysed in the following chapter.

[116] DFID (May 1999) "Genetically Modified Organisms and developing countries"

Chapter 3: Analysis of costs and benefits

Summary

- The Strategy Unit has carried out a detailed analysis of the potential costs and benefits of GM crops and has identified a number of key areas:

- Impacts on the economics of agriculture, which include the potential cost and convenience implications of growing GM crops, for both current and future varieties.

- Consumer demands for segregation of GM and non-GM products throughout the product chain, which could affect cost and current practices in the food supply industries.

- Wider impacts on the rural economy and communities.

- The interaction between agriculture, the environment and human health. This includes the possible impact of GM crops on pesticide use and farm management. The options for monitoring systems to look at the impacts of GM crops are considered, as well as the potential for future traits to deliver environmental or human health benefits.

- Impacts on the science base in the UK, including the potential impacts of GM crops on multinational and SMEs in the UK. There may also be effects on other biotechnology industries, and the wider science base.

- It is also important to consider the international context for the UK and GM crops, especially the potential impact of UK action on developing countries.

3.1 Introduction

Purpose of the chapter

3.1.1 This chapter summarises the Strategy Unit's analysis of the costs and benefits that could be associated with commercially cultivating GM crops – or choosing not to cultivate them, in the UK. It provides a summary of the analysis set out in the report's accompanying analysis papers, which provide more detail on the individual subject areas.

3.1.2 In many areas, the conclusions of this chapter are tentative. There are many reasons for this. Whilst there is a large body of international evidence on the impacts of cultivating GM crops, for instance, the different environmental, economic and other conditions in the UK mean that the findings may not be directly applicable here. And there are also considerable complexities surrounding the science of GM crops, which are being explored in the Science Review.

3.1.3 Within this context, this study has not attempted to attach overall monetary values to the costs and benefits associated with commercialisation. The Strategy Unit has concluded that any attempt to do so would rely too heavily on some arbitrary assumptions, and would be potentially misleading. Instead, the aim has been to give a mainly qualitative analysis of the nature of the impacts that may occur in the UK under different assumptions for the commercial use of GM crops. This analysis is illustrated with quantitative information wherever this is available.

3.1.4 Rather than looking at costs and benefits in isolation, the analysis focuses on the question of whether GM crops or food could help in the achievement of policy goals. Throughout the analysis, we have also attempted, where possible, to identify whether there are alternative ways of achieving these goals.

3.1.5 This chapter covers the following issues:

- Section 3.2 considers the variety of ways in which GM crops might impact on the economics of agriculture – from direct cost implications, to regulatory costs, to impacts on farmer income;
- Section 3.3 discusses the practicalities and costs of keeping GM crops and foods separate from their non-GM counterparts;
- Section 3.4 looks at wider impacts on the rural economy and communities, including possible impacts on rural cohesion and on society;
- Section 3.5 considers the possible environmental and human health implications of introducing GM crop cultivation to the UK;
- Section 3.6 looks at how the future direction of GM crop policy may affect the UK science base;
- Section 3.7 considers how the UK's policy on GM crops may have a range of important international implications;
- Finally Section 3.8 concludes.

3.2 Impacts on the economics of agriculture

Different types of farm are likely to be affected by GM crops in different ways

The UK farming sector is very varied…

3.2.1 There are a wide variety of farms in the UK. Broadly speaking, they can be categorised into grassland farming; arable farming; upland farming; and mixed farming (that is, a mixture of livestock and crops).[117] Within these categories, farmers may use a range of farming practices.

[117] This is the categorisation used, for instance, in DEFRA's pilot entry level agri-environment scheme. See http://www.defra.gov.uk/erdp/reviews/agrienv/entrylevel.htm

3.2.2 There are also regional differences. Farms in East Anglia, for instance, tend to be large in size, and specialise in large-scale production of arable crops. Those in Wales and Scotland tend to be more mixed, and Northern Ireland's farms largely concentrate on livestock production.

…and so the impacts of GM crops could be just as varied

3.2.3 GM crops would therefore impact on, or be of interest to, different farmers in different ways. Farmers using non-organic but low-input systems, for instance, would be interested in GM crops if they offered a way to control pests with reduced chemical use. Farmer with large farms may be less worried about issues to do with the spread of GM materials to their neighbours, as they could keep crops more contained within their own farm.

3.2.4 Livestock farmers are already affected by GM crop growing worldwide. The UK imports a large amount of animal feed, including 2 million tonnes of soya – some of which comes from countries that grow GM soya. Farmers, therefore, already have to decide whether to use feed which is guaranteed to be non-GM – and is therefore more expensive – or whether to use unlabelled feed, which may or may not have a GM content.[118] Were commercial cultivation of GM crops to be allowed in the UK, they could also choose to grow GM feed themselves.

3.2.5 Finally, the impact of GM crops would also be felt by farmers not choosing to grow them, including organic farmers, mainly through the unintentional transfer of GM material into non-GM crops (see Section 3.3).

GM crops have been designed to offer specific cost or convenience savings; the scale of these will vary, and may be offset by other costs

There are a range of factors which will determine the magnitude of any cost or convenience savings

3.2.6 The scale of any cost impacts arising from changes to agronomic practices associated with the growing of GM crops will depend on a number of factors:

- *The scale of the problem which the crop is designed to address.* Bt corn, for instance, is popular in countries which have a problem with the corn borer insect, such as the US; however, the corn borer is not present in UK agriculture, and so current varieties of Bt corn are unlikely to be of any benefit here. In contrast, potato blight can cause significant damage to the UK potato crop. If GM technology could deliver a blight-resistant potato, for instance, then there could be significant benefits to UK farmers.

- *Effectiveness of the trait.* Some herbicide tolerant crops, for instance, do not suffer at all when the relevant herbicide is sprayed on them. Others may suffer a degree of "knock-back" (a period of stunted growth following

[118] GM feed currently does not have to be labelled, although this is in the process of changing under a forthcoming EU directive on food and feed. See the Regulations Analysis Paper, available on the project website, for further details.

spraying). Over the longer term, the development of pests or weeds which are resistant to the control methods used by the GM crop could also impact on its effectiveness – although it should be noted that this is also a problem in other methods of agriculture.[119]

- *Incidental costs or benefits.* GM crops may have a range of secondary impacts which could affect farm management. These could include, for instance, greater hybrid vigour;[120] easier harvesting, due to the lower incidence of weeds; or physiological changes such as changes to lignin content that could make harvesting more difficult.[121]

3.2.7 Looking at the UK as a whole, clearly the biggest potential impacts come from crops that are grown on a large scale here. Wheat, for instance, is the most commonly grown arable crop, and GM wheat could therefore have a potentially significant impact on UK farmers.

3.2.8 Costs and benefits may also vary over time. For example, a build-up of volunteer crop weeds (that is, crop plants which grow from seed left over from the previous year's harvest) which are resistant to one or more herbicides, could cause problems for farmers when they use the field for another crop.

Some farm-level cost savings are possible from currently available GM crops, although these are hard to predict and vary between different crops and traits

3.2.9 Box 3.1 illustrates the type of cost impacts that could be associated with the use of herbicide tolerant crops, the main trait found in commercially available GM crops which could be grown in the UK.[122] It shows that the potential size of impact depends to a large degree on the effectiveness and cost of *existing* methods of weed control.

[119] The Science Review is looking in detail at whether GM crops could accelerate the development of pest resistance.
[120] The Invigor varieties of oilseed rape claims to have higher levels of hybrid purity due to the use of the GM trait in the seed breeding process. See PG Economics (2003), page 66, available on the project website.
[121] Soil Association (2001) "Seeds of Doubt".
[122] A large amount of international evidence exists on other GM crops, such as herbicide-tolerant soybeans and insect-resistance maize. This evidence is reviewed by PG Economics (2003). However, as these crops would not be grown in the UK, we do not consider this evidence here.

Box 3.1: *Examples of farm-level agronomic impacts from GM crops that could be grown in the UK*[123]

Herbicide tolerant oilseed rape. Oilseed rape is an important UK crop, making up around 10% of the total UK arable crop area.

Weed control is currently reasonably effective in oilseed rape production in the UK. Expenditure on herbicides ranges from £36-£45 per hectare (in comparison, total variable costs[124] of growing are around £200 per hectare). Expenditure on glufosinate for an HT crop would probably be in the region of £21-£65 per hectare, and so might only offer savings to farmers with worse than average weed problems.

However, it is possible that the crop could deliver yield increases. This could occur through a combination of reasons: there may be a reduction in knock-back[125]; better weed control may improve the reliability of yield; and some varieties may offer improved hybrid vigour due to the use of the HT characteristic in the seed production process. The majority of international evidence suggests that yield benefits would arise, although there is a wide range of results (-15% to +22%).

One Canadian study found that this yield impact helped to produce a 30% increase in gross margins[126] against a conventional crop, even after taking into account the higher cost of GM seed[127]. In contrast, a second Canadian report[128] found that HT oilseed rape produced a lower return than conventional, by up to 7%. These results may not, in any case, be applicable to the UK, as market conditions here could be very different.

Herbicide tolerant sugar beet. Sugar beet, which is grown largely in Eastern England, makes up 4% of the total UK arable crop area.

In contrast with oilseed rape, weed control in sugar beet is currently relatively difficult and costly. Farmers may spend in the region of £84-£167 per hectare on weed control (including application costs). Desk-based studies suggest that UK farmers growing GM sugar beet might be able to cut this cost to £26-£40 per hectare, although there would be additional costs in other areas, particularly the increased price of buying GM seeds.

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[123] The evidence presented here is drawn largely from the literature review conducted by PG Economics. The analysis paper: *Analysis of the Costs and Benefits of GM crops in Product Chains* (available on the project website or on request from the SU) gives more detail on the costs and benefits associated with these, and other, crops

[124] Total variable costs include all costs incurred on an ongoing basis in the operation of the farming activity. They do include fixed costs such as the cost of the land.

[125] The knock-back effect is tested when in the pesticides approval process, and pesticides with an average impact of over 5% are not approved; this therefore provides an upper limit to the gains from this specific impact.

[126] The gross margin is equal to total revenues earned less total variable costs incurred, before taking into account items such as taxation.

[127] Canola Council of Canada (2001) “An agronomic and economic assessment of transgenic canola”.

[128] Fulton & Keyowski, University of Saskatchewan (1999) “The producer benefits of herbicide-resistant canola”.

Evidence on yield impacts is hard to assess, as there is no commercial growing of this crop in the world now. What evidence there is suggests that at worst there is no yield impact, and at best there may be yield gains of 5-15% from HT sugar beet, due to reduced damage from chemical spraying, and better weed control.

Less debatable is the fact that weed control in HT sugar beet is likely to be easier and more flexible than in conventional sugar beet. Financially, this could lead to savings in terms of labour costs, and money spent on buying agronomic advice.

Herbicide tolerant maize. Almost all the maize grown in the UK is used for animal feed. It makes up around 2% of the total arable crop area, and is grown predominantly in southern and central areas of the country.

Current methods of weed control in maize are reasonably economic and effective, with total herbicide costs amounting to £15-£42 per hectare, out of total costs of around £400 per hectare.

However, they are based on the use of atrazine, a chemical that is very persistent in the soil. As well as being environmentally undesirable, this also restricts which crops can be grown in subsequent rotations. Weed control without atrazine would be more expensive (perhaps rising to over £50 per hectare).

Herbicide costs for an HT variety would be around £25-£60, depending on how many applications were needed. This may not be economically attractive to farmers growing maize, therefore, unless atrazine were to become unavailable.

3.2.10 The complexity of the issues discussed in the box demonstrates how the introduction of a GM crop may have a range of effects on costs and revenue. The box also shows that the impact may vary widely from crop to crop.

3.2.11 Despite a large body of evidence on HT crops, the effects described in the box are still subject to a degree of uncertainty. This is both because different pieces of research have come up with different estimates of impact, and because the impacts themselves may not be replicated in a UK context.

Future developments in the technology could offer more significant benefits – but their development is subject to considerable uncertainty

3.2.12 Crops are currently being developed which address a range of other agricultural issues. These include crops which offer new ways to deal with a range of pests and diseases, such as viruses and fungal infections, either in a way which is, it is claimed, more effective or cheaper than existing methods, and/or less environmentally damaging. Other areas of research are looking at ways to make crops more resilient to environmental conditions, such as drought, saline or cold resistant crops; and at ways to make crops which use resources more effectively, for example through nitrogen-fixation (the transformation of nitrogen in the air to nutrients which can be absorbed by the plant).[129]

3.2.13 Many of these developments are still at laboratory stage, and efforts are also being made in parallel to gain similar results through alternative methods such as non-GM crop breeding, and the use of more integrated agricultural systems. For these reasons, it is hard to give an overall idea of the potential impact of these future crops.

3.2.14 But as Box 3.2 suggests, such crops do at least have the potential to deliver significant benefits to UK agriculture – if they could be successfully developed. Scenarios which envisage a widespread use of GM crops as well as rapid technological developments could therefore see more benefits from this type of crop – although this may be accompanied by new types of risk.

Box 3.2: Potential impacts of possible future GM developments

Fusarium resistant wheat.[130] A wet climate means that wheat growing in the UK is vulnerable to fungal infections. One of these is fusarium, which is of particular interest since infested wheat can contain mycotoxins, which are dangerous to human health. The incidence of fusarium (and of its treatment) varies widely from year to year; survey evidence[131] shows that at its worst, it can affect up to 60% of the UK wheat crop, although in other years only a very small proportion of the crop may be affected. A precise financial benefit is therefore hard to ascribe. However, effective control of fusarium could improve quality levels and reduce the instance of crops being rejected outright due to infestation, making farm incomes more stable. It could also reduce risks to human health.

Nematode resistant potatoes. The potato cyst nematode (PCN) is one of the key pests of the potato crop, causing annual yield losses of approximately £43 million. The pest is currently controlled by a combination of crop rotations and chemicals (nematicides); these chemicals are relatively toxic and many are being phased out. Research at Leeds University[132] has used GM technology to develop an alternative way to control the PCN which has a lower environmental impact. The product could potentially give farmers a replacement for pesticides that have been withdrawn, as well as producing a more reliable yield. However the technology is still at the stage of early research, so its full impact has not been thoroughly tested.

[129] A list of crops under development, based on the AEBC Horizon Scan, is given in the background working paper on industry and science (published on the project website in January 2003).
[130] Fusarium resistant wheat is currently under development by Syngenta.
[131] Annual survey, Central Science Laboratory (www.csl.gov.uk).
[132] See the response to the project-scoping note from Professor Howard Atkinson, available on the project web site.

But these potential benefits may be offset by additional costs, or by the lower marketability of the crop

3.2.15 Farm incomes have been low in recent years, and farmers are looking ever more keenly for cost savings. In this context, the kind of cost and convenience advantages described above would be appealing to many farmers.

3.2.16 However, there are other important factors involved which would offset some of these cost savings, and could limit the take-up of any commercially available GM crop, at least in the short term.

- GM seeds would be sold at a *higher price* than conventional seeds, so that agricultural biotechnology firms can recoup some of their research and development costs. Overseas, this has generally taken the form of a premium on seed prices (along with a requirement that farmers buy new seed each year). This may be accompanied by a contractual requirement that farmers only use a particular brand of herbicide.[133] However, these requirements are becoming less common in the US, and the economics of the sale of GM products are becoming more like that of other newly-developed crops – with profit coming purely through higher seed prices.[134] The size of the premium varies between crops and countries. As an example, GM soybean seeds in the US cost around 30-35% more than their conventional counterparts; but due to weaker market conditions, the premium in Argentina is around 20%.[135]

  The size of the seed premium that could apply in the UK is hard to predict, as this would vary by crop, and depend on European market conditions. Companies would set a price which they believed would make the crop economically attractive to farmers, as well as providing them with a good return.

- A second element of additional costs may be the financial cost and/or inconvenience involved in *complying with the regulations* surrounding the commercial cultivation of GM crops. Connected with this, farmers may be concerned that they might be held *liable* for any adventitious presence of a GM crop in neighbouring fields. These issues are discussed in Section 3.3.

- A third, and critical, factor is whether there would be a *market* for the crop. The key message of DEFRA's Strategy for Sustainable Food and

[133] Some herbicide-tolerant crops will only work with a particular branded herbicide, which is produced by the same company that makes the seed, so allowing them to sell more of this herbicide without the need for contractual conditions. However, this is not the case with Monsanto's widely-used Roundup Ready crops, which are tolerant to glyphosate. The chemical used in the "Roundup" herbicide is off-patent, meaning that proprietary brands are available at a cheaper price than Monsanto's Roundup brand.
[134] Monsanto used a simple royalty system to sell its Roundup products in both 2002 and 2003.
[135] PG Economics (2003).

Farming[136], and of parallel strategies in the devolved administrations, is of reconnection. A vital part of this is that farmers should reconnect with consumers; like all businesses, the report says, farmers “have to respond to what consumers care about and want”. At present, though, many consumers have a negative attitude towards GM foods, and most retailers do not stock GM products. Producing GM products, albeit at a slightly lower price, would therefore – *in the current climate* – not be consistent with the vision set out in these reports, and could leave farmers facing a low market price or, in the extreme, no market at all.[137]

Of course, public attitudes could change, particularly if GM crops start to deliver specific consumer benefits. Any such change may, however, take time to filter through into actual demand if retailers are reluctant to change their policies. It is also important to stress that this argument applies to a much lesser extent to crops grown for animal feed (such as maize, one of the Farm Scale Evaluation crops), and non-food crops (such as GM cotton, grown widely overseas). Indeed, imported soybeans with a GM content are already used in UK livestock production, though some sectors use non-GM feed only, including the poultry industry, and organic livestock farmers. Some farmers may also be able to grow GM crops for export markets, although the crops for which GM varieties are currently available are not ones which are exported on a large scale.[138]

3.2.17 Ultimately, individual farmers would have to take decisions about whether the benefits outweighed the costs. The overall costs and benefits of current generations of crops appear to be fairly finely balanced, and in the short term other developments are likely to be more important to farmer incomes, particularly reform of the Common Agricultural Policy.

3.2.18 Future crops may, though, bring more important cost savings. If farmers do not have access to these crops, then they could ultimately lose competitiveness in international markets. However, it is possible that these crops could also introduce new risks.

3.2.19 Finally, there are questions over whether cutting the cost of producing commodity crops such as maize will be an appropriate strategy for all UK farmers. Undoubtedly, the efficient production of commodity crops will remain important for UK farmers in the near future. But analyses of the British farming sector, such as the Foresight report,[139] suggest that rather than just trying to make farming more efficient, farmers should also be trying to diversify their output – by producing new types of product, or even moving into areas such as tourism – or to add value to the crops they produce through, for instance,

[136] http://www.defra.gov.uk/farm/sustain/newstrategy/index.htm.
[137] For instance, British Sugar, which is the monopoly buyer of sugar in the UK, currently has a no-GM policy.
[138] Just over 10% of oilseed rape produced in the UK is exported, two-thirds of which is destined for other EU countries. The proportion of exports of refined sugar is higher but (as noted above) British Sugar, the UK processor, has a no-GM policy. Maize exports are negligible.
[139] Foresight report for the Food Chain and Crops for Industry Panel (2001) “Agriculture in the UK – its role and challenge”.

the production of premium-quality goods. The next section looks at the potential role that GM crops may play in this.

New crops could help farmers to diversify their businesses

Farmers are looking for new sources of income

3.2.20 The search for higher or more stable sources of income by UK farmers has already led to significant changes in the way in which the agricultural sector operates. There is an increasing trend towards the production of high-value added products such as organic produce (particularly in horticulture) – which has generally, to date, attracted a price premium – and towards adherence to assurance standards of production.[140]

3.2.21 Some farmers are also attempting to capture more of the profit margin of their products by cutting out stages of the food chain, for instance, through selling directly to consumers in farmers' markets, although this remains a small-scale activity.

GM products may open up some new options…

3.2.22 GM crops could contribute to this shift if the technology can be used to produce goods that have high value-added, or are tailored toward specific needs.

3.2.23 For instance, products could be designed which may have particular appeal to consumers. These might include fruit and vegetables with a longer shelf life, or enhanced nutritional value, and foods with reduced allergenicity.[141]

3.2.24 Other possibilities include GM crops which meet the needs of livestock farmers, such as crops with added protein value. Crops could also be designed to fulfil particular non-food niches, such as the more efficient production of paper from GM trees,[142] or of industrial inputs.[143]

3.2.25 Many new products could also be produced using non-GM techniques – particularly as the pace of non-GM crop development has accelerated recently, due to a better understanding of crop genomics. One recent development, for instance, is a broccoli with enhanced levels of a cancer-preventing substance which was developed using non-GM techniques.[144]

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[140] Examples include the "Little Red Tractor" logo, which denotes products made under the British Farm Standards scheme.
[141] Annex 1 to the Industry and Science Background Working Paper (January 2003) set out a range of possible developments, based on the AEBC Horizon Scan.
[142] Agricultural Biotechnology in Europe (2003), discussed in "Future developments in crop biotechnology".
[143] The environmental and human health impacts of such crops are discussed in Section 3.5, and in more detail in the analysis paper: *Analysis of the Costs and Benefits of GM crops to the Environment and Human Health* (available on the project web site or on request from the SU)
[144] http://www.seminis.com/news/news_2003/PR_2003_January29.html

3.2.26 However, the availability of GM technology would at least provide an extra option for crop developers, and so could ultimately expand the range of available products. In scenarios which encourage rapid developments in GM crop technology, therefore, there may be a wider range of such products available, and/or faster development times.

…although some potential downsides have to be taken into account

3.2.27 Depending on the product, there could be uncertainties over the acceptability of such crops – both to consumers, and to the regulatory authorities. Non-food crops, for instance, might have to be grown under glass – both to reduce the risk of contaminating food crops, and to assuage public concerns about the release of GM crops into the environment. Similar suggestions have also been made for food crops, as a way of reducing risks and making them more acceptable. However, growing under glass could prove to be a costly option, and would certainly have a material impact on the economics of growing GM crops.[145]

3.2.28 Another consideration is that farmers may not reap the benefits from some developments in this area. Research into the use of crops to produce pharmaceutical products, for instance, is quite far advanced, and such crops would be likely to have a high market value. Alternatives to GM crops as a source of pharmaceuticals exist;[146] and even if such crops were used, they would be likely to be grown in very small quantities, under highly controlled conditions, and so are unlikely to have a significant impact on the overall economics of farming.

3.2.29 Finally, it is possible that the introduction of GM crops could, whilst opening up some options, also limit others. In particular, if co-existence measures prove to be less effective than is currently expected, then organic farming may become a more expensive and less attractive option, because of the risk of the accidental presence of GM material. This could make the aims to expand organic farming set out in the Organic Action Plan for England[147] harder to achieve, and reduce consumer choice. This issue is discussed in detail in the following section.

3.3 Practicalities of the supply chain: providing consumer and farmer choice

Segregation of GM and non-GM products requires a range of measures to be taken

[145] Actual costs of growing under glass would depend on the level of containment needed. A normal greenhouse used for horticulture would not prevent the escape of pollen or insects into the environment; something much more sophisticated would be needed to provide a completely sealed space. Data from DEFRA and the HSE Inspectorate suggest that typical set up costs for high-specification GM research glasshouses (of 500 -1000m^2) range from £1-2 million, indicating the upper end of the potential cost range).
[146] See Industry and Science analysis paper available on the project website.
[147] DEFRA (2002) “Action Plan to develop Organic Food and Farming in England”.

Segregation is seen as important to maintain consumer choice

3.3.1 Keeping GM crops and foods separate from non-GM[148] crops and foods is currently considered important for economic reasons, both in order to provide choice for farmers and consumers, and to maintain price differentials for products that are valued differently by consumers. There are also legal obligations on the labelling of GM products under European regulations. However, segregation is not a safety issue, as the GM crops in question would all have been judged to be safe under the approvals system.

Segregation of GM and non-GM crops may have different elements

3.3.2 There may be different elements to the segregation of GM and non-GM products.

3.3.3 At the farm level, ***co-existence*** measures could be used to limit adventitious presence of GM material in neighbouring non-GM crops.[149]

3.3.4 Proposed EU-wide legislation on ***traceability and labelling*** will require producers of GM crops to trace and label final products of GM, whether or not they take additional steps to keep their produce separate from non-GM crops.

3.3.5 Non-GM producers who wish to guarantee the non-GM nature of their products may choose to adhere to an ***identity preservation system***, which seeks to minimise the level of GM adventitious presence. This would require farmers, and others in the product chain, to take a number of practical steps to minimise adventitious presence, and to put in place records to confirm that these steps have been taken.

3.3.6 Such identity preservation systems are already in place for a number of high-value products, such as soya for the production of tofu. In the future, it is also possible that they might be used to preserve the purity of high-value GM products against the adventitious presence of other GM or non-GM crops.

There are different views on the appropriate threshold for GM presence

3.3.7 The mixing of GM and non-GM crops and foods may happen in many different ways – from impurity of the original seed, to pollen drift from one field to another, to the use of a truck that has not been cleaned out.

3.3.8 For these reasons, the absolute absence of GM content in non-GM products cannot be guaranteed (just as the absence of other unwanted material, such as dirt, also cannot be guaranteed). This applies whether or not GM crops are grown here.

3.3.9 However, the accidental presence of GM material can be kept to a minimum. The limit of reliable detectability is currently thought to be 0.1%. At this level, though, tests may give misleading results unless large sample sizes

[148] The definition of "non-GM" is the subject of some controversy – see following text.
[149] The forthcoming AEBC report on co-existence and liability will consider this issue in detail. See www.aebc.gov.uk.

are used. Such a low threshold may also be expensive to achieve, given the large number of variables that may affect the ability to detect GM presence in particular crops, including potentially long supply chains from third countries. At the European level, therefore, adventitious presence is currently defined as up to a 1% presence[150] across the board.

3.3.10 Different groups view these limits in different lights. Parts of the organic sector, as well as many consumers of organic foods, would prefer a 0% limit, although others would accept 0.1% as a limit for GM presence in organic food. The SU's discussions with retailers suggest that currently, many are telling their suppliers that any GM presence should be below the 0.1% limit of detectability. These stances might change if GM crops were commercially grown in the UK, and/or if consumer attitudes changed.

Segregation issues already arise in relation to imports; but additional systems may be required if GM crops are cultivated in the UK

3.3.11 In response to their customers' demands, some commercial importers have put in place voluntary systems to segregate non-GM and GM imports of particular commodities - mainly soya[151] - and to check for the purity of seed imports. Unless there is a major shift in European consumer opinion, these systems may have to develop to deal with increasing volumes of segregated imports, whether GM crops are cultivated here or not. The scale and cost of this will depend on the capacity of the global market to supply non-GM crops.

3.3.12 In addition to this, if GM crops are commercially cultivated in the UK, additional measures may need to be considered to facilitate the co-existence of GM and non-GM crops at the farm level. The next section looks at the possible costs of this.

At the farm level, many of the measures required are in line with existing good practice…

3.3.13 Given the number of different routes by which adventitious presence may occur, keeping GM and non-GM crops separate at the farm level requires a range of measures to be taken.

3.3.14 It is not easy to judge whether these types of measures would impose additional costs on farmers, or whether they would merely require the application of good farming practice combined with co-operation between neighbours.

3.3.15 The most useful parallels are other types of segregation systems which currently exist in the UK. Examples include the production of certified seeds, which have to attain a certain level of purity, and of high erucic acid or HEAR rape, which is grown for the production of industrial chemicals and cannot enter the food chain. On a larger scale, the separate production and use of

[150] This may change once new regulations on traceability and labelling come into force. See the Regulations Analysis Paper, available on the project website, for further details.
[151] A number of crops, including soya, are currently approved for import into the EU. These are mostly used for animal feed.

organic produce is another example. None are perfect parallels to the GM crops situation – either because they are from relatively small-scale growing or, in the case of organic produce, because the market conditions are very different. However, it is still useful to consider on a general basis how these systems work.

3.3.16 The production of HEAR rape and certified seeds, for instance, require fairly similar segregation measures to be taken as would the production of GM crops. To date, these have worked well. Separation distances are generally achieved through co-operation between neighbouring farmers, who may agree to change crop rotations in order to avoid having neighbouring fields of the same crop.

3.3.17 There is more direct evidence from the Farm Scale Evaluations, which required farmers to adhere to guidelines to keep the crop segregated from the food chain.[152] A survey of farmers who have taken part in the Farm Scale Evaluations of GM crops found that 94% considered the guidelines "very straightforward" or "fairly straightforward" to comply with, although three-quarters agreed that they did impose some extra effort in terms of record-keeping or practical issues.

3.3.18 Experience therefore suggests that segregation is achievable without excessive costs. However, a range of factors would affect whether this would, in practice, be the case for GM crops. These are explored below.

…although costs may arise, depending on a range of factors

3.3.19 Whilst it is very difficult to attach monetary values to the costs of co-existence, it is possible to identify the factors that determine whether any costs will arise, and what their magnitude is likely to be.

- *Type of crops:* crops that cross-pollinate over a wide area, such as oilseed rape, will be much harder to keep separate than those (such as soybeans) which are self-pollinating. Also, it would be easier to conduct hygiene measures, such as machinery cleaning, with large crops such as potatoes than with small seeds such as oilseeds.

- *Farming system:* the maintenance of separation distances may require changes to crop rotations. This will be more difficult in systems that rely on rotations for weed control or nutrition, such as low-input systems or organic farming.

  Non-GM farms using farm-saved seed may also face problems due to a possible accumulation of GM presence in seeds over the years: this could also have a serious effect on the farm-saved seed industry itself. If the supply of farm-saved seed is reduced, this may increase the market power that seed companies hold over farmers.

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[152] SCIMAC, the Supply Chain Initiative on Modified Agricultural Crops, developed a set of guidelines to be used by farmers growing GM crops. See www.scimac.org.uk

- *Degree of co-operation:* in cases where farmers find it easier to co-ordinate their crop rotations, any co-existence system is likely to be less costly.

- *Stringency of the measures put in place:* the more cautious the regulatory approach – and the lower the level of adventitious presence which is allowed – the more costs are likely to be imposed on farmers. However, more stringent requirements for GM farmers would minimise potential problems for non-GM or organic farmers. This trade-off could vary significantly between the scenarios set out in Chapter 4.

  If the organic sector sets lower thresholds than conventional non-GM farmers, then segregation would be harder to achieve. However, organic acreage of the crops being considered for commercialisation in the short term is currently fairly low – only 0.05% of the total 2002 oilseed rape crop, for instance, was organic. This issue would become more pressing if GM varieties of commonly grown organic crops such as vegetables became available.

- *Farm size:* adherence to any guidelines on co-existence is likely to be more difficult in areas with a large number of small farms or small fields, due to the more widespread sharing of machinery, and the larger number of neighbours with whom the individual farmer has to co-ordinate crop rotations.

- *Current adherence to good practice:* if a farmer already operates according to good practice standards, such as the Assured Combinable Crops Scheme, then the introduction of GM might only require changes to existing systems. However, if they do not, then they may have to introduce entirely new systems.

- *Technological developments:* future developments in GM technology could help to reduce some of the problems with co-existence. This might involve, for instance, breeding GM plants that have different flowering times to their conventional counterparts.

3.3.20 Because of all these factors, there is considerable uncertainty about what the actual costs of co-existence might turn out to be. The forthcoming AEBC report on co-existence and liability will shed fresh light on the issue. But this is an area that would have to be kept under close review if GM crops were commercialised in the UK.

3.3.21 Costs would also arise if a co-existence system were backed up by inspections to check compliance. Box 3.4 sets out the costs of the current regime of inspecting GM field trials in the UK. The regime checks adherence to the consent conditions attached to release approvals, not to co-existence protocols. However, there is some overlap in the type of work that would have to be done in each case, and the numbers provide a reasonable comparison. If GM crops were grown on a wide scale, some economies of scale may result as several farms could potentially be inspected during one visit.

Box 3.4: Costs of inspection[153]

The GM Inspectorate (for England and Wales[154]), part of DEFRA's Central Science Laboratory (an Executive Agency of the Government), is responsible for field inspections of GM releases. In 2002-3 the Inspectorate carried out 124 routine field inspections (largely FSE sites), at an average cost of approximately £400, and a number of call-out emergency visits at £430 per visit.

In addition, the Inspectorate carries out desk-based audits of compliance with consents. It also investigates any problems - such as the 2002/3 seed contamination incident, where a proportion of seeds supplied by Aventis (now owned by Bayer) for a Farm Scale Evaluation trial were found to contain modifications conferring a type of antibiotic resistance, as well as herbicide resistance.[155] Dealing with this incident has so far cost the Inspectorate over £40,000.

Those further along the product chain may also have to change some of their practices – although many of these measures may be needed to deal with imports anyway

3.3.22 Segregation does not end at farm level. To achieve segregation of GM and non-GM crops, measures have to be taken all the way through the product chain, to the level of the retailer or caterer.

3.3.23 This may impose costs on organisations throughout the product chain, such as transporters, grain processors, and food manufacturers. The diversity of systems used by different players, and the differences between different organisations, makes it hard to generalise about the costs imposed.

3.3.24 However, it is possible to identify some possible areas of cost. The importation of both GM and non-GM soya, mainly for animal food, provides an example of the measures that have to be taken, which include, for instance, the use of separate silos for storing each type of product.

3.3.25 The handling of the segregation of organic and conventional crops may be analogous to the way manufacturers might handle GM. One major food manufacturer told the SU that organic and conventional foods could be processed on the same production line if this was timed carefully. Specifically, they make organic products in the morning, after machines have been cleaned down, and conventional products in the afternoon. It is likely that similar measures would be taken for handling GM, rather than more drastic steps such as setting up separate production lines. Again, this would depend on the thresholds set for adventitious presence.

[153] Source: GM Inspectorate.
[154] In Scotland the GM Inspectorate is the Scottish Agricultural Science Agency (SASA).
[155] See http://www.defra.gov.uk/news/2002/020815a.htm.

3.3.26 Manufacturers and processors may also wish to carry out testing to check the integrity of non-GM products. The costs of tests vary,[156] depending on the nature and accuracy required of the results; examples of costs for basic tests are given in Box 3.5.

Box 3.5: Costs of testing[157]

The most basic tests are **strip tests for the presence of a particular protein,** which cost £5, give a quick answer and can be performed by non-experienced personnel. However, these have limitations: for instance, they only detect a particular GM trait, and do not work if the protein is not expressed in the particular tissue tested. They also do not give any idea of the scale of GM presence.

ELISA[158] tests also look for protein, and so are subject to some of the same limitations, but can produce a quantitative result. They cost £10-£20 and are generally performed in laboratories.

A **PCR test** looks for the presence of the transgene itself, rather than the protein it produces, and is therefore more reliable. The test uses a range of primers specific for various traits and events and can thus test for several GM constructs at once. It can also be made quantitative. The PCR test normally takes 5-10 days to process, and costs around £200.

3.3.27 The likely extension of GM technology to new types of crop internationally will add to these costs, whether the UK grows such crops or not. It is therefore possible that commercial cultivation in the UK would not create many additional costs.

Adventitious presence will still occur, even if this is rare – the further along the food chain this is discovered, the costlier it will be

3.3.28 Even if measures are taken to minimise adventitious presence, it is inevitable that it would still occur, even if very rarely. Measures have to be in place to deal with this eventuality, in particular a system of apportioning liability for economic loss.

3.3.29 If accidental presence were detected at the farm level, then the cost incurred would amount to the loss of the non-GM or organic premium from the harvest.

3.3.30 The question of who is liable in the event that adventitious presence is discovered is a complex one.[159] Blame would be hard to prove, and might

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[156] Similar testing technologies are being developed for medical and other purposes. Overall the costs appear likely to diminish as technology develops.
[157] Source: GM Inspectorate. The forthcoming AEBC report on co-existence and liability will consider the issues around testing in more detail.
[158] Enzyme-Linked Immunosorbant Assay.
[159] The P has been working on the issue of liability at the farm level, and their forthcoming report will discuss this issue. This study has therefore not dealt with the issue in detail.

depend on whether it can be shown that the farmer growing the GM crop had complied with any relevant industry guidelines or regulations. The fear of incurring liability for economic loss arising on a neighbour's farm could potentially prove a deterrent to farmers thinking of growing GM crops.

3.3.31 Non-GM farmers might decide to take out insurance to cover possible costs, as a way of reducing the risks they face. Currently, however, such insurance is not available.[160] Were a workable co-existence system to be in place, a market would be likely to develop. However, in situations where co-existence proved to be problematic, then insurance might remain unavailable, or be prohibitively expensive.

3.3.32 If a problem were only discovered after the product had left the farm, then costs might be higher. If the product had reached supermarket shelves, then costs would be incurred in removing the mislabelled product.[161] Liability would also be harder to prove, as the product would have been through many intermediate stages, and individual harvests would have been mixed together.

3.4 Wider impacts on the rural economy and society

The promotion of a "green" reputation has economic value for many rural areas…

3.4.1 Many areas of the UK actively promote their "green" reputation in order to market goods and services. Areas which are heavily dependent on rural tourism – such as parts of England, and many areas in Wales and Scotland – rely on a positive image of their countryside to attract visitors. And food-producing regions may be able to attract a higher price if they have a reputation for purity (Scottish salmon is one example).

…and some believe that a "GM-free" label may help to maintain this image

3.4.2 A "GM-free" label is seen by some as a way of reinforcing this reputation. This has been a factor in the decision of several councils to declare themselves "GM-free zones", as well as in the establishment of movements to keep Scotland and Wales "GM-free".

3.4.3 There is no evidence that tourism would be affected by the growing of GM crops. Canada, for instance, still promotes its environmental image strongly in attracting tourists, whilst also growing GM crops.

3.4.4 However, there are more specific concerns about the impact of adventitious presence of GM material. Some food producers argue that even a minimal amount of GM content, well below the threshold for statutory labelling, may damage the reputation of their products. An example is honey.

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160 "Technical Bulletin on Genetically Modified Crops", NFU Mutual May 2000
161 The costs of such a move are described in the Environment and Human Health Analysis paper, available on the project website.

Research suggests that even if GM crops were grown in honey-producing areas, the small amount of pollen in the final product would mean that the GM content in the honey could be expected to be only 0.00000000003g in a 500g jar.[162] However, submissions to the SU's review suggest that beekeepers are still concerned about the risk to their reputation.

The broader social impact of the introduction of a new technology also needs to be taken into account

3.4.5 Any wider social controversies over GM crops are likely to be replicated in rural communities. But problems specific to farming communities may also occur. For example, tensions over the introduction of GM crops may damage relations between neighbouring farmers, or between individual farmers and their local communities. Such tensions are more likely to arise if there are low levels of trust in the regulatory systems set up around GM crops, or confusion about liability and segregation.

3.4.6 This effect may be more likely to arise in circumstances where problems emerge with the co-existence system.

3.5 Agriculture, the environment and human health

The interaction between agriculture, the environment and human health is a complex one

3.5.1 Agriculture and the environment are very closely linked in the UK. In the past, the introduction of new technologies has often had unforeseen and significant impacts. Increasing mechanisation, for instance, led to larger field sizes and the destruction of hedgerows, which damaged farmland biodiversity. Against this background, it is important to assess the potential environmental and human health impacts in the case of GM crop commercialisation.

3.5.2 It is also possible that GM crops could help to achieve some of the UK's environmental and human health objectives, such as those set out in DEFRA's recent Strategy for Sustainable Food and Farming, and in similar documents in the devolved administrations.

3.5.3 This section gives the SU's assessment of how GM crops might change the way in which farming is conducted in the UK, and the environmental implications of this. It does not consider the scientific evidence of the direct impacts of GM crops, such as, for instance, the possibility that an allergen is found in a GM food, as these are being considered in detail in the Science Review, as well as being looked at as part of the regulatory process. However this section does discuss the potential role of monitoring in picking up adverse effects on the environment or health, and Chapter 4 contains a more general discussion on the impact of unexpected events, be these positive or negative.

[162] MAFF funded study (1997) "Honey from genetically modified plants: Integrity of DNA and entry of GM-derived proteins into the food chain via honey."

GM crop cultivation could lead to significant changes to the type, timing and quantity of pesticides used

Pesticides are integral to conventional agricultural methods…

3.5.4 Increasing chemical inputs have helped to increase yields across a range of crops in the UK and in other developed countries over the past half-century.

3.5.5 A major component of this has been pesticide use. Pesticides comprise a range of chemicals which kill or control weeds or pests, including herbicides (weedkillers), insecticides, and fungicides (to control mould and fungus).

…but there has been mounting evidence of their costs, leading to initiatives to minimise their impact

3.5.6 The approvals system for pesticides checks for detrimental impacts on the environment or human health. However, the use of pesticides can still be damaging to the environment or to human health in a number of ways, which may include[163]:

- Drinking water quality impacts: ground and surface waters may not meet standards for drinking water quality, leading drinking water suppliers to use alternative drinking water sources or (more likely) deploy measures to remove pesticides;
- Agro-ecosystem and biodiversity impacts: including harm to non-target species, damage to ecosystems through the treatment of the pest and harm to non-target species, and wider impacts associated with their role in facilitating the intensification of agriculture; and
- Human health impacts: pesticide users, bystanders, and consumers of food with pesticide residues.

3.5.7 In recognition of this, there is a UK-wide voluntary initiative to promote best practice in pesticide use. If this initiative does not achieve its objectives, then a pesticides tax may be introduced.

3.5.8 This section talks mainly about herbicide-tolerant crops, as these are already commercially grown in other countries and there is a body of evidence on their impact. However, many of the arguments would also apply to crops designed to change or replace other types of pesticide.

The cultivation of GM crops could lead to significant shifts in pesticide use…[164]

3.5.9 Herbicide tolerant crops generally allow the replacement of existing herbicides with "broad-spectrum" herbicides, which are effective against a

[163] These points are taken from DETR (1999) "Design of a tax or charge scheme for pesticides".
[164] The scientific evidence on these impacts is considered as part of the Science Review.

broad range of weeds. The crops are resistant to either glyphosate or glufosinate ammonium.

3.5.10 There has been a great deal of debate over whether these crops reduce the *quantity* of chemicals used. No clear conclusions have emerged in this area; the evidence varies from crop to crop, and much depends on the decisions made by the individual farmer.

3.5.11 However, the use of GM crops would undoubtedly affect the *type* of chemicals used. Glyphosate and glufosinate ammonium have some advantages over some of the chemicals they would replace; glyphosate in particular has a low persistence in the soil, minimising run-off into water courses; and both chemicals have a low toxicity to animals.

…which could have broad impacts

3.5.12 One particular impact that could be significant is the effect of GM crops on the *effectiveness* of pest control. Unlike conventional methods, HT crops offer the possibility of very effective weed control at all points in the growing cycle. Whilst this presents potential advantages to farmers (as discussed in Section 3.2 above), it could reduce the quantity of weeds and, in the winter, weed seeds in fields, reducing both plant biodiversity and the amount of food available for animals throughout the year[165]. Conversely, if crops were managed with the objective of conserving biodiversity, farmers could suffer yield losses[166]. Here, therefore, there could be a trade-off between agricultural and environmental objectives. The Farm Scale Evaluation results will shed fresh light on this issue in the case of maize, oilseed rape and sugarbeet.

3.5.13 The use of GM crops could also affect the *timing* of pesticide spraying. Glyphosate or glufosinate could be sprayed onto GM crops at a relatively late stage. This might help to conserve in-field biodiversity by allowing weeds to grow at certain times of the year, although if spraying is delayed too long then farmers could lose yield[167].

3.5.14 The ultimate impact of these changes will depend on farmer behaviour. This can be influenced in a number of ways. “Soft” incentives include codes of good practice, and product stewardship schemes run by the biotechnology companies. “Harder” incentives include the financial rewards attached to membership of agri-environment schemes (see Box 3.5), as well as actual regulation. Positive impacts would therefore be more likely to be realised if GM crops were introduced into a carefully regulated environment, whereas if regulations were more *laissez-faire* in their nature, net impacts might in principle be either positive or negative.

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[165] Additional information about the biodiversity impacts of HT crops will be available later this year, with the publication of the results of the FSEs.

[166] For instance, Dewar et al (2000) “Delayed control of weeds in glyphosate tolerant sugar beet and the consequences on aphid infestation and yield”, shows that delaying pesticide spraying on suger beet can result in yield losses of almost a third.

[167] These types of changes are taken into account in the regulations governing pesticides, under which any new crop/pesticide combinations and use patterns need to be approved. See http://www.pesticides.gov.uk/committees/acp/acp.htm.

Box 3.5: Agri-environment schemes in the UK

Agri-environment schemes aim to reward farmers for managing their land in a way which is environmentally sustainable. The main government-led schemes currently in place are set out in chapter 2 (paragraph 2.4.19).

Looking forward, the government plans to introduce an "entry level" scheme that would be available to all farmers[168]. This scheme, which would present farmers with a menu of options for changes to farm management, is currently being piloted. It would be complemented by a higher-level scheme, offering higher rewards for more significant action.

Such schemes are voluntary, but can have a significant impact by providing an economic reason for farmers to follow good environmental practice.

Currently, there are no specific provisions for GM farmers in the pilot entry level scheme, as there is no commercial cultivation of these crops in the UK. However, adding some GM-specific elements would be one option for influencing how farmers used these crops, and therefore, their overall environmental impact.

3.5.15 The impacts from the replacement of chemicals and changes to pest management regimes will, clearly, be larger if GM crop growing is widespread.

3.5.16 Pesticide use also raises a number of other environmental issues, such as the risk that a chemical used either on the crop – or engineered into the crop – may affect a wider range of animals or plants than its intended target. This type of effect is considered in the regulatory process, and is also being considered by the Science Review. The implications of an adverse impact being unexpectedly discovered is considered in Chapter 4.

GM crops are not the only option for changing pesticide use

3.5.17 The potential for GM crops to help achieve improvements in the sustainability of pesticide use also needs to be put carefully into context. There are many other ways to improve pest control without chemicals, such as better planning of crop rotations, or the use of predator insects in greenhouses. These methods could deliver significant environmental improvements, akin to those which are claimed for some GM crops, although they may also bring their own risks, such as the impact of predator insects on local biodiversity, should they escape from greenhouses.

3.5.18 Some systems, such as integrated pest management, could use GM as part of a package of farm management techniques.

GM crops could lead to changes in farm management – though the impacts of this are subject to considerable uncertainty

[168] http://www.defra.gov.uk/erdp/reviews/agrienv/default.htm

3.5.19 The methods of crop management associated with GM crops could also lead to other changes, some of which could have environmental impacts. Because of the easier weed control associated with herbicide tolerant crops, farmers may be able to reduce the amount of *tillage* (ploughing) they have to do, which could reduce soil erosion and the run-off of nutrients into watercourses[169], as well as reducing energy usage. In the UK context, the overall benefits from this would probably be fairly marginal, though could be important in some areas.

3.5.20 A potentially more significant, though much more uncertain, development in GM technology could be crops which help farmers to *reduce their reliance on inputs* (other than the chemical inputs mentioned above). Many farmers are already doing this by, for instance, planning their crop rotations so as to minimise the need for additional inputs of nutrients. Future GM crops could facilitate this through more efficient use of existing nutrients. A GM drought-tolerant crop, were it to be developed, could also help to reduce the use of *water* in agriculture – which could be particularly important in the context of climate change.

3.5.21 It is also possible that crops with these desirable attributes could be developed through non-GM techniques. However, it is likely that GM methods would be a useful tool, and that by not using it, development may be more difficult. If the regulatory system imposes few restrictions on developing GM technology, then technological developments may be encouraged and there could be a wider range of this type of crop.

3.5.22 As with chemical inputs, the success of any such technologies in achieving environmental goals will depend on the actions of farmers. The introduction of any such crops could be paired with schemes specifically aimed at achieving environmental targets in order to maximise any possible benefits.

Over the longer term, shifts in crop growing patterns could emerge

3.5.23 Over the past decades, there have been very significant shifts in crop growing patterns in the UK. The area of land used for growing oilseed rape, for instance, has grown by 60% over the last two decades, and the winter growing of crops has become much more common. These changes may be driven by economic circumstances or by technological developments.

3.5.24 Such shifts often have environmental consequences. Winter growing of crops, for instance, can reduce the availability of food for birds which would otherwise be available in fields of stubble.

3.5.25 It is therefore important to consider whether the introduction of GM crops might lead to further shifts in the type or location of crops grown. This is very difficult to judge – not least because there is no international evidence, as yet, on any such shifts. Some changes are certainly possible. Modifications to the efficiency of nutrient use, for instance, may change patterns of crop

[169] The advantages of low-till agriculture are discussed in the Environment and Human Health Analysis Paper, available on the project website.

rotations; and the availability of GM crops could affect the diversity of crop growing. These changes are likely to be more significant in scenarios where the use of GM crops is widespread. But it is not possible at this stage to say whether the ultimate environmental impact may be positive or negative.

Monitoring could be important in picking up any adverse impacts

3.5.26 Despite the existence of a thorough regulatory system, it is important to consider the possibility that a particular GM crop could have an adverse impact on the environment or human health. Ongoing monitoring of GM crops and food would help to pick up any such impacts at an early stage, making it easier to deal with them if they were to arise.

Requirements are already in place for the monitoring of environmental impacts…

3.5.27 The new European Directive on deliberate release (2001/18/EC) contains a requirement for all applications for commercial growing to contain a plan for post-market monitoring. The effectiveness of this requirement will depend on how it is interpreted[170]. Monitoring could also be carried out (or funded) by the Government, by regulators, or by independent researchers.

3.5.28 Monitoring plans might, in principle, range from packages of measures based largely on the reporting of problems by those using the crop, to ones including extensive plans for primary research into a range of risks that could be associated with the crop. Clearly, the latter type of monitoring would carry higher costs than the former, and if required as part of post-market monitoring could discourage firms from commercialising crops.

3.5.29 To be effective, monitoring should make the best use of existing data on the environment and biodiversity. Additional costs may also be incurred, which range from the costs of desk-based exercises correlating data on biodiversity with that on the location of GM crop growing, to the costs of conducting primary research. An example of the latter is the Farm Scale Evaluations, set up with the purpose of monitoring impacts on biodiversity of HT crops at a cost of £5.9 million to Government (plus substantial additional costs to industry). The degree and type of monitoring is assumed to vary between the five overall scenarios in chapter 4.

3.5.30 The identification of impacts on the environment could be hampered by the complexity of the relationship between agriculture and the environment. Baseline data on farmland biodiversity in the UK is fairly patchy, although it is set to improve as a result of new plans for the co-ordination of monitoring from the Joint Nature Conservation Committee[171]. It can therefore be difficult to spot changes in a timely fashion, as well as to determine the relationship between cause and effect.

[170] In the UK, the Advisory Committee on Releases to the Environment (ACRE) has recently published draft guidance on interpretation (http://www.defra.gov.uk/environment/acre/postmarket/index.htm).

[171] JNCC (March 2003) “The future role of JNCC in biological surveillance and monitoring”.

…though impacts on human health are harder to monitor

3.5.31 The identification of an impact on human health is by its nature difficult, as people eat a very wide range of foods. Food is also only one of a range of environmental and genetic influences on health. It is therefore often difficult to pin a particular problem to a specific food, or indeed to food more generally rather than some other problem.

3.5.32 A severe impact, such as a dangerous allergy, would almost certainly be picked up in the regulatory process. However, it is far more difficult to identify more subtle impacts, or ones that only occur cumulatively over time. In these cases, cause and effect are hard to prove. It would also be easier to identify risks arising from a "whole" GM product, such as an apple, rather than from an ingredient, such as maize; but it is the latter type of product which is likely to be commercialised first.

3.5.33 Effects would be easier to identify if a monitoring system were in place. The Food Standards Agency has commissioned a feasibility study into how such a system could work, due to be published in summer 2003. This issue was initially considered by a subgroup of the Advisory Committee on Novel Foods and Processes (ACNFP), which is responsible for recommending whether to approve novel (including GM) foods.

GM crops might also contribute to the delivery of products with environmental or human health benefits

3.5.34 Most of the GM crops which are currently commercially available have been modified to contain agronomic traits – that is, traits which make the crop easier to manage. It is possible that future developments in the technology may result in crops which have been engineered to deliver specific benefits to the environment and human health. Box 3.6 lists some possible benefits, and the SU's Environment and Human Health analysis paper discusses in detail how significant these benefits might be, and whether they could be developed through non-GM routes[172].

Box 3.6: The possible future uses of GM technology to deliver environmental or human health benefits[173]

Possible human health benefits:

- Nutritional benefits, such as reduced fat absorption in potatoes
- Disease prevention, through the overexpression of substances which are beneficial to human health
- Reduced allergenicity, such as wheat with a low gluten content
- Longer shelf life, which could maintain a food's nutritional content for longer, and perhaps encourage the consumption of fruit and vegetables

[172] Section 3.2 discusses the possible value of such products in terms of their potential economic value-added.

[173] More detail on each of these, as well as references, are given in the Environment and Human Health analysis paper, available on the project website.

- Pharmaceutical crops, which could produce pharmaceuticals at a lower cost

Possible environmental benefits:

- Crops engineered to produce biomass energy more effectively, or to produce fuels such as bioethanol
- Environmentally sustainable materials, for instance biodegradable plastics
- Crops which are designed to reduce energy used during processing, such as trees with altered levels of lignin which are easier to convert into paper

3.5.35 However, as the analysis paper explains, these possibilities are subject to a very great degree of uncertainty. Potential benefit will also depend on other circumstances, including whether government policy is supportive. For instance, changes to government's energy policy, and to the price of oil, would affect the prospects for energy crops. Benefits will also depend on whether consumers, processors and others accept the technology.

3.5.36 Again, non-GM methods could be used to develop these crops. Indeed, the UK is already growing a limited amount of willow and other crops for the production of energy. Recent developments in non-GM technology include, for instance, a maize-based fibre and plastic[174].

3.5.37 Still, by restricting the use of GM technology in developing new varieties, it would become less likely that some of these benefits would be achieved within a given time. SU scenarios which either explicitly or implicitly do not include GM crop cultivation are therefore likely to see a slightly smaller range of such crops being developed. GM technology might also influence the economics of some of these products, as well as their availability: herbicide tolerant sugarbeet, for instance, may be cheaper to grow than its conventional counterpart (see Box 3.1), and may therefore be marginally more attractive as a source of bioethanol fuel.

3.6 Impacts on the science base in the UK

Impacts from GM crops could affect the achievability of the UK's aims in science policy

3.6.1 As outlined in Chapter 2, the Government's overall aim for science and technology is to expand the UK's research activity and to exploit the outputs to generate social goods and economic growth.

3.6.2 Some areas of UK science and industry will be directly affected by the fate of GM crops. These include the agricultural biotechnology (ag-biotech) industry, and public research institutions working on ag-biotech. Groups that may be indirectly affected include other biotechnology sectors (such as healthcare (red) and industrial (white) biotechnology), venture capitalists, and potential students.

[174] See, for instance, http://www.cargilldow.com/ingeo/home.asp.

Multinational ag-biotech companies will be directly affected

Multinational Ag-Biotech activity has declined in the UK

3.6.3 The UK's historical position as a leading location for commercial agrochemical and crop research has been eroded over the past two decades. The number of UK R&D posts in the sector has fallen by over 60 % in that time. This situation has been brought about principally by industry consolidation, but exacerbated by recent public opposition and regulatory approaches to GM crops. Syngenta's research station at Jealott's Hill is the only major private research facility that has not been closed or severely scaled down[175].

3.6.4 Although some multinational research previously conducted in the UK has moved to France and Germany, the focus of most multinational ag-biotech companies has switched away from Europe and is increasingly on expanding markets: the USA and particularly the Far East.

It could decline further, be maintained or expanded

3.6.5 A deterioration, or even continued uncertainty, in the climate for GM crops in the UK – such as that described in some of the scenarios in chapter 4 – could reduce the companies' already small activity in the UK still further. The companies' research programmes tend to bundle together many different crop development activities, and they are unlikely to maintain their expenditure in the UK by switching it from GM to non-GM crop development.

3.6.6 Even in a more positive climate for GM crops, it is unlikely that major new research facilities would be built in the UK in the near future, particularly given the growing interest in Far Eastern markets. A more likely outcome of a more positive climate for GM crop research would be that existing facilities would be maintained and in some cases expanded.

3.6.7 The potential to collaborate with experts in leading research institutions is one of the most attractive elements of the UK as a location for crop research. Multinational sponsorship of public sector research is probably the most likely area of expansion in a more favourable GM crop climate. This is discussed in the following section.

Multinationals are also important as purchasers/sponsors of Small and Medium Sized Enterprises (SMEs) and public sector research

3.6.8 Because of the high regulatory costs involved, ag-biotech products (and intellectual property) developed by SMEs and public sector research can often only reach the market if they are bought up by, or licensed to, multinationals.

3.6.9 Multinationals can also sponsor specific research and development work in SMEs and public sector research establishments (PSREs). This is a significant revenue stream for SMEs and is also increasingly important to

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[175] See the Industry and Science analysis paper, available on the project website, for details of recent events in multinational involvement in the UK.

PSREs, who are being encouraged by Government to conduct work more in line with industry requirements. Prospects for GM crop commercialisation will affect the amount and direction of the external research that multinationals are prepared to sponsor.

3.6.10 Collaborative work tends to be most effective between institutes and companies that are co-located; thus decisions about multinational research stations in the UK will therefore also affect the extent to which this collaborative work will be conducted here.

SMEs in crop technology research face their own set of problems…

3.6.11 The UK's research-based ag-biotech SME sector is small, and has been relatively stagnant in the last five years. Its involvement in GM crops is limited by access to investment, in particular venture capital, which has been in short supply in recent years.

3.6.12 However, venture capital companies tend to want to be involved in the next wave of technical developments, and if the climate for GM crop development were to improve, funds for SMEs could become available fairly rapidly.

…but are potentially very important in developing novel applications of plant biotech

3.6.13 SMEs have accounted for only 6% of the GM crop trials in the EU. Their work has focused on modified nutrients or ingredients, a reflection of their need to create products for potential niche markets.

3.6.14 As discussed in Section 3.2 above, this type of specialised, high-value crop may be attractive to farmers and consumers in the future; the absence of a thriving SME sector may make it less likely that such crops would be developed in the UK.

PSREs in plant science and ag-biotech have been hit by the decline in commercial opportunities for GM crops

3.6.15 In principle, GM crops might be a way to help PSREs achieve some of their objectives, such as improving links with industry[176]. However, the reduction in commercial activity in UK GM crop development has reduced the ability of PSREs to win commercial sponsorship of research.

Many other applications of biotechnology to plant science and agriculture exist – though may not in practice substitute for GM

3.6.16 GM is only one way of using modern biotechnology in plant breeding (see Section 3.4). Agricultural crops can also benefit from biotechnology through, for instance, diagnostic techniques to improve the targeting of

[176] This point is explored in the Industry and Science analysis paper, available on the project website.

pesticide applications. Genomics can also be used to identify suitable varieties for growth in organic systems.

3.6.17 However, some of this research may be inherently difficult to turn into major revenue streams (it may not be patentable, or it may generate environmental or quality of life improvements but not profit-making ones). As a result, sources of commercial sponsorship may be difficult to find. If multinational sponsorship dries up, there is no guarantee that research will expand to focus on these alternative areas of plant and agricultural biotechnology. Additional public sector support may be required to develop these areas of research.

Effects on other biotechnology sectors will largely be indirect

3.6.18 The other main areas where biotechnology has been applied are in healthcare and in environmental and industrial processing. Healthcare – particularly drug discovery – is the dominant application of biotechnology, and there are already some important and widely-used medicines derived from GMOs, such as insulin.

3.6.19 The life science strategy that temporarily united pharmaceutical and agricultural biotechnology companies has been largely abandoned. As the situation currently stands, most of the links between the two sectors come in terms of fundamental knowledge and supporting technology, such as the modelling of biological systems.

3.6.20 Many aspects of the sectors are quite distinct. Separate regulations often apply, although regulations on the release of GMOs will apply to GM vaccines and GM bacteria for soil remediation as well as to GM crops. Customers, markets and profit potential are markedly different in these different areas; and public attitudes also differ between biotechnology applications. Impacts from GM crop policy would therefore only be indirect.

3.6.21 Other industrial sectors may also be affected through the use of non-food crops as replacements for petrochemicals as sources of raw materials. These might include, for instance, the energy sector or the chemicals industry. There are considerable uncertainties about the development of these areas, and the role that GM might play in them. However, without GM methods, one option for their development would be ruled out.

Signals about approaches to new technology are important

3.6.22 One wider influence of any decisions on GM crops will be the signal they send about how the UK chooses to approach controversial new technologies. The relative influence of public opinion, scientific advice, industry, and NGOs is an important consideration for many future commercial developments of biotechnology in its widest sense, as well as more generally. Negative signals to GM crops would send a negative (or neutral) signal to wider biotechnology and science, whilst a more positive approach to GM crops would send a positive (or neutral) signal. Even fairly marginal effects may still be important in the globally competitive market for biotechnology.

3.6.23 Potential students of biosciences may be affected by the signals given out regarding GM crops. Since expanding UK biotechnology will require more qualified personnel, encouraging or discouraging people to study relevant subjects may have long term effects. However, evidence to date shows that biosciences are very attractive to students: bioscience student numbers rose 50% between 1994/5 and 1999/2000.[177]

3.7 International impacts

Any action the UK takes will have international repercussions

3.7.1 The UK does not take decisions in isolation; it is embedded in an international context that includes the European Union, international rules on trade, multilateral environment agreements and links with trading partners and other overseas bodies[178]. The UK has legal obligations to some of these – such as the European Union (EU) and the World Trade Organisation (WTO) – and less formal relations with others.

3.7.2 In a globalising world, and with a technology as mobile as GM crops, the actions taken by the UK will have repercussions at the international level. This international influence will only be one factor in a complex global policy environment, but will, nevertheless, form part of the overall impact of UK action.

Some of these impacts will be direct, others indirect

3.7.3 Some of the influence will be *direct*, through the immediate impact of policy decisions. These could include the effects of labelling food and feed products on trade, legal implications of a decision to reject GM crops, or influence derived from the type and effectiveness of the regulatory regime.

3.7.4 Other UK influences will arise *indirectly* from signals sent out on the grounds of decisions and the process through which they arose. The role of the public in "GM Nation? The Public Debate", for example, could provoke similar processes elsewhere.

UK action will have an impact on the context in which developing countries[179] decide about GM crops

[177] See the Industry and Science analysis paper, available on the project website.
[178] See also Chapter 2.
[179] The "developing countries" term includes all countries designated as such by DfID. These are all the countries in Part I of the OECD Development Assistance Committee (DAC) eligible to be in receipt of official development assistance (see Statistics on International Development, DfID 2002).

Whether GM crops are "good" or "bad" for developing countries remains a highly contested issue - this study does not make any assumption regarding the impact

3.7.5 There is considerable debate about whether GM crops could have a positive, mixed or negative impact in developing countries. On the one hand, claims are made that GM crops hold the solution for world hunger through, for instance, the creation of crops which are less sensitive to environmental conditions such as drought. On the other hand there are claims that the technology generates profits for large companies while failing to meet the needs of impoverished farmers.

3.7.6 An initial overview of available evidence suggests that it is too early to make firm conclusions, though it is possible to identify potential areas of benefit as well as potential sources of costs[180]. The impacts will be heterogeneous and specific; GM crops are unlikely to be either a blanket solution or an unequivocal failure. Like all technologies, they may contribute to addressing certain problems, but could also exacerbate or create others.

UK action on GM crops is likely to impact on the context in which developing country decisions are taken

3.7.7 UK Government policy states that developing countries should be able to make their own choices about whether and how to use GM crops[181]. These choices will differ between countries and involve trade-offs and constraints.

3.7.8 UK action will almost certainly have some impact on the context in which developing countries make these choices about GM crops. The nature of the UK's impact will depend not only on the actual action taken by the UK, but also on the grounds for that action and the process used. That said, the impact is difficult to pin down empirically and will only be one of many sources of influence.

UK impact could occur through three principal routes – trade, signalling and technology transfer

3.7.9 What is clear is that UK impacts could occur through three principal routes: trade, signalling and technology transfer[182]. The fact that GM policy and trade impact is mostly at the EU level means that this will be the main route by which the UK has an impact. Signals could be generated by unilateral action by the UK.

Trade matters most, though it is too soon to predict specific impacts

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[180] See the SU's Background Working Paper on developing countries (January 2003), available on the project website, for details.

[181] "Genetically modified organisms and developing countries", DfID (May 1999). The term "developing country" includes countries such as Argentina, China and South Africa which have already made decisions regarding GM crops. However, other developing countries have made fewer or no choices at all.

[182] *Potential UK impact of GM crops on the decision-making contexts of developing countries: Analysis paper* (available on the project web site or on request from the SU) contains a full analysis of each of these three routes

3.7.10 The potential impact of European GMO regulations on trade is significant for developing countries. Current and potential regulations will require importers of GM food and feed into the EU to have approval for the GM variety or varieties and to meet standards of labelling and segregation.

3.7.11 This could increase the costs of exporting to the EU. It could also prevent certain GM crops from being grown in developing countries if getting approval, maintaining separation, and labelling the resulting GM products is too costly or requires greater regulatory capacity than currently exists.

3.7.12 However, the actual regulatory impact will depend on the range of GM crops available to developing countries[183], the nature of trade flows and the practical implications of regulatory requirements. These would vary between the scenarios set out in Chapter 4.

Signalling, though nebulous, is a significant source of influence

3.7.13 Anecdotal evidence suggests that actions and processes undertaken in the UK could generate signals for developing countries. These signals could come from a range of sources including government decisions, policy processes and consumer demand.

3.7.14 The UK, in its role within Europe and its relationship with its major trading partners, is a potentially important source of signals about a controversial technology such as GM crops. Though their specific impact cannot be predicted, the mechanism for influence remains important.

Technology transfer from the UK government will not be a major influence

3.7.15 The Government's impact on developing countries via GM crop-related Official Development Assistance is not likely to be significant in the global context. The Department for International Development (DFID) does not currently prioritise GM crops and its impact in this area is small. Future varieties of "pro-poor"[184] tropical GM crops which are deliverable to the poorest and developed using UK-based expertise could increase UK government influence in this area. However, overall government impact looks set to remain small unless the technology can be proven to address the needs of the "poorest of the poor".

3.7.16 This study has not looked in detail at technology transfer from UK public sector research establishments and private research. However, technology transfer to developing countries from these sources could significantly increase overall UK impact.

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[183] For example, there are few GM horticultural varieties at the moment, so direct trade impacts on these exports are currently low or negligible.

[184] "Pro-poor" technologies are those that address the specific needs of the poorest, such as low input costs and availability in areas with weak physical infrastructure.

An explicit rejection of GM crops could cause tensions within Europe, and with our other major trading partners

3.7.17 It is not within this project's scope to look in detail at how a decision to reject wholesale the cultivation GM crops – either at UK or EU level – might be effected in practice. However, it is important for this study to note that taking such a decision would be far from clear-cut.

3.7.18 At the very least, there could be a messy stalemate; more likely, in the long term, is that there would have to be a fundamental rethink of European directives on GM. Either could cause serious international tensions if the direction of policy was considered to inhibit trade.

3.7.19 Already, the EU's GM crops approvals process has caused tensions with our trading partners, which culminated in the recent filing of a WTO case. This case risks not only generating fresh antipathy over GM crops, but could also have serious knock-on implications for trade relations and international law more generally.

3.8 Applying the analysis to the scenarios

3.8.1 As the analysis of this chapter has shown, the impact of GM crops will be felt across a range of areas. In most cases, it is not possible to say whether this impact will be "positive" or "negative". In part, this is because of the uncertainty which is inherent in any such forward-looking analysis – such as gaps in scientific knowledge, and uncertainty over how various players will behave. It is also clearly the case that an impact which, to one individual or organisation, may be seen as a benefit, may be seen by others as a cost.

3.8.2 The following chapter applies this analysis to the five scenarios to illustrate different possible futures for the UK with or without GM crops.

Chapter 4: Scenario analysis and conclusions

Summary

- In response to future uncertainties and the limitations in the evidence base, the SU has used a scenario analysis to look at different possible futures for the UK with or without GM crops.
- Scenarios allow consideration of a range of plausible possible futures. They are not predictions, but they are useful in illustrating how costs and benefits may vary in different futures for the UK with or without GM crops.
- Five scenarios have been developed, including an explicit “no GM” scenario. The scenarios use different assumptions about possible public attitudes to GM and the nature of the regulatory regime as the main determinants of different futures.
- Unexpected events may throw these scenarios off course. These “shocks and surprises” have a low or uncertain, and often contested, probability but – if they arose – they could have potentially high impacts. These impacts could either support or damage the delivery of particular policy objectives.
- The scenarios illustrate the trade-offs inherent in any future for the UK with or without GM crops. They show that the nature of the regulatory system will have an important bearing on our ability to deal with any risks to the environment and human health, as well as on the impact of GM crop cultivation on non-GM and organic farmers.
- The scenarios also illustrate the central importance of public attitudes in determining the impacts of GM crops. In the short term, negative consumer attitudes can be expected to limit the demand for products containing GM foods, and therefore the economic value of the current generation of GM crops.
- But there is significant potential for benefits from future developments in GM crop technology, as well as the potential for impacts in wider science and industry. The scenarios also demonstrate that international implications could be significant.

This chapter sets out the Strategy Unit’s scenario analysis and the project conclusions. Section 4.1 describes the scenarios as five plausible futures for the UK with or without GM crops, which build on the assessment of costs and benefits in Chapter 3. The next section (4.2) explains the axes used for the scenario analysis. It then sets out the five scenarios and the main costs, benefits and trade-offs associated with each. Section 4.3 introduces the role of shocks and surprises as potential disrupters of the scenario outcomes. These high impact events that have a low or uncertain, and often contested, likelihood could have positive or negative implications for policy objectives. The chapter then ends with overall conclusions (section 4.4).

4.1 Introduction

The costs and benefits of GM crops have been developed into five plausible scenarios

4.1.1 As the previous chapter demonstrates, there are a range of costs and benefits that could be associated with growing, or not growing, GM crops in the UK. These costs and benefits will have impacts in a very wide range of areas. In many cases, it is not clear whether the impacts will be “positive” or “negative”. An impact which may be positive for one person or organisation, may have negative consequences for another.

4.1.2 To take these issues into account in the study, the Strategy Unit has developed a set of scenarios. Scenarios do not predict the future, nor do they have probabilities attached to them. They are a means of identifying key factors that could influence future developments, making assumptions about how these might change and exploring the implications of these changes in different possible futures.

4.1.3 As Chapter 1 explained, the nature of these scenarios was determined by a stakeholder workshop. The two axes illustrate two key factors that determine the impact of GM crop cultivation - public attitudes, and the nature of the regulatory regime[185]. A distinct fifth scenario looks at the possibility that the UK may choose to reject GM crops outright.

4.1.4 These scenarios have been developed by applying the analysis of costs and benefits set out in Chapter 3 to each of the five plausible futures. In particular, the costs and benefits were assessed according to how they might vary in each of the different scenarios.

4.1.5 The scenarios could potentially be disrupted by events with a low or uncertain, and often contested, probability which – if they arose - could have a high impact. These “shocks and surprises” could arise from external or GM-related sources and could shift some or all of the scenario outcomes.

4.1.6 Overall, the scenarios illustrate the potential relative costs and benefits of alternative futures for the UK, both with and without the commercialisation of GM crops. We have based this scenario analysis on the information contained in the analysis papers accompanying this report, as well as on discussions with our Expert Advisory Groups and with other stakeholders.

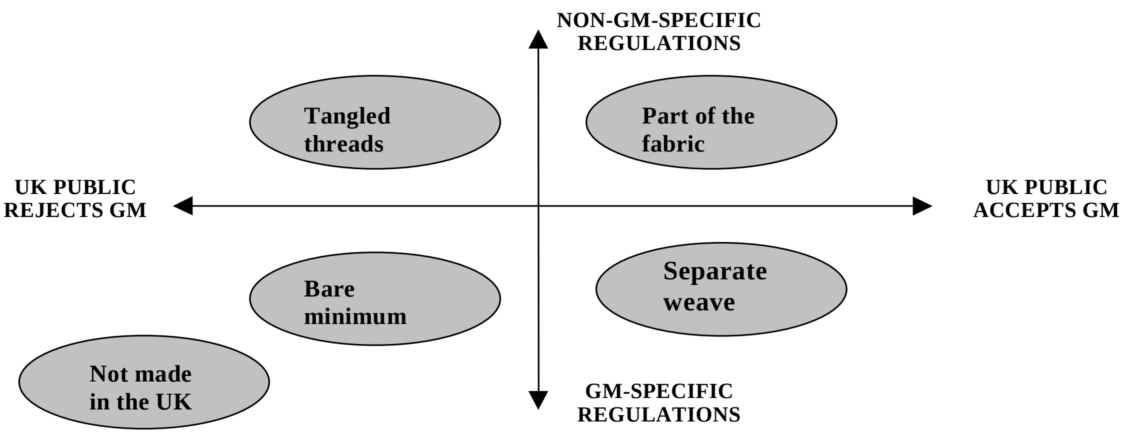
[185] Further details of the process to generate these axes are set out in the Overview Methodology paper and the note of the SU “Scenarios workshop” held 2nd December 2002, both found on the project website.

4.2 Scenario Analysis

The scenarios are driven by two key factors – public attitudes and regulations

4.2.1 The scenarios adopted in this study are illustrated in Figure 4.1, and described below. They represent possible future outcomes which could occur over 10 to 15 years.

Figure 4.1: Scenarios used in the Strategy Unit study



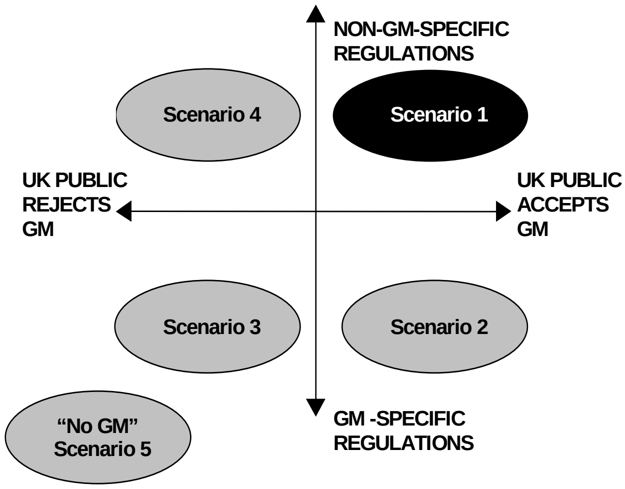
4.2.2 The vertical axis on regulations represents a range of possible regulatory regimes. At the top are "Non-GM-specific regulations" which describes a regime which treats GM crops and foods much like any other novel crop or food. That is, subject to approval but not to a list of specific regulations. At the bottom of the axis are "GM-specific regulations" which describes a regime that could include an exhaustive approvals process and a comprehensive regime for coexistence. Conditions for use would also be attached to approvals of GM crops, such as ongoing monitoring.

4.2.3 The horizontal axis represents a range of public attitudes. Public attitudes are complex and heterogeneous. They include, but are not synonymous with, consumer attitudes, which are themselves highly varied. This axis is a representation of broad shifts in public attitudes towards being more positive or negative in respect of GM foods and crops. However, it is assumed that public attitudes will continue to reflect a range of views.

4.2.4 The following pages contain the results of the scenario analysis. Each scenario is described briefly in terms of its principal characteristics, which are determined by the axes. This description is followed by an assessment of the likely costs and benefits that could be expected to occur.

Scenario 1: Part of the fabric…

…explores the full potential - upside and downside – of GM crops



In this scenario, there is a growing level of public acceptance of GM foods. Due to this general acceptance, GM ingredients become common in foods, and consumers make less distinction between GM and non-GM.

In response, the regulatory regime around GM crops and foods becomes more relaxed, treating them very much like any other novel foodstuff. There is widespread commercial cultivation of GM crops across the UK and EU.

Globally, GM and non-GM crops are generally not segregated, although a limited number of organic and non-GM product chains are maintained.

Developments in GM crop technology increase the range of products available…

- Faster technological development, stimulated by low levels of regulations, would result in a greater potential for new GM crops.
- The introduction of a range of new crops gives farmers a greater choice of what to grow.
- New commercial GM crops could have environmental benefits or increased nutritional content. Non-food crops could include those that produce renewable materials.

*…***and some positive economic impacts are likely for GM farmers, processors and consumers**

- There are likely to be cost savings from at least some of the new GM crops, which would also be easily marketable.

- New types of GM crop, especially non-food, could help some farmers to diversify their business.

- Consumers willing to consume GM food could benefit from lower prices, if lower costs are passed through the supply chain. Consumers could also benefit from a range of new products with longer shelf life and nutritional enhancement.

- With workable thresholds for adventitious presence, food manufacturers and retailers may incorporate GM into their product chains with little additional costs

The combination of consumer acceptance and a cheaper, less stringent regulatory regime could benefit UK biotechnology …

- The UK GM crop development industry is boosted and public sector research expands.

- Overall, a positive signal is sent to the wider biotechnology sector.

- Developing countries wishing to locally adapt GM crops could benefit from the strong UK science base, to the extent that it contributes to “pro-poor” crop development.

…and a very pro-GM message is sent to the rest of the world

- There would be a strong positive signal from the UK Government and consumers regarding the use and acceptance of GM crops.

- Developing countries growing GM crops would have a market for their exports and would not face additional costs because of few GM regulatory requirements.

However, the rapid advances in technology with few GM-specific regulations may carry a higher likelihood of adverse impacts…

- Negative impacts could be more likely to arise from unexpected environmental or human health effects because of the large range of GM crops approved.

- The relatively hands-off approach to regulation, including little or no monitoring, means that it would be difficult to identify, attribute and influence any impacts on the environment or human health, whether these are positive or negative.

…and producers and consumers preferring non-GM products may feel their choice is restricted

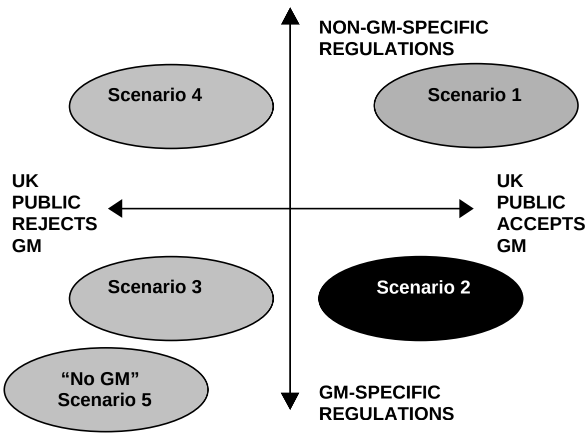
- Conventional and organic farmers may find it difficult and costly to keep GM material out, due to relatively low-key co-existence measures.

- Consumers wishing to avoid GM products might choose to buy organic products, to minimise the likely amount of GM presence, and could face higher prices as a result.

- Developing countries wishing to avoid GM imports may find this difficult due to limited availability of segregated commodities.

Scenario 2: Separate weave…

…considers a future in which public confidence is restored



Under this scenario, GM crops are introduced gradually to the UK and the rest of the EU, under a strict regulatory regime with an exhaustive approvals process, conditions for use attached such as ongoing monitoring, and a clear regime for co-existence. GM food is clearly labelled. Gradually, public confidence and consumer acceptance of GM foods grows. Consumers are particularly attracted to goods offering specific benefits, such as better flavour, longer shelf-life or nutritional benefits – whether these be GM, non-GM or organic.

Globally, the EU model is seen as successful and is used as a model for some countries. Some non-GM supply chains are maintained as a result of consumers' demand for choice.

Consumer and producer choice is supported by the regulatory approach…

- Labelling ensures consumer choice, and strict regulations create consumer confidence in GM products.

- Farmers may choose between GM and non-GM crop varieties. Co-existence measures aim to ensure that an acceptable level of adventitious presence is reached.

- Developing countries would be able to avoid GM imports if they wished, because of some separation and labelling of GMOs in commodity markets.

…and the likelihood and impact of any adverse impacts is limited

- The strict regulatory regime and focus on crops that do not outcross easily reduces the likelihood of adverse impacts on the environment or health.

- Monitoring of environmental and (to some extent) health impacts, plus inspection to verify compliance with any consent conditions, means that there is a strong ability to pick up any possible adverse impacts.

- These impacts would be more easily attributed and dealt with given the segregation of GM and non-GM products in the product chain.

Although a more careful regulatory regime would impose some additional costs on the food chain…

- GM crops may only prove to be economic for farmers who find existing methods of weed and pest control difficult or expensive.

- Costs would also be incurred in keeping a wide range of GM, non-GM and organic produce separate at the farm level and through the product chain. This could increase the overall cost of food if these costs are passed through the product chain to the consumer.

- Food and feed imports from developing countries would need to meet segregation and labelling standards. This could mean some developing countries forego benefits from certain GM crops if meeting these standards is challenging or costly.

…as well as slowing technological developments to an extent

- The regulatory approval process is relatively slow and costly, so GM crops would be worth developing only if they had major markets, high added value, or obvious agronomic benefits.

- These crops would offer good opportunities for UK ag-biotech research. Multinationals would have a significant role in bringing SME/PSRE research to market.

- The slow rate of development in the technology may mean that some future benefits – such as environmental or human health benefits - are foregone or delayed.

- Fewer scientific developments in the UK may reduce the likelihood that "pro-poor" GM crop varieties are created for developing countries wishing to adapt them locally.

The nature of GM crop introduction means that potential environmental benefits could be realised

- Policy measures such as GM-specific agri-environment schemes or codes of good practice encourage environmentally sensitive use of GM crops by farmers, meaning that the potential positive impacts of changes to chemical use are more likely to be realised, with less of the downsides

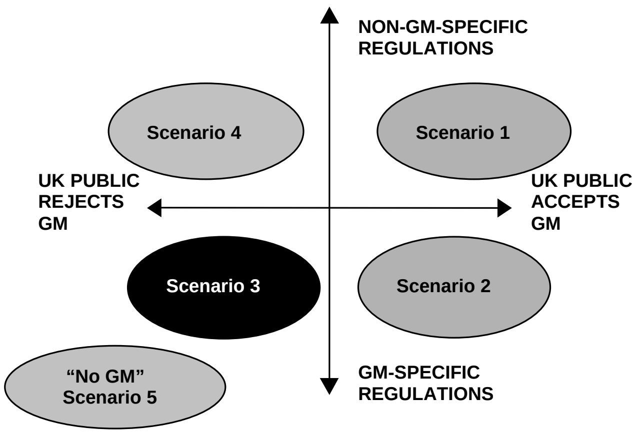
- Such measures could also help other potential benefits to be realised, such as reductions in tillage.

The signal from the UK would be positive and supportive of strong regulations

- The signal from the UK government and consumers would be positive while emphasising the importance of effective regulations

Scenario 3: Bare minimum…

…sees a very low level of GM crop growing



This scenario assumes that a combination of strict regulation and negative public attitudes results in the UK having very low levels of GM cultivation for the foreseeable future. A rigorous approvals process – together with the prospect of extensive post-market monitoring – make ag-biotech companies reluctant to introduce crops. Farmers are wary of liability concerns and UK supermarket demand for GM products is low. Most consumers are negative towards the technology, preferring conventional or organic produce. However, agronomic benefits may be appealing in feed and non-food markets, and a small amount of GM crops may be both grown and imported for animal feed and non-food uses.

Globally, some segregated non-GM supply chains are established and some countries avoid GM crop cultivation.

Regulatory costs would be incurred…

- Regulations impose significant hurdles for GM crop commercialisation, which discourages applications for new GM crops.

- Costs of coexistence and segregation at the farm level discourage farmers from growing GM crops and offset potential gains.

- Food and feed imports from developing countries would need to meet segregation and labelling standards. This potentially significant cost may affect developing country decisions about whether GM crops are grown and exported.

…and many GM crops would not reach commercialisation in the UK

- Most consumers are not willing to buy GM food and the market for produce is small. This means that potentially beneficial GM crops may not reach the market.

- Multinational research focus shifts further from the UK (and EU), and research activity in the UK diminishes.

- The potential use of GM crops as a tool to help reduce the use of pesticides or other chemicals is largely rejected in the UK, meaning that other measures have to be taken to achieve these objectives.

- Slow scientific developments in the UK may reduce the likelihood that "pro-poor" GM crop varieties would be developed for developing countries wishing to adapt them locally.

- The UK is on the "back-foot" when it comes to the exploitation and development of GM crop technology.

But consumer choice would be maintained…

- Labelling and segregation of GM from non-GM, including co-existence, means that consumers can choose between organic, conventional and (mainly imported) GM products.

- Developing countries may be able to avoid GM imports if they wished, because of some segregation and labelling of GMOs.

…non-GM crops may be boosted…

- Crop development research shifts towards public sector dependence. With adequate funds, some areas – such as organic and marker assisted breeding – may be boosted.

- Conventional crops and crop protection products continue to be developed to meet world-wide demand for non-GM food. This will include the UK market.

- Some non-GM crops – particularly where price is largely determined by the UK market - are available without much of a price premium, because of the relatively small amount of GM crop production in the UK.

…and the likelihood of negative impacts is reduced

- As few GM crops are grown or food consumed, there is limited potential for negative impacts from GM sources.

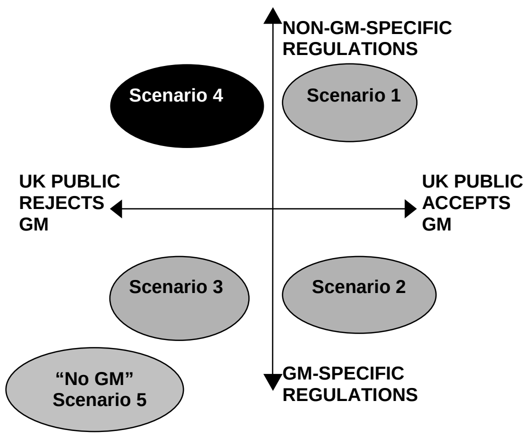
- Post-market monitoring means that any problems are more likely to be picked up and attributed.

Internationally, the messages sent would be mixed

- There would be mixed signals from the UK, with the signal from Government being that GM crops can be grown but only subject to regulatory approval; while the signal from UK consumers is negative.

Scenario 4: Tangled threads…

…looks at a failure of regulatory policy to meet public expectations



In this scenario, there is a discontinuity between public attitudes and regulatory policy. EU regulations on GM crops and food prove to be expensive or unworkable in practice. UK public and consumer attitudes are generally against GM crops, but exporting countries may find it difficult to comply with EU thresholds for adventitious presence.

Over time, the regulatory approach changes to improve its workability, but consumer attitudes remain generally unsupportive of the technology. This means that many consumers are demanding GM-free products which the regulatory regime is struggling to deliver. There is some demand for certain GM products, including non-food crops, and UK farmers limit their growing of GM crops to meet this limited domestic as well as export demand.

Globally, problems with the EU model discourage other countries from having a GMO-specific regulatory regime.

Uncertainty over the regulations and acceptance of GM confuses industry, producers and farmers alike…

- Regulatory processes have been reduced in scope, but research, trials and products are unpopular. There is little incentive to develop GM crops for the UK.

- In view of a weak regulatory environment, some farmers wishing to sell identity-preserved conventional and organic crops could be faced with additional costs due to effects from their neighbours growing GM crops. This could contribute to tensions within rural communities.

- It may be difficult for developing countries to choose to avoid GM imports if they wish, due to low levels of separation and labelling of GMOs.

- Developing countries wishing to export GM food and feed products would have relatively few regulatory requirements to meet for entry to the UK market, but there would be little consumer demand.

…leading to dissatisfaction among consumers…

- There is demand for non-GM produce but a blurring between GM and non-GM sources. Any non-GM products that can maintain a low adventitious presence of GM will be boosted.

- Organic and conventional farmers could bear costs to maintain their non-GM status, depending on how liability is dealt with. These costs would need to be passed onto consumers as a "purity premium" which may be easier for organic than conventional products.

- GM crops are unpopular, but can be grown and protests against GM crops and trials are common. Consumer choice is seriously affected and public trust in regulatory authorities is diminished.

…and a poor ability to deal with adverse impacts…

- Low levels of monitoring mean that if problems are caused by GM crops, they may take some time to be noticed.

- The lack of segregation between product chains means that attributing the impacts will be difficult.

The overall outcome is messy, with benefits for some but problems as well…

- High demand for organic produce means that the organic sector grows more quickly than is currently envisaged; chemical use falls, and there is a possible increase in the diversity of rural environments.

- There is less overall capacity for the UK to benefit from any positive GM crop developments such as new developments in environmentally or health-beneficial GM crops. However, there could be developments in non-GM techniques.

- Regulatory confusion and consumer pressure for choice generates costs for food manufacturers and retailers.

- The slowing in scientific developments may reduce the likelihood that "pro-poor" GM crop varieties would be created for developing countries wishing to adapt them locally.

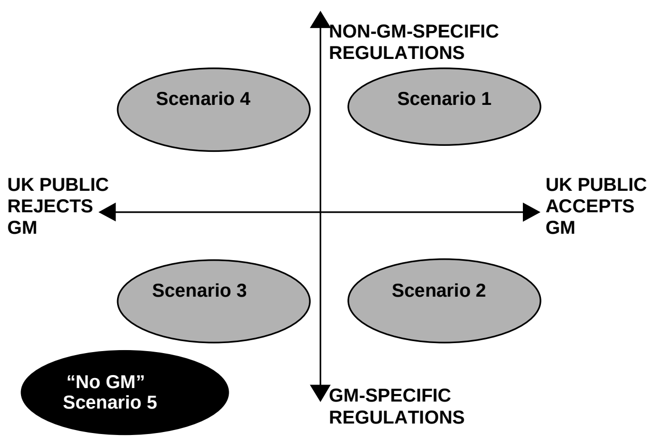
- Developing countries could specialise in organic exports, but this may involve foregoing certain GM crop benefits if segregation is difficult.

…and the rest of the world views developments with some alarm

- There would be conflicting and messy signals from the UK. The regulatory approach, once adjusted, could send a positive message about the technology, but there would be a negative signal about GM crops from consumers.

Scenario 5: Not made in the UK…

…considers the case where no GM crops are grown



This scenario is based around an explicit policy against the commercial cultivation of GM crops. It shares many similarities with Scenario 3, but the explicit decision precludes any GM crops from being grown on a commercial basis, and sends a clearer and firmer signal about attitudes to GM crops. At the same time, there is no need to design and introduce rules for coexistence, insurance, etc. Most consumers are against the technology, preferring conventional or organic produce, and therefore retailers continue to demand non-GM products. However, a minority are not put off by GM foods, and there is a small import market for GM foods.

Globally, some segregated non-GM supply chains are established and some countries avoid GM crop cultivation.

An explicit no-GM policy has international implications…

- The UK signal about GM crops would be strongly negative from both Government and consumers.

- The policy decision could be difficult to achieve and the route by which it could be made is not clear cut. It would also generate trade-related tensions.

…and there is a reduction in the types of crops available to producers and consumers

- Farmers could be faced with increasing competitive pressure from GM production elsewhere, particularly in the export market.

- The potential use of GM crops as a tool to help reduce the use of pesticides or other chemicals is lost to the UK, meaning that other measures have to be taken to achieve these objectives.

- The UK is reliant on non-GM methods for producing non-food crops such as energy crops, and so could forego some benefits. More generally, using GM crops to meet policy objectives would not be an option.

- Consumers and other groups, such as livestock farmers, who wished to buy GM products, would rely on imported products. Some supermarkets may not stock GM products.

- Developing country exporters of GM crops would have little UK demand coupled with significant regulatory hurdles. This could mean they avoid exporting to the UK or specialise in non-GM products for the UK market. The latter may involve foregoing certain benefits from some GM crops if segregation is costly or challenging.

…as well as limiting options in the ag-biotech industry…

- There would be no point developing any GM crop, including niche GM varieties, for UK markets.

- There are also negative signals sent to the wider biotechnology science base, the nature of which will depend upon the basis for the decision to rule out GM crops.

- The slowing in scientific developments could reduce the likelihood that “pro-poor” GM crop varieties would be developed for developing countries wishing to adapt them locally.

Some, but by no means all, of the costs of regulation are avoided

- There is no need to design or implement a coexistence or monitoring regime. However, regulation would still be required to deal with imports of GM products including costs of segregation through the product chain which include testing and labelling.

…and consumers and producers wishing to avoid GM food can do so

- As no GM crops are grown in the UK, and all GM imports must be labelled as such, it is possible for producers and consumers who wish to avoid GM products to do so.

Risk of adverse effects is reduced…

- GM crops are not grown and there is little consumption of GM food, so there is very limited potential for adverse impacts from this source.

- Any negative impacts could be relatively easily detected and attributed to the small number of imported GM products.

…and the UK could see benefits from having a “GM free” environment

- As a “GM-free zone” the UK could benefit from a reputation for an environment that does not contain GM crops.

- The UK could develop niche non-GM products for domestic and international markets.

<u>Summary of scenario analysis</u>

The scenarios highlight the importance of trade-offs and the weighting of different costs and benefits

4.2.5 These scenario outcomes are based on the SU’s assessment of costs and benefits and represent a range of possible futures related to GM crop cultivation in the UK. They highlight the importance of trade-offs in decisions about GM crop cultivation, and how different groups and individuals will be affected differently by a variety of future paths.

4.2.6 Although the scenario outcomes set out possible futures, no assessment has been made of the likelihood of a particular scenario occurring, or which possible future is better than any other. Value judgements and “weighting” of different factors will be required to assess how costs and benefits should be traded off against one another.

Levels of trust in the UK may affect how the scenarios pan out…

4.2.7 The scenarios will be sensitive to levels of trust in institutions and regulations. The outcome of the scenarios could be affected by the degree to which different groups in society trust the basis and implementation of the regulatory framework. A regulatory framework that does not command widespread trust may shift the costs and benefits associated with that scenario.

…as well as global developments

4.2.8 International developments will also affect the outcome of the scenarios. For instance, scenarios with very limited growing or consumption of GM crops may be harder to sustain if the majority of countries in the rest of the world decide to use GM crops. Conversely, should there be a slowing or reversal in GM crop uptake globally, then a UK future with widespread GM crop growing could be problematic in the long term.

Liability could affect the distribution of costs and benefits in the scenarios

4.2.9 The nature of liability for economic or environmental damage will play an important role in the distribution of costs and benefits in scenarios where GM crops are grown in the UK. This issue will be considered in the AEBC's forthcoming report on coexistence and liability.

4.3 Potential disrupters – the impact of shocks and surprises

The scenarios could potentially be disrupted by events with a low or uncertain, and often contested, likelihood that could have a high impact – either positive or negative

4.3.1 The scenarios are built on the assessment of costs and benefits set out in Chapter 3. This analysis reflects the SU's understanding of the range of costs and benefits that could arise under conditions that look broadly as they do today. The scenarios are plausible, therefore, in the sense that they could occur without having to rely on unlikely events.

4.3.2 However, when looking forward over 10 to 15 years it is impossible to rule out that such events could occur. These events could have a low or uncertain, and often contested, likelihood of occurring, but a high impact if they do happen. To address this source of change and uncertainty, the SU has introduced the tool of "shocks and surprises".

Shocks and surprises have a low or uncertain probability but could have important implications

4.3.3 Shocks and surprises are events which are perceived to have a low or uncertain probability of occurring; and their likelihood may be disputed among different groups of stakeholders. Events which, to some, are highly unlikely or even impossible, are deemed probable, or even expected, by others. And the shock or surprise itself could have a range of different impacts or be subject to different interpretations.

4.3.4 They are events that have the potential to disrupt the scenarios and change their outcome – in ways that may be generally supportive of, or damaging to, policy objectives.

Shocks and surprises could be "internal" or "external"

4.3.5 Shocks and surprises can be classed as "external" or "internal". External shocks and surprises arise from events outside of GM crops; internal shocks and surprises are generated from GM crop-related sources. This distinction will be explored more fully below and discussed with reference to how they could impact on the scenario analysis.

They can be discussed in illustrative terms only

4.3.6 However, by their very nature, shocks and surprises cannot be predicted - they can only be discussed in terms of what *could* happen, not what will happen. All examples and discussion of shocks and surprises are therefore *illustrative* only.

External shocks and surprises – changes in the outside world

4.3.7 The SU's basic analysis assumes that the "outside world" – everything other than GM crop-related issues – looks broadly as it does today. This may be the case. But equally "outside world" conditions could change markedly from current circumstances.

4.3.8 It is important to consider how external shocks and surprises could disrupt the context in which GM crops are, or are not, grown. These shocks have no direct link to GM issues, but they could affect the impact of GM crops.

4.3.9 Some illustrative examples of external shocks and surprises are given below:

- **Health** – a food scare in another type of agriculture could change perceptions about the safety of GM crops;
- **Environment** – climate change could alter the types of pests found in the UK, and therefore the type of pest strategies needed in UK agriculture;
- **Political / economic** – an oil price shock could change the economics of energy crops;
- **Innovation** – a breakthrough in genomics could change the economics of GM technology.

The impacts of external shocks and surprises on GM crops…

4.3.10 All of these external shocks and surprises would alter the context in which GM crops operate; for example:

- External shocks and surprises would alter the **policy context** in which GM crops occur. Changes to this context could generate new goals and objectives which GM crops could be in a strong, or weak, position to meet.

- External shocks and surprises could also generate **new drivers** for GM crop decisions, making GM crops more attractive.

- **Trust** in key institutions would also be affected by external shocks and surprises. The way an external event was dealt with by an institution could affect public trust, which could indirectly affect perceptions of GM crops.

- External shocks and surprises could also be **amplified** by GM crop issues. For example, pre-existing concerns about GM crops could exaggerate the reaction to health issues in another area of agriculture.[186]

- GM crops could also be a **lightning rod** for external shocks and surprises. A shock that is unrelated to GM crops could increase or reduce public concern about GM crops.

4.3.11 Box 4.1 below highlights an illustrative external shock that was generated independently by stakeholders for the SU's Seminar on Shocks and Surprises[187]. It is discussed with reference to its potential impact across the scenarios.

Box 4.1: Stakeholder-generated external shock or surprise

This political "shock or surprise" is discussed for illustration only

Nature and impact of the event
Anti-globalisation and xenophobia combine to promote a new localism. At the same time, radical environmentalism develops out of a series of eco-disasters. These two forces lead to authoritarian radical environmental political forces operating at a regional level. The result is a set of strong, regional political units with independent approaches to GM crops. Some areas instigate full bans, while others introduce strict regulations. Border conflicts flare up between different jurisdictions.

Implications of the event across the scenarios
Overall, this event would cause a shift along the regulatory axis towards the GMO-specific end. The event would also change the public attitudes axis by shifting "average" attitudes towards the negative end of the spectrum. The event could make scenarios 1 and 2, with positive public attitudes,

[186] Likewise, pre-existing concerns about GM technology could amplify concern about a GM-related shock. A recent report from the Pew Initiative on Food and Biotechnology and the John F. Kennedy School of Government, "When Media, Science and Public Policy Collide", indicates that media coverage during the Starlink case seemed to convey the message that contamination by a transgenic strain was more likely to cause an allergic reaction than that by a conventional crop. In practice, this is not necessarily the case; the report states, for example, that contamination by ordinary peanuts would have been more serious.
[187] Further details are set out in the note of this seminar, available on the project website.

unsustainable in the long term. It would have less overall impact on scenarios 3, 4 and 5 because the public is already negative towards GM crops, and would be less disrupted by more restrictive policies on the technology.

External shocks and surprises across the scenarios…

4.3.12 By definition, external shocks or surprises do not have any direct relationship with GM issues, but by changing the context in which GM crops occur, they will shift GM crop-related outcomes in various ways. Overall, external shocks and surprises do not appear to impact across the scenarios in a systematic way. However, an external shock or surprise could make a scenario unsustainable over the long term. It could also affect non-GM crop outcomes.

Internal shocks and surprises – GM crops as the source

4.3.13 Internal shocks and surprises are generated from GM crop-related sources. They are therefore related to how, and to what extent, GM crops and foods are developed and used.

Internal shocks and surprises could have positive or negative policy impacts

4.3.14 An internal shock or surprise could support policy objectives. If there was an unexpectedly early or completely unanticipated breakthrough in the development of a particular GM crop variety, for example, this could assist certain agricultural policy objectives to be met. A drought resistant GM crop variety developed earlier than expected would constitute an internal shock.

4.3.15 An internal shock could also be generated by an unexpected shift in innovation that changes the principles of GM crop development. This could make the creation of GM crops easier or quicker, generating new benefits and reducing some costs. The development of alternatives to GM crops could also undergo an unexpected shift that affects their contribution to agriculture.

4.3.16 An internal shock or surprise could also damage policy objectives. The likelihood of a negative internal shock occurring will depend upon the nature and effectiveness of the regulatory regime, as well as the range of crops and traits that are approved. The impact of any such shock will depend, in part, on whether or not it is reversible, and at what cost.

The current regulatory regime aims to minimise negative shocks

4.3.17 As Box 4.2 below shows, current European risk assessment procedures are detailed and take into account potential shocks from direct or indirect effects of GM crops.

Box 4.2: GM crop risk assessment in place

All GM crops undergo a risk assessment for their impacts on human health and the environment. The risk assessment process is specific to the GM crop being considered and contains a range of scientific information, including:

- potential cumulative long-term effects associated with the interaction of the GM crop with other GMOs, the ecosystem where it would normally be grown and the environment more widely;
- any toxic, allergenic or other harmful effects on human or animal health;
- description of monitoring plans to trace and identify any direct or indirect, immediate, delayed or unforeseen effects on human health or the environment of GMOs after they have been placed on the market;
- measures to minimise or prevent the dispersal of reproductive material from the plant to neighbouring species that are sexually compatible;
- emergency plans should any unexpected events occur.

The 2001/18/EC Directive provides for:

- detailed assessment by the lead member states expert advisers;
- detailed scrutiny by the expert advisers of the other 14 member states during EU decision making and by the European commission's Scientific Committee on Plants;
- EU wide public consultation.

The Directive also provides for the possibility that new evidence may come to light in future that could change the basis of the risk assessment. If new information on risk becomes available (i.e. from monitoring or elsewhere) which casts doubt on a risk assessment, the Directive provides a means by which consents can be varied or revoked.

4.3.18 However, for the purposes of the scenario analysis, it is important to consider different regulatory approaches and their capacity to prevent and deal with negative internal shocks.

4.3.19 With any regulatory system there are tradeoffs between its **ability** to prevent negative shocks versus its financial **cost**. If the regulatory regime is as exhaustive as possible, it may be more effective at picking up risks, but at a high financial cost. At the other extreme, a laissez-faire approach to regulation could allow some potentially serious risks to go unnoticed.

However, shocks and surprises are - by definition - unexpected

4.3.20 Whichever approach is taken, an effective regulatory regime would minimise the chances of any adverse impacts occurring. However, regulations themselves cannot guarantee that such impacts will not arise for two main reasons:

- Regulatory regimes focus on **known** and **foreseen risks**. It is difficult to deal with hazards that are presently unknown, although monitoring would increase the likelihood that any of these adverse shocks are detected.

- For regulatory regimes to operate effectively, they rely on **compliant behaviour** from all actors involved. Unexpected impacts may occur if regulations, or conditions attached to regulatory consents, are not fully followed.

4.3.21 For these reasons, the impact of a negative internal shock or surprise is not necessarily the sign of regulatory "failure". It could be the result of where the line was drawn between cost and effectiveness, how regulations were complied with, what information was available at the time and which shock or surprise actually occurred.

4.3.22 Some illustrative examples of internal shocks and surprises are given below:

- **Health** – a completely new toxin could be identified for which a number of GM crops, even those already with approval, must be tested.
- **Environment** – greater scientific understanding of ecosystems identifies a new environmental impact of GM crops that has not been taken into account by current regulations.
- **Political / economic** – research into GM crops becomes less expensive, more quickly than expected, which changes the structure of the ag-biotech sector.
- **Innovation** – there is a breakthrough in key traits that enable the development of nitrogen fixation using GM and a subsequent reduction in the use of fertilisers, with associated environmental benefits.

The impacts of internal shocks and surprises on GM crops and food…

4.3.23 In a similar fashion to external shocks and surprises, these internal shocks and surprises share a number of features which will affect GM crops and foods:

- Internal shocks or surprises could generate possible **ramifications** beyond the immediate issues that also affect GM. For example, concerns about unlabelled GM soya ingredients contributed indirectly to labelled GM tomato paste being removed from UK supermarkets in the late 1990's.

- The way that key institutions - such as Government and the media – react to an internal shock or surprise will affect its overall impact. This could either increase or reduce support for GM crops.

4.3.24 Box 4.3 highlights an illustrative internal shock or surprise generated independently by stakeholders for the SU Seminar on Shocks and Surprises. It is discussed with reference to its potential impact across the scenarios.

Box 4.3: Stakeholder-generated internal shock

This health shock or surprise is discussed for illustration only

Nature and impact of the event
A pattern of illnesses are attributed to an allergic reaction from food consumption. There is a possibility that the allergic reaction may be linked to a protein giving insect-resistance, which is used in a range of GM crops. The impact of this shock will depend upon whether the pattern is linked to GM crops or not. However the official reaction to the shock and how it is dealt with will also determine the impact. Any negative public association between the shock and GM crops may persist even if the scientific evidence proves there is no connection.

Implications of the event across the scenarios
If this shock occurred and was proved to be GM-related, it would be harder to deal with in scenarios 1 and 4 because of the relatively weak labelling and segregation between GM and non-GM, and because of reduced monitoring. This shock would be easier to deal with in scenarios 2, 3 and 5 because of the more extensive regulatory regime. In 3 and 5 only a small amount of imported GM food would need to be tested.

Internal shocks and surprises across the scenarios…

4.3.25 There is likely to be a large variation in how internal shocks and surprises impact across the scenarios. This is due to the link between the likelihood of the GM-related shock or surprise occurring and the extent of GM crop cultivation and consumption in different scenarios.

Conclusions on the impact of shocks and surprises

4.3.26 A particular pattern emerges with respect to **internal shocks and surprises**. There is a key trade off between the susceptibility of the scenario to *negative* internal events and ability for the scenario to benefit from *positive* internal shocks or surprises.

- **High impact from internal shocks and surprises:** a scenario able to capitalise on *positive* internal shocks or surprises will also be more vulnerable to *negative* internal shocks. For example, in scenario 1 a breakthrough in GM crop technology could be quickly developed and used. But it would also be more difficult in this scenario to deal with an unexpected environmental issue from GM crops.

- **Low impact from internal shocks and surprises:** a scenario that is relatively resilient to *negative* shocks will have less potential to benefit from *positive* shocks. For example, in scenario 3 there would be relatively few sources of internal *negative* shocks because of the small amount of GM crop and food used. However, at the same time, the slowing in scientific developments means that it is less likely that benefits could come from a *positive* GM development such as a new trait.

4.3.27 The impact of **external** shocks and surprises will depend more upon the event itself than the scenario, although their impacts will differ across scenarios.

4.3.28 Overall, this section demonstrates the importance of taking the impact of shocks and surprises into account when assessing the overall implications of each scenario. The costs and benefits from the basic SU analysis could be significantly disrupted – in a direction that supports or damages policy objectives – from the occurrence of shocks and surprises.

4.4 Overall conclusions

The scenarios illustrate the trade-offs inherent in any future for the UK, with or without GM crops

4.4.1 None of the scenarios are universally good or bad. Instead, they all represent trade-offs between costs in one area and benefits in another. Different individuals will have different views on the desirability of each scenario outcome. Value judgements and "weighting" of different factors will therefore be required to assess how costs and benefits should be traded off against one another.

4.4.2 The Government is particularly interested in whether GM crops can help to achieve policy objectives. The analysis shows that different objectives may be supported more or less in different scenarios.

The scenario outcomes could be shifted by interactions between policies and attitudes

4.4.3 The scenario outcomes could be shifted by interactions between different factors. Dynamic relationships between, for example, regulatory policy, public attitudes and global developments, could affect the overall outcome in any scenario. These interactions are unpredictable, and the uncertainty surrounding their potential impacts should be noted when assessing the overall conclusions to this study.

The scenarios show that the nature of the regulatory system will have an important bearing on our ability to deal with any risks to the environment and human health…

4.4.4 The current EU regulatory system has been designed to limit adverse effects as far as possible – and as the regulatory system evolves over time, it will continue to retain this aim. But no procedures can be 100% effective, and there will always be the possibility – however small, or disputed – that some unforeseen (and possibly unforeseeable) adverse impacts to the environment or human health may occur, particularly in the longer-term. The potential irreversibility of some of these impacts also has to be taken into account when considering this possibility.

4.4.5 In light of this, a key trade-off will be between the costs and burden of regulation, and its effectiveness in anticipating and handling risk. A regulatory system which required large amounts of information, such as many years' worth of testing, might be more effective in anticipating problems or in dealing with unexpected events should they arise. But it could also be expensive and may discourage biotechnology firms from developing potentially valuable new crops in the UK.

…as well as on the impact of GM crop cultivation on non-GM and organic farmers

4.4.6 The nature of the rules on the growing of GM crops will determine how effectively they can be kept separate from non-GM crops at the farm level, and to what extent non-GM and organic farmers may have to incur costs themselves in ensuring the integrity of their products. Whether they could pass on any such costs would depend on the relative demand for their goods, which would be higher in scenarios where the public has negative views about GM produce.

They also illustrate the central importance of public attitudes in determining the impacts of GM crops

4.4.7 Consumer attitudes are a very important determinant of the impact of GM crops. In scenarios with negative attitudes, there is only a limited market for GM crops, and hence low take-up. Attitudes are complex and heterogeneous, and may vary between different uses of GM crops – the use of crops for industrial purposes or animal feed, for instance, might prove to be more acceptable than their use in food.

In the short term, negative consumer attitudes can be expected to limit the demand for products containing GM foods, and therefore the economic value of the current generation of GM crops

4.4.8 Applying this to the current situation in the UK means that if consumer attitudes towards GM foods are negative in the short term, then any net cost and/or convenience savings associated with the current generation of GM crops would be likely to be outweighed by the lack of a market, limiting their economic value. Interest from farmers may be limited to goods destined for export markets, for the production of animal feed.

But there is significant potential for benefits from future developments in GM crop technology…

4.4.9 The availability of GM crop technology may help in the development of new and potentially beneficial crops in the future, such as those with particularly useful agronomic traits which make agricultural production easier or cheaper. These traits may be important in maintaining competitiveness in internationally-traded commodities. GM crop technology may also help the development of products with health or consumer benefits. And the potential for GM crops to be used in the production of a range of non-food products, such as renewable materials or pharmaceuticals, could provide benefits outside the farming and food industry.

4.4.10 However, this potential needs to be balanced against the possibility that new GM crops could introduce new risks. Much would depend on the ability of the regulatory system to keep up with the technology in the future, and to anticipate and manage risks and people's concerns effectively.

…as well as the potential for impacts on wider science and industry

4.4.11 GM crop policy may also have wider impacts on UK science and industry. The UK has a leading position in biotechnology in Europe. The UK also has a global reputation for wider scientific excellence, and science-based industries as a whole make an important contribution to national output. This contribution, and its future expansion, is likely to be affected if changes in GM crop policy send signals, either positive or negative, about the UK's attitude to biotechnology, science and industry.

The scenarios demonstrate that international implications could be significant

4.4.12 The scenarios show that the global impact of UK or EU GM policy should not be underestimated. The ability of developing countries to choose whether or not to adopt GM crop technology may be affected by considerations about the possible impact on exports to the EU. And taking a significantly different policy direction from other countries could cause serious trade tensions.

Chapter 5: Next steps

Summary

- This SU study has to be considered in the context of the work that is currently being carried out by the Science Review and by "GM Nation? The Public Debate".
- The final reports of the three strands of the overall GM Dialogue are intended to support the Government in making forthcoming decisions about the commercial development of current generations of GM crops in the UK, as well as to inform GM policy making in the longer term.
- This study has highlighted some interesting areas of research which, although not directly related to decisions about the commercial development of current generations of GM crops in the UK, may provide fruitful areas for further research in the future.
- In the longer term, the availability of more information will enable some key issues to be looked at in more depth.
- The report is published for comment – responses should be sent to the Strategy Unit by Friday, 17th October 2003.

The analysis presented in chapter 4 represents a first attempt at drawing out the potential economic implications of various GM and non-GM scenarios. This chapter outlines the scope for further analytical work in this field as well as the next steps following the SU's GM crops project.

5.1 Recommendations for further analytical work

5.1.1 This SU study has to be considered in the context of the work that is currently being carried out by the **Science Review** and by **"GM Nation? The Public Debate"**:

- Final outputs from the Science Review will add to some of the areas of analysis in this study, in particular the work on costs and benefits associated with environmental and human health impacts. For example, the Science Review may make it possible to draw clearer conclusions about costs of monitoring, clear-up and remediation, and about the trade-offs between costs of regulation and the likelihood of "shocks" arising.
- The conclusions of the Public Debate will expose those areas that are of particular concern to the public, and this may warrant further analysis in some areas. It will also provide valuable information on the likely reactions of consumers in the event of different scenarios – or "shocks" – arising,

which will in turn inform analysis of the costs and benefits that are likely to occur.

5.1.2 The final reports of the three strands of the overall GM Dialogue are intended **to support the Government in making forthcoming decisions about the commercial development of current generations of GM crops in the UK, as well as to inform GM policy making in the longer term**.

This study has highlighted some interesting areas for further research

5.1.3 The remit of the SU study has necessarily been focused on supporting Government in its decision-making. However, the study has also touched on some other interesting issues, which - although not directly relevant to decisions about the commercial development of current generations of GM crops in the UK - may provide fruitful areas for further research in the future.

5.1.4 The first area of potential research would be to build a stronger evidence base on **alternatives to the commercial cultivation of GM crops** – such as organic farming, conventional farm management and the use (in plant breeding) of genomic techniques not involving genetic modification. This study has made a preliminary attempt to assess the merits of these alternative approaches, because they provide a benchmark against which the costs and benefits of GM crops may be assessed – without such a benchmark, any analysis would have been meaningless. However, there are no comparable studies on the costs and benefits of these alternatives, and this has raised considerable difficulties. It should be possible to draw on work carried out to inform DEFRA's "Strategy for Sustainable Farming and Food"[188], and also the "organic action plan"[189], as well as similar initiatives in the Devolved Administrations[190]. The aim would be to assess the way in which these alternatives to GM could contribute to the goals of agricultural policy.

5.1.5 The second area of potential research would build on the outputs of "GM Nation? The Public Debate" by assessing in more detail the **sociology of attitudes to GM crops and foods**, and other examples of the commercial application of new technologies. This could include an assessment of how attitudes evolve and how they impact on decision-makers.

5.1.6 The final area of potential research relates to the **costs and benefits of GM crops in developing countries**. The "Developing country background working paper: Potential UK impact on developing countries", published as part of this study, included a very broad overview of the costs and benefits

[188] DEFRA (December 2002) "Strategy for Sustainable Farming and Food - Facing the Future", available at http://www.defra.gov.uk/farm/sustain/newstrategy/index.htm.
[189] DEFRA (July 2002) "Action Plan to Develop Organic Food and Farming in England", available at http://www.defra.gov.uk/farm/organic/actionplan/index.htm. The Scottish Executive Organic Action Plan is at http://www.scotland.gov.uk/library5/agri/orap-00.asp.
[190] In Scotland, the Scottish Executive has published "A Forward Strategy for Scottish Agriculture" (2001), available from http://www.scotland.gov.uk. In Wales, agriculture is a key element of the "Rural Development Plan for Wales 2000-2006" (2001), available from http://www.wales.gov.uk. In Northern Ireland, a vision for the future of the agri-food sector is described at http://www.dardni.gov.uk/.

associated with GM crops in developing countries.[191] But there was no intention to carry out a "cost-benefit analysis" of GM crops in developing countries, and the Strategy Unit's assessment was by no means comprehensive. And although this report, and the associated analysis paper, have considered the way in which UK decisions may impact on decisions taken in developing countries, the complexity of the interactions, the inherent uncertainties, the very wide varieties of potential applications, and the significant differences between developing countries have all made it difficult to draw firm conclusions.

5.1.7 Of course, the quality and quantity of information on GM crops – and alternative approaches – in developing countries is even more limited than in relation to developed countries. On the other hand, many developing countries are facing difficult decisions about GM crops and foods, and might well be willing partners in work to provide better information.

5.1.8 What this suggests is that any further work – perhaps involving (or even sponsored by) DFID – should not take the form of a "root-and-branch" analysis. Instead, it should look to sound out with developing countries and international agencies the merits of work to improve understanding of the possible contribution that GM crops – and equally of alternative approaches – may make to agricultural development objectives in these developing countries. It would be important to focus on the objectives, and to consider GM crops as one possible solution – rather than to consider GM crops in isolation. This should help to ensure that decisions on funding[192] and on agricultural practice are tailored more closely to developing country needs.

In the longer term, the availability of more information will enable some key issues to be looked at in more depth

5.1.9 In addition, as further information (see section 3.2) becomes available, the analysis presented in this report should be kept under review. Particular **areas of analysis that could be revisited** in the light of further information are:

- The costs of regulatory activities, such as traceability and labelling; monitoring of impacts; and policing of rules for coexistence. What is the magnitude of these costs? To what extent do they vary according to the area and range of GM crops grown? Who bears the costs? What is the impact on the prices and choice faced by consumers?

- Progress in crop development R&D relative to expectations, including both GM and non-GM techniques. What GM traits are being brought to market, and in which crops? What attributes are being developed through non-GM techniques? How do the costs, timescales and scope compare?

- Patterns of demand for products from GM crops. Are consumer attitudes stable or volatile? What are the distinctions between different types of

[191] The background working paper is available on the project website.
[192] See, for example, section 2.1 of the Developing Countries Analysis Paper, available on the project website.

product (e.g. food versus non-food)? What is impacting on these attitudes? How important does price seem to be?

5.2 What happens next?

5.2.1 As the Department with lead policy responsibility for GM crops, DEFRA will take responsibility for this report's dissemination and for ensuring that the report's analysis is reflected in future policy decisions. Ministerial responsibility will rest with the Secretary of State for the Environment, Food and Rural Affairs, reporting to the SCI(BIO) Cabinet Committee.[193] In particular, the report will play an important role in informing Government's policy towards GM crops and foods, on which an announcement is expected towards the end of 2003. DEFRA will need to work closely with other Government Departments and with the Devolved Administrations in disseminating and using this report.

5.2.2 Finally, the Strategy Unit will be responsible for collating and publishing responses to this report. The Strategy Unit also plans to publish a summary of the responses received, and will pass all responses on to DEFRA.

5.2.3 Responses should be sent to

GMCrops@cabinet-office.x.gsi.gov.uk

GM Crops Project Team
Strategy Unit
4th Floor, Admiralty Arch
The Mall
London SW1A 2WH

to arrive by **Friday, 17th October 2003**.

[193] The Ministerial Sub-Committee on Biotechnology (SCI(BIO)) is chaired by the President of the Council and Leader of the House of Commons, and has as its remit, "To consider issues relating to biotechnology - including those arising from genetic modification, biotechnology in healthcare and genetic issues - and their economic impact; and to report as necessary to the Committee on Science Policy." Full information is available at http://www.cabinet-office.gov.uk/cabsec/2003/cabcom/sci_bio.htm.

Annex A: The role of the Strategy Unit

The Strategy Unit was created by a merger of the Performance and Innovation Unit, the Prime Minister's Forward Strategy Unit and part of the Policy Studies Directorate of the Centre for Management and Policy Studies. The unit performs a range of functions, including long-term strategic reviews of major areas of policy, studies of cross-cutting policy issues, strategic audits and joint work with departments to promote strategic thinking and improve policy-making across Whitehall.

The Unit's Director is Geoff Mulgan and it reports directly to the Prime Minister through the Cabinet Secretary.

Comprehensive information about the work of the Strategy Unit and its projects can be found on the Strategy Unit's web-site at www.strategy.gov.uk.

Annex B: Project team, Sponsor Minister and Expert Groups

This report was prepared by a multi-disciplinary team guided by a Sponsor Minister and non-Government Expert Advisory Groups.

The Strategy Unit Project Team

The Strategy Unit team included team members with experience in economics, science, policy-making and issues affecting developing countries. The team was made up of a mix of some civil servants and some drawn from outside Whitehall. None of the team had previously worked for organisations with a financial interest in GM crops or GM foods, neither had they been associated with campaigning activities on GM issues.

The project team comprised:

Vicki Bakhshi	Economist, Strategy Unit
Ian Coates (team leader)	Economist, Strategy Unit
Dominic Cookson	Strategy Unit
Nicholas Garland	Strategy Unit
Dr Adam Heathfield	Scientist, Strategy Unit
Matthias Kempf	Economist, Strategy Unit
Halima Khan	Strategy Unit
Lizzy Lomax	Economist, Strategy Unit
Jamie Rentoul	Deputy Director, Strategy Unit
Alison Sharp	Strategy Unit

Additional assistance was provided by Kevin Mochrie from the Communications Team in the Strategy Unit. Research assistance was provided by Clare Blomeley (on work placement from the Government Chief Whips Office) and by Ester Barnabas on work experience.

The Sponsor Minister

The work of all Strategy Unit teams is overseen by a Sponsor Minister, in this case Rt Hon Mrs Margaret Beckett MP, Secretary of State for the Environment, Food and Rural Affairs.

The Expert Advisory Groups

The project team appointed three Expert Advisory Groups to assist with different aspects of the analysis. Individuals were selected to give a range and balance of expertise and backgrounds. Each met on three occasions to consider the scoping note, scenario development/ background working papers and draft report respectively. The Expert Advisory Groups played a crucial part in the project, but were advisory and this report does not necessarily reflect their views.

Expert Advisory Group Members

Environment Expert Group

Professor Jim Dunwell	University of Reading
Dr Timo Goeschl	Department of Land Economy, University of Cambridge
Dr Brian Johnson	English Nature
Dr Guy Poppy	Division of Biodiversity and Ecology University of Southampton
Professor Jules Pretty	Centre for Environment and Society University of Essex
Professor Clive Spash	University of Aberdeen and Macaulay Institute
Dr Jeremy Sweet	National Institute of Agricultural Botany (NIAB)

Product Chains Expert Group

Richard Ali	British Retail Consortium
Gundula Azeez	The Soil Association
Dr Philip Cain	University of Newcastle upon Tyne
Jill Johnstone	National Consumer Council
Professor Terry Marsden	University of Cardiff
Archie Montgomery	National Farmers Union
Dr Geraldine Schofield	Unilever

Industry and Science Expert Group

Dr Paul Burrows	The Biotechnology and Biological Sciences Research Council
Dr Glenn Crocker	Ernst and Young
Dr Bruce Pearce	Elm Farm Research Centre

Dr Paul Rylott	Bayer Crop Science
Professor Alison Smith	John Innes Centre
Professor Joyce Tait	ESRC Centre for Social and Economic Research on Innovation in Genomics (INNOGEN)
Dr Roger Turner	British Society of Plant Breeders

Annex C: Organisations consulted and submissions received

Organisations consulted

The team was also assisted by being able to draw on the experience and advice of a number of experts and stakeholders who attended workshops associated with the project or bilateral discussions with the team:

Action Aid

Adams, Professor John, Department of Geography, University College, London (UCL)

Advisory Committee on Pesticides (ACP)

Advisory Committee on Releases in the Environment (ACRE)

AfricaBio, South Africa*

Agribusiness Advisory Group (linked to DTI)

Agricultural Biotechnology Commission (ABC)

Agriculture and Environment Biotechnology Commission (AEBC)

Agriculture and Rural Development Committee, National Assembly for Wales

American Soybean Association

ANBio, Brazil*

ANBio Whitehouse Consultancy

Association of Applied Biologists

Barnes, Dr Simon, Imperial College

Bayer Cropscience

BioIndustries Association Scotland

Biotechnology and Biological Sciences Research Council (BBSRC)

British Crop Protection Council

British Overseas Agencies Groups (BOAG)

British Retail Consortium

British Society of Plant Breeders (BSPB)

British Sugar *

Broom's Barn

CAB International

Cambridge University Research Centre

Catholic Agency for Overseas Development (CAFOD) (as part of BOAG representation)

Center for International Development, John F. Kennedy School of Government, Harvard University, USA*

Central Office of Information (COI)*

Central Science Laboratory

Centre for Ecology and Hydrology
Centre for Environment and Society, University of Essex
Centre for Social and Economic Research on the Global Environment (CSERGE), University College London
CETOIM, France
Chinese Academy of Agricultural Sciences*
Christian Aid (as part of BOAG representation)
Consumer's Association
Council for Nature Conservation and the Countryside
Cropgen
Department of Agriculture and Rural Development, Northern Ireland
Department for Environment, Food and Rural Affairs (DEFRA)
Department for International Development (DFID)
Department of Environment Northern Ireland (DOENI)
Department of Trade and Industry (DTI)
Division of Biodiversity and Ecology, University of Southampton
Economic and Domestic Affairs Secretariat, Cabinet Office
Elm Farm Research Centre
English Nature
Environment Agency
Environment Business and Development Group (as part of BOAG representation)
ERGO Communications
Ernst and Young
European Centre for Development Policy Management*
European Commission Directorate General, Development
European Commission Directorate General, Environment
European Commission Directorate General, Health (SANCO)
European Commission Directorate General, Trade
FARM
Federal University of Parana, Brazil*
Fiddaman, Bob
Five Year Freeze
Food and Drink Federation
Food Standards Agency
Foreign and Commonwealth Office
Forum for Biotechnology and Food Security, India*
Friends of the Earth
Frontline Consultants
The Gatsby Charitable Foundation
Gene Campaign, India*
Genewatch UK

“GM Nation?” Public Debate Steering Board
Green Alliance
Greenpeace
Health and Safety Executive
HM Treasury
Horticulture Research International
IACR Rothamsted Research
The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kenya*
Innogen
Institute of Development Studies, University of Sussex
John Innes Centre
Kings College, London
Lancaster University
Lexington Communications
Maharashtra Hybrid Seeds Company, India*
Medical Research Council
Michigan State University, USA*
Monsanto
National Assembly for Wales
National Consumer Council
National Farmers Union (NFU)
National Institute of Agricultural Botany (NAIB)
Natural Environment Research Council
Nawaz, Mahmud (Consultant)
Neville Craddock Associates
New College, Oxford
New Zealand Ministry of Research, Science and Technology
New Zealand Treasury
No 10 Policy Directorate
Northern Foods
Northern Ireland Environment Link
Northern Ireland Grain Trade Association
Northern Ireland Plant Breeders Association
Nuffield Council on Bioethics*
Office of Science and Technology (OST)
Office of the Gene Technology Regulator, Australia
Open University
Organisation for Economic Co-operation and Development (OECD)
Overseas Development Institute
Parliamentary Office of Science and Technology (POST)
PG Economics

Queen’s University Environmental Science and Technology Research (QUESTOR) Centre, Belfast

Rockefeller Foundation

Royal Institute of International Affairs

Royal Society

RSPB

Safeway

Sainsbury’s

Science and Technology Policy Research (SPRU), University of Sussex

Science and Technology Policy Research Institute, Ghana*

Science Review Panel

Scottish Agricultural College

Scottish Beekeepers Association

Scottish Crop Research Institute

Scottish Executive

Scottish Organic Producers Association.

Scottish Universities Policy Research and Advice network

Sekona Partnerships

Soil Association

Supply Chain Initiative on Modified Agricultural Crops (SCIMAC)

Sustainable Development Commission

Syngenta

Tesco Centre for Organic Agriculture

Ulster Farmers Union

Unilever

United Kingdom Agricultural Supply Trade Association (UKASTA) (inc UKASTA Scotland)

United Kingdom Environmental Law Association (UKELA)

United Kingdom Patent Office

United Kingdom Permanent Representation to the European Union

United Nations Industrial Development Organisation*

University College London

University of Aberdeen and Macaulay Institute

University of Cambridge

University of Cape Town, South Africa*

University of Cardiff

University of Newcastle upon Tyne

University of Reading

US Embassy, London

Washington University, St Louis, USA*

Wynne, Professor Brian

Zambian delegation of scientists and Government officials

Entries marked with a * are those for which contact was via telephone and/or e-mail only.

Submissions received

Correspondence with stakeholders and experts also provided important input to the project. Submissions were invited via the Strategy Unit website in response to publication of the project's Scoping note, overall methodology paper and a series of working papers. The Scoping note, all papers and responses to them are available at http://www.strategy.gov.uk/2002/gm/sub.shtml.

Annex D: The GM Dialogue: links with the Public Debate and the Science Review

The Strategy Unit study is part of a three strand national dialogue on genetic modification (GM). The box below has been taken from the GM Public Debate Steering Board Statement of Relationships and outlines the three strands of the national dialogue. Further details can be found at www.gmnation.org.uk.

Please note that the text in the box is quoted verbatim from the “Statement of Relationships”, as published earlier this year. Some of the references in the text - particularly to dates of activities - are therefore out of date.

INTERACTION OF THE GM PUBLIC DEBATE, THE GM SCIENCE REVIEW, AND THE STRATEGY UNIT STUDY ON GM CROPS

Government announced last year that there should be a national dialogue on genetic modification (GM). The dialogue has three main strands of activity: an independently run public debate, a review of the science around GM, and a study into overall costs and benefits. The strands are different but closely related. This note summarises who is doing what, when, and how the activities interact.

‘GM Nation? The Public Debate’ is a programme of public deliberation with the issues for debate framed by the public. The debate is being conducted at arm’s length from Government by an independent steering board. The main period of activities will be in June and the first half of July. The Public Debate Steering Board will report to Government in September 2003 about what the debate has indicated about public views, particularly at grass roots level, to inform Government decision-making.

The **Science Review** is being led by Professor Sir David King (Government Chief Scientific Adviser) working with Professor Howard Dalton (DEFRA Chief Scientific Adviser). An expert Science Review Panel, chaired by Professor King, is reviewing and summarising the state of scientific knowledge, consensus and areas of uncertainty on GM science issues and examining where any further work is needed. The science review will produce a first report in summer 2003 and plan then to revisit the report in the autumn, in order to take into account the results of the public debate and any new scientific information.

The study into overall costs and benefits is an analysis of the nature and distribution of costs and benefits that could arise under different scenarios for the possible commercialisation (or not) of GM crops in the UK. The Prime Minister’s Strategy Unit (SU) is carrying out this study. The SU expect to publish their report in June 2003.

The Public Debate Steering Board, Science Review Panel and Strategy Unit have undertaken to:

- address the public's framings of the issues;
- draw on each other's key outputs as appropriate;
- operate with transparent and open processes, including publishing key outputs as they go along;
- inform each other about their activities.

The SU project team provides regular reports to the Public Debate Steering Board, and the board in turn has been providing views on the SU team's work. The SU has also invited the Public Debate Steering Board's comments on drafts of key papers. The SU is also drawing on the emerging work of the science review on the scientific evidence on potential impacts of GM as part of its assessment of overall costs and benefits. Two members of the Science Review Panel are on the SU Expert Advisory Group and others have contributed to the SU's work on an ad hoc basis.

The Science Review Panel and the Public Debate Steering Board are keeping each other updated on their respective work at steering board and science panel meetings. Professor Phil Dale, one of the Public Debate Steering Board members, is also a member of the Science Review Panel. The Food Standards Agency (FSA) is providing advice to the Science Review Panel on the issues the Panel is considering.

Those responsible for each strand meet as required in addition to interactions between the strands at Public Debate Steering Board and Science Review Panel meetings. The secretariats and project teams for each strand liaise regularly to organise implementation of any actions agreed. Communications advisers to each strand also exchange information about planned activities.

The FSA has been separately assessing consumer views on the acceptability of GM foods and consumer choice. Activities have included a schools debate and a citizen's jury broadcast live on the internet. Following review and evaluation of the results by the FSA Board at its public meeting on 8 May, the FSA will report to Government on what it has found. The FSA has also undertaken to inform the Public Debate Steering Board of its findings and to publish them.

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