Nanotechnologies: Influence and Inform the UK Strategy

Summary of Evidence

January 2010

Contents

1. Introduction

In June 2009, the UK Government announced its intention to develop a new strategy for nanotechnologies, which would be informed by a stakeholder dialogue exercise. The website, *Nanotechnologies: Influence and Inform the UK Strategy*, was launched in July 2009. It invited stakeholders from academia, industry, Government and other interested organisations to respond to a series of questions relating to nanotechnologies on five cross-cutting themes and fifteen industry sectors, which are listed below with the number of respondents for each section given in brackets;

Cross Cutting Themes

- Anticipating opportunities and concerns (13)
- Managing risks and uncertainties (14)
- Innovation and business climate (15)
- Public and stakeholder dialogue (10)
- Measurement and standards (11)

Sectors

- Agriculture (1)
- Chemicals/formulated products (9)
- Cosmetics (3)
- Energy (3)
- Environmental remediation (2)
- Food (6)
- Printing and packaging (3)
- Sensing and instrumentation (4)
- Aerospace and defence (1)
- Automotive (1)
- Construction (1)
- Electronic (3)
- Healthcare (4)
- Materials (3)
- Textiles (2)

Evidence gathering was closed on 31st October 2009. There were 41 respondents in total who answered sets of questions in the above sections. Others posted public comments on the website. Contributors from many industry sectors, universities and consumer organisations submitted their thoughts on the challenges and opportunities which nanotechnologies present to the UK economy and society. The exercise was promoted amongst the stakeholder community by Government Departments involved in the development of the UK Nanotechnologies Strategy. Efforts were made to ensure that key contacts and organisations were represented. The greatest level of response was received to the questions on cross-cutting themes; in excess of 10 contributions for each. However, many industry sectors did not receive as many responses.

In addition to the input received through this exercise, a project conducted by the Nanotechnology and Materials Knowledge Transfer Networks (KTNs) and Materials UK invited a wide range of key industry figures to participate in a mini-Innovation and Growth Team to feed into the Government exercise. This involved the industry representatives participating in a survey and a series of focus groups. The resulting report included recommendations for Government to consider when developing the UK Nanotechnologies Strategy. The evidence gathering exercises of the two projects

ran concurrently, and we understand that many industry stakeholders chose to contribute their opinion to development of the Strategy through the KTN's mini-Innovation and Growth Team. Taken together, *Nanotechnologies: Inform and Influence the UK Strategy*, which we on report here and the KTN's Industry Led Report, *Nanotechnology: a UK Industry View,* (which was published on the 14th January 2010[1]) present opinions from a comprehensive cross-section of organisations and individuals with an interest in nanotechnologies and both will be used to inform the development of the Strategy.

The evidence collected was analysed qualitatively and summarised; this document contains the summaries produced. In addition, the Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses for each sector and cross-cutting theme have been updated on the basis of comments received and are included here. Responses to the sector sections have been analysed and summarised together to give a joined-up view from all the areas of industry represented. However, where specific views applied to individual or groups of sectors, this has been reflected. The purpose of the summaries presented here (both the cross-cutting theme and sector summaries) is to accurately reflect the range of responses to the questions we posed. It is not intended that they should be taken to represent the view of every stakeholder, but those that responded to our evidence gathering exercise. It should also be noted that some responses represented many individuals, for example, an industry association representing many companies.

In order to verify the consistency of the views expressed during this exercise, we have undertaken to sense check them as much as possible, for example by cross referencing findings with independent reports and other dialogue exercises. In doing so, we have established that the responses detailed here are broadly in line with comparable findings.

It has been possible to draw out some significant themes which have been brought up by respondents in their views on many of the sectors and cross cutting themes. These are;

- nanotechnologies are believed to hold potential for a positive impact on a wide range of manufacturing and consumer industries including those which are pivotal to the economy, such as the automotive industry and those which underpin wider societal challenges, such as the alternative energy industry;
- concern over the level of Government funding of research into the environmental, health and safety (EHS) risks of manufactured nanomaterials and strategic coordination of research efforts;
- requirement for a consolidated source of information for;
    - the public – detailing Government activity on nanotechnologies;
    - industry – detailing regulatory/reporting/risk assessment requirements.

[1] *Nanotechnology: a UK Industry View* can be downloaded from www.nanoktn.com

2. Cross-cutting Themes

2.1. Anticipating Opportunities and Concerns

SWOT Analysis

Strengths
The UK has developed a community of researchers in academia and business with inter-disciplinary skills and avenues for sharing equipment. UK Government Departments and agencies work closely with industry and academia to agree and collaborate on delivering the priorities for EHS research. The UK also plays a leading role in international fora and influences EU and Organisation for Economic Cooperation and Development (OECD) research priorities. The world-leading Environmental Nanoscience Initiative (ENI) will involve consortia from both the USA and UK.

Weaknesses
The programme of publicly funded research into the EHS implications is not directed or fully-funded and progress towards the UK's objectives has been patchy. Research to produce the evidence needed, for instance to inform risk management approaches, are uncoordinated, resulting in gaps, duplication of effort and non-comparable results. Some of the research areas are not seen as academically challenging, or suitable for responsive mode funding. There are skills shortages in some areas and the ability to perform full life cycle analysis is needed.

Opportunities
There are opportunities for nanotechnologies research to make a substantial contribution to issues of wide concern, for example to mitigate climate change and improve healthcare. The Research Councils' Grand Challenges offer funding for research in these areas and show how public dialogue might be used to steer research priorities. In addition, the UK has an opportunity to pioneer the concept of pursuing innovation and development in parallel with early identification and investigation of risks.

Research opportunities include the development of;

- environmentally safe designs for nanomaterials and designs for nanomaterials that do not pose a public health risk;
- toxicological tests for those kinds of nanomaterials for which tests do not currently exist and, using those tests, developing a predictive toxicology based on functionality.

The UK has the opportunity to play an active role in the coordinated international effort to develop reference nanomaterials and standards to underpin the characterisation of nanomaterials and studies on their toxicological effects.

An improved understanding of potential risks could be achieved through medical researchers sharing information with those addressing health implications.

Threats
Shortages of toxicologists and ecotoxicologists may hinder the UK's ability to research, develop and regulate products containing nanomaterials. The patchy

progress towards the research objectives on the EHS implications mean we may not fully understand the properties of nanomaterials and any risks may not be proportionately or appropriately controlled.

Companies may be reluctant to share information on products containing nanomaterials due to the cost of fully assessing EHS risks, intellectual property and confidentiality issues, and fear of penalty if risks are later identified.

Questions and Summaries of Responses

1. What steps would you expect a responsible company to be taking to identify and address implications (EHS, social or ethical)?

The respondents to this question generally expected a responsible company to observe existing nanotechnologies guidelines or codes, demonstrate good governance on managing and minimising risk, and uphold Corporate Social Responsibility (CSR).

The majority of respondents suggested that a company should look beyond the existing legal obligations and consult published guidelines (e.g. the Responsible Nano Code and Nano Risk Framework), standards (e.g. ISO TC 229 and BSI NTI/1) and up-to-date research on EHS work. Respondents also highlighted the importance of engaging proactively with external networks where such information is disseminated, such as the Nanotechnology KTN, Nanotechnology Industry Association and the Institute of Nanotechnology.

Many respondents agreed that a responsible company should demonstrate good governance, such as having clear procedures regarding safety and conducting traceable audits. It was widely accepted that the company should carry out case-by-case risk assessments over the full life cycle of the product or process in development, showing due diligence and seeking advice where applicable.

CSR was perceived as important by many respondents. This included transparency about the type of nanomaterials produced, safe product handling through the supply chain, clear labelling for consumers and developing an ethical policy. Respondents mentioned the need for public engagement such as identifying consumer demands and managing consumer concerns early on for the specific products or procedures developed.

A number of respondents considered companies responsible for ensuring that their products or processes are safe before their launch, and thought that they should be prepared to conduct appropriate health and safety (H&S) research where adequate knowledge about safety is not yet available.

Quotes

“Take account of existing guidelines published by a number of organisations including Safenano, OECD, NTI/1 (guidance for safe handling of nanomaterials), HSE [Health and Safety Executive]. Consider the life-cycle of materials and devices containing them, if in doubt seek expert advice. Implement corporate social responsibility – be transparent about nanomaterials produced and provide information to consumers and businesses that are supplied. Sign-up to codes of conduct, contribute to good governance, and be pro-active with regulatory engagement.” – **Mark Morrison, Institute of Nanotechnology**

"If a responsible company is unable to assess risks because of a lack of scientific knowledge it should not make the product available to consumers until such a time when the risks have been thoroughly assessed […] Companies must be transparent throughout product development. This will allow them to identify consumer demands, issues and concerns and to respond to them. Companies must be precautionary, transparent and consultative in their approach." – **Rob Reid, Which**?

2. What measures would help responsible companies identify and address implications?

- **adopting a policy of CSR;**
- **following a Code of Conduct;**
- **reporting to the Government (on a voluntary or mandatory basis); or**
- **adopting some other policy?**

Please explain your answer.

It was generally felt that the measures listed above could be helpful, however there was no consensus on which combination would be the most effective. Several respondents commented on the benefits of greater transparency about products, processes, risks and benefits which these measures could bring about.

The majority of respondents agreed that adopting a CSR policy and/or following a Code of Conduct is important for making sure adequate standards are being maintained and a system is in place to deal with any issues. A few respondents also suggested compliance with voluntary industry standards or product accreditation to help increase public confidence.

There was a divide of opinion on whether a Government reporting scheme would be effective for identifying and addressing implications. Some respondents felt that a Code of Conduct alone may not be enough for ensuring companies assess unknown risks or social and ethical issues adequately, and they supported a reporting scheme for these reasons. The perceived benefits of a reporting scheme included greater transparency about the latest nanotechnologies developments and the ability for the Government to ensure compliance and identify areas of greatest concern so that regulatory or research efforts can be prioritised. The perceived disadvantages of a reporting scheme are that the extra bureaucracy would not directly help companies tackle issues, and may be time consuming, especially for Small/Medium-sized enterprises (SMEs). Of those who supported a reporting scheme, several respondents commented that the existing UK Voluntary Reporting Scheme for engineered nanoscale materials does not work satisfactorily due to a lack of support, and a mandatory scheme may be more effective. It was suggested by one respondent that the reporting scheme could be pan-European or global, and should not duplicate data already supplied through Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) and Classification, Labelling and Packaging (CLP) regulations, but that information similar to the REACH pre-registration may be appropriate.

In addition to the above, some respondents expressed a wish for extra Government support to fulfil their obligations to identify and address safety implications of the use of nanomaterials. One respondent suggested clearer guidance on risk assessment, which is currently very difficult due to fundamental uncertainties about the risks involved and a lack of data. There are some disagreements on whether existing codes on handling materials (e.g. Control of Substances Hazardous to Health (COSHH) and waste disposal regulations) are adequate in their present form, or they require amendment to provide specific guidance on nanomaterials.

Quotes

"Not imposing undue risks on your customers or workers is not CSR, but ordinary good business" – **Hilary Sutcliffe, Reponsible Nano Forum**

"Industry self-regulation has an important role to play. Corporate Social Responsibility is an essential part of the chemical industry's business ethos […]. CIA [Chemicals Industry Association] member companies are committed to this through both their own policies, as well as the industry's voluntary initiative called Responsible Care […]. Companies are thereby committed to product stewardship (our responsibility for ensuring safe product handling through the supply chain); nanomaterials like any other chemical substance are part of this." – **Dr Anne-Gaelle Collot, Chemical Industries Association**

3. Do companies have access to sufficient information and support to know what they should be reporting or aware of?

With the exception of one respondent from a large pharmaceutical company, the majority of respondents did not think that companies have sufficient access to information which enables them to assess the potential safety implications of nanomaterials and/or reporting requirements. Respondents generally felt that, although much information already exists, it is often not readily accessible, and it may also be contradictory or difficult to evaluate.

Several respondents expressed the desire for a "one-stop-shop" for H&S information and advice associated with nanomaterials. This was perceived to be helpful especially for small companies and end-users. Suggested approaches for this include the creation of a centralised database, national/European centres of expertise on EHS, as well as promoting or expanding existing initiatives such as SAFENANO.

A respondent commented that, due to the lack of available information, the Government or relevant agencies may need to highlight areas thought to be of particular concern. One respondent suggested that an improved definition for what constitutes a nanomaterial would help companies in meeting regulatory or reporting requirements. In addition, it was suggested that the development of risk ranking tools may help manufacturers and users carry out exposure assessments for nanomaterials.

Quotes

"There is much information regarding the wider issues of nanotechnology (risks, ethical and societal concerns), however it is difficult for SMEs to access all of this and to be sure of the validity and relevance to their particular materials and processes." – **Mark Morrison, Institute of Nanotechnology**

"We would feel the answer to this is no. There is currently no one-stop shop for companies to refer when assessing the potentially hazardous effects of nanoparticles they are producing or using within processing. Companies currently adopt a 'proceed with caution' approach, which can leave them open to significant liability should any disasters ensue. Any Health & Safety information that is held within companies on nanoparticles is infrequently shared openly due to the fear of relinquishing market lead in a particular field as well as due to the significant cost associated with fully characterising nanoparticle families." – **Dr Chris Jones, (Research Councils UK**

(RCUK) Nanoscience Programme (in a joint response on behalf of the Research Councils)

4. Do you think that the Research Councils' approach to anticipatory risk management through their Grand Challenge call is the way forward?

Most respondents agreed that the anticipatory risk management approach is a step forward for responsible innovation in nanotechnologies, and the same principles could also be applied to industrial research. However, many respondents have emphasised the importance of separate studies tackling safety, exposure and risk management.

Respondents commented that anticipatory risk management follows the precautionary principle and prompts a significant proportion of academic researchers in nanotechnologies to consider risk, impact and responsible innovation early on. It was mentioned that the same principles are already being applied in some industrial research.

Several respondents commented that the research effort in the Grand Challenge call is focused on scientific innovation, and there is a lack of proposals tackling safety, exposure and risk management which has resulted in a lack of funding in these areas. A few respondents suggested that the gaps could be filled by direct commission of risk management research, possible as a part of a larger nanotechnologies research framework.

A few positive comments were received on the public consultation that preceded the Research Councils' Grand Challenge calls, which were regarded to have revealed additional insights on societal issues and focused research priorities. A suggestion was made that an expert ethical review may have value as a precursor to public engagement for such purposes.

Quotes

"The Grand Challenge call is a step forward. However, it relies on academics responding with appropriate proposals, which often will aim to tackle the more scientifically interesting parts of the puzzle. Regulators and the NRCG [Nanotechnology Research Coordination Group] should be directly commissioning research to fill in the gaps and to pull together the work sponsored by the Research Councils Grand Challenge." – **Dr Mark Gee, NPL**

"The EPSRC [Engineering and Physical Sciences Research Council]-led project Nanoscience through Engineering to Application has used a series of stakeholder meetings, consultations, town meetings and public dialogue to help focus its research priorities. The application of such an approach to nanomaterials is a positive step as it avoids the danger of focusing research on applications without considering demands, issues and risks and gives experts and the public the opportunity to highlight knowledge gaps and uncertainties" – **Rob Reid, Which?**

5. If potential implications are identified, who should be responsible for any follow up work?

Many respondents commented that the responsibility depends largely on the nature of the implication and the stage of development. While a number of respondents stated that companies or researchers should be responsible, many respondents felt

that the Government regulatory bodies have an important role to play alongside development of national facilities and expertise.

A significant number of respondents commented that the question was too broad, and the responsibility for follow up work depends largely on the nature of the implication, the confidence in the analysis of outcomes, the material or device in question, the usage, the stage of development as well as any existing (e.g. legal) responsibilities.

A number of respondents stated that companies and researchers should be responsible for ensuring that they understand the implications of their products and processes, and take suitable steps to address them. However, one respondent commented that it would be difficult for small companies to bear the cost of further research when implications are identified.

Many respondents felt that the Government regulatory bodies (e.g. Health Protection Agency (HPA) and Medicines and Healthcare products Regulatory Agency (MHRA)) have an important role to play. One respondent commented that the HSE would have the relevant expertise to judge the scale of issues and advise on level of response and/or appropriate further work, which could be carried out in association with expert laboratories. Alternatively, there was a suggestion for the creation of an independent body which can review data objectively and report to the appropriate regulatory authority.

Other respondents felt that while companies are responsible for specific products and processes, the Government has a clear role in supporting development of more generic solutions, such as research into fundamental issues, maintenance of national facilities and maintaining a sufficient number of qualified scientists so that the UK can maintain a pool of expertise to draw on long-term.

Quotes

“Heath and Safety Executive should have the relevant experience/ expertise to make judgements on scale of issues relative to known ones and so advise on level of response/ further work. If materials are at product stage then responsibility for funding work should at least partly lie there.” – **John Shaw, Tyco Safety Products**

“Companies should be responsible for work on specific products but backed up by appropriate support for research into fundamental issues from Government. Support is needed to develop and maintain both national facilities and a significant number of qualified scientists so that the UK can maintain a pool of expertise to draw on long-term.” – **Professor Mark Gee, NPL**

6. How can we encourage the nanotechnologies community, and particularly researchers and business, to share information about developments and implications?

There was a general perception that companies may be reluctant to share information due to confidentiality and intellectual property issues, and the need for competitive advantage. A number of approaches were suggested to encourage information sharing, including implementing mandatory requirements, developing novel sharing routes that do not compromise intellectual property, or establishing a central body to facilitate collecting and disseminating information.

Respondents noted that researchers currently share information effectively through presentations at scientific meetings, forums and publication in scientific journals. One respondent suggested that the substantial costs involved in fully assessing the H&S implications may be a deterrent for making the results open access, even though such costs could be reduced if organisations commit to sharing information openly at an early stage.

The respondents suggested a number of approaches to encourage the community to share information;

- implementing mandatory requirements. For example, the data sharing policies that already apply to RCUK supported work could be extended to all publicly funded research. Companies could be mandated to share environmental and safety information with regulatory authorities, who can make the judgement about whether the information should be further disseminated;
- developing a route for information sharing that address confidentiality and intellectual property issues adequately, for example following an open innovation model or sharing data in a member's repository;
- establishing a single body as the central focus for collecting and disseminating information, or the creation of public-private centres similar to the Nanoscale Science Research Centres in the USA which can link and disseminate information from different areas of research;
- promoting the clear benefits of sharing information to the nanotechnologies community;
- rewarding organisations who show a responsible and open approach, by considering this as a criteria of funding or using other incentives such as Responsible Nano Awards.

Quotes

"Perhaps the greater problem is that the quality of information is highly variable through poor standardisation of techniques and metrology. This is clearly evident with the contradictory results for many different nanomaterials (e.g. nanosilver). It is difficult to see how improved information sharing will be beneficial until that information can be trusted." – **Professor Mark Gee, NPL**

"It needs to be made clear that it is not acceptable to hide bad news on environmental impact from regulatory authorities […]. If by failing to pass on information companies or individuals contribute to generation of hazards then they must expect to be liable." – **John Shaw, Tyco Safety Products**

2.2. Managing Risks and Uncertainties

Updated SWOT Analysis

Strengths
The UK's open, collaborative approach to understanding and addressing the potential benefits and concerns and active role in international fora mean that we have strong domestic and international research links and are thus well-placed to react promptly to emerging evidence of risks. Existing legislation provides powers to respond promptly to evidence of risk. The existing framework is broadly adequate to deal with risks from nanotechnologies (although there is a need to make some changes and there may also be some regulatory gaps). This evidence- and risk-based approach has avoided a moratorium on nanotechnologies.

Weaknesses
The UK Government has found it difficult to gain a good understanding of developments in industry, in part due to the lack of support for the Voluntary Reporting Scheme, and this has hampered the prioritising of publicly funded research into the EHS implications. Clearer priorities, coordination, funding mechanisms and timescales for delivery are needed for this programme of work.

There is a lack of clear guidance on how existing legislation is applied to nanomaterials, and there is insufficient underpinning research which hampers the evidence based policy development and regulatory enforcement. Legislation may need to be revised to fully address the use of nanomaterials and it can take several years to amend EU legislation, even once the evidence is available to inform changes.

Opportunities
The UK has pioneered public dialogue and engagement activities to inform policy decisions and has an opportunity to build on this to develop new ways of managing the development of new technologies in a socially responsible manner. Nanotechnologies provide a good opportunity to experiment with new approaches that meet the needs of all stakeholders.

The development of specific financial risk analysis tools would provide UK entrepreneurs with an ability to manage risk exposure in concert with CSR.

Threats
Uncertainties of how the regulatory framework applies to nanomaterials, the inability to conduct meaningful risk assessments and the fear of public rejection can lead to a low risk appetite amongst executives, insurers, market advisers and others and can stifle innovation.

A lack of understanding and expertise in the regulatory and enforcement bodies could lead to a failure to prevent harm or enforce breaches of legislation. There is currently little expertise in some UK Government agencies on nanotechnologies or on the management of nanomaterials intentionally or unintentionally entering the environment.

Questions and Summaries of Responses

1. Is the right amount and level of information available to enable compliance with the legislation and enforcement action in the event of non-compliance? If not, what more is needed and by whom?

Many respondents commented that regulation and policy development requires more underpinning research. Respondents perceived a lack of clear guidance available on how existing legislation is applied to nanomaterials, and asked for better communication across the supply chain and clearer enforcement.

In particular, many respondents commented that more underpinning research is required in areas such as the interaction of nanomaterials with the body and environment, the classification of nanomaterials into hazard groups, and an understanding of the effect of size, shape, morphology, charge, pH and temperature in order to inform policy and regulation. Some respondents feel that there are gaps in the current data and that a considerable amount of existing data have not been fully analysed.

Several respondents also commented that there is a lack of clear guidance available on how existing legislation should be applied to nanomaterials, and that relevant information is not clearly communicated across the supply chain, to companies and enforcement officers. One respondent felt that SMEs are apprehensive about legislative actions being taken against them in the future in the event of published work showing potential risks. Another respondent expressed concern that the relevant legislation has not been effectively enforced for some products on the market where safety concerns have been raised. Several respondents commented that SMEs in particular need extra support in accessing relevant information, and it was suggested that accreditation schemes such as AssuredNano, or information sources such as SAFENANO and *Nano and Me* may be possible ways to address these issues.

A few respondents mentioned the need for internationally agreed standard definitions and testing protocols for nanomaterials when determining standards for regulatory control. It was suggested that the lack of standard definitions and testing protocols currently hampers the development of legislation and it is difficult to determine whether a product falls into the nanoscale category. A respondent commented that this is being slowly addressed by the work on national and international standard committees such as ISO TC229 and BSI NTI/1, but more effort is needed to help enforce regulation.

Quotes

“Where material properties are not fully known then clearly there is a danger of non compliance. Users/producers need to be aware that compliance based on similar compositions not in nanoform may not in itself be adequate. There needs to be a presumption that changes in properties and toxicity need to be considered. However this should not be too prescriptive preventing use where reasonable judgement of the effects of going nanoform may be made.” – **John Shaw, Tyco Safety Products**

“Currently there seems to be little specific information from UK legislative or regulatory bodies available regarding the management of risks for nanotechnologies. This may be a result of the limited availability of comprehensive, meaningful and robust data to inform legislators and regulators. Two exceptions are the recently published HSE guidance note on CNTs [Carbon Nanotubes], and the Environment

Agency note on disposal of CNTs, which must be kept under review and revised in the light of new evidence which could alter the initial standpoint they have adopted." – **Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin and Sheona Peters, SAFENANO / Institute of Occupational Medicine**

2. Are there specific pieces of legislation that should be updated as a priority? Please explain your answer.

Respondents highlighted several areas where REACH could be adapted to ensure it is appropriate for nanomaterials, including the registration of nanomaterials alongside their bulk equivalent, lowering the threshold quantity for registration and including an exposure assessment. Other pieces of legislations mentioned were the EU Novel Foods Regulation, the Medical Devices Directive and the General Product Safety Directive.

Many respondents commented that REACH is an appropriate mechanism for regulation but highlighted the need for adaptation to ensure it is appropriate for nanomaterials. Suggested areas include;

- lowering the threshold quantity for reporting of nanomaterials, regardless of whether the material is intended to be released;
- amendment of registration to include exposure assessment in the safety assessment;
- clarification on whether and when nanomaterials need to be registered in addition to their bulk equivalent, since these are currently not considered new substances under REACH despite showing novel properties;
- an agreement on definitions of nanomaterials and effective guidelines to support the above;

Since these changes are unlikely to be completed before 2012 it was suggested that the Government could consider the implementation of interim measures.

Respondents also mentioned other pieces of legislation that could be updated. For medicine, it was suggested that the review of the Medical Devices Directive provides an opportunity to address concerns and provide guidance for the use of nanomaterials in medical technologies. It was also felt that guidance is needed on how the General Product Safety Directive applies to nanomaterials and how the EU Cosmetics Directive covering nanomaterials would be enforced in practice.

Quotes

"REACH is likely to be the primary route through which information on the sources, fate, behaviour, and effects of most nanomaterials will be generated in Europe… However, current uncertainty about exactly how nanomaterials will be regulated under REACH is hampering progress… Resolution of this issue and confirmation of when and how nanomaterials need to be registered is likely to unblock investment and allow test commissioning to proceed." – **Mark Crane, WCA Environment Limited**

"Greater clarity is also required on how requirements for a risk assessment to be conducted under different pieces of consumer protection legislation should be applied in practice given fundamental uncertainties." – **Rob Reid, Which?**

3. What measures (voluntary or mandatory) should be put in place to ensure early risk identification and management? How easily could such measures be implemented? What support would be needed?

The respondents identified a number of measures which could help ensure early risk identification and management, including following voluntary initiatives and best practice guides, adopting a reporting scheme or product register, and a greater effort to collect and share data on risk issues.

Respondents suggested that companies and researchers involved in nanotechnologies development should comply with existing chemical legislation, voluntary initiatives and best practice guides as well as adopt a code of practice to demonstrate adequate consideration to risks. It was also suggested that they should conduct a satisfactory level of testing on each new material or product to provide some confidence on product safety. Respondents suggested that the Government can help companies and researchers by nurturing an environment of support rather than penalty on early risk identification, and encourage companies to work with academia to develop new screening and testing methods for nanomaterials.

A few respondents agreed that a reporting scheme or product register would provide the Government with a better understanding of the status of nanotechnologies development for monitoring business trends and highlighting potential problem areas. To minimise the burden, it was suggested that such a scheme should request the minimum information sufficient to conduct effective exposure analysis. One respondent commented that the Government should be proactive in following up potential safety issues and be prepared to take prompt action rather than relying solely on international cooperative efforts. Finally, a few respondents mentioned the need for a greater effort to collect and share data on risk issues, and to resolve differences in data sets between laboratories.

Quotes

"A balance must be struck to allow innovation and market development and an agreed level of risk for unanticipated consequences must be implicit in enabling economic development of the UK. At no point is a product completely risk free. The key problem at the moment is the lack of validated and agreed test methods for toxicology and ecological impact." – **Dr Neil Harrison, NPL**

"The development of a central framework to collect and store information relating to the H&S implication of nanoparticles is necessary to underpin both research and commercialisation endeavours. An interdisciplinary and cross-stakeholder approach is required in a similar vein to the OECD PROSPEcT initiative." – **Dr Chris Jones, RCUK Nanoscience Programme (a joint response on behalf of the Research Councils)**

4. Are there issues or challenges that are not being adequately addressed by the methods for coordinating activities? Please explain your answer.

Respondents widely perceived a need for improved coordination on research activities, especially in relation to safety and risks. Several respondents suggested the establishment of a single high-level body to bring together key Government Departments and stakeholders, coordinate efforts and prioritise actions.

Respondents commented on the current complexity and lack of an effective structure, with responsibilities on different research areas being spread across Government, agencies and research councils, each with their own budget and priorities. It was felt that this makes it difficult for the NRCG to coordinate activity based on an overall strategic view, to initiate actions and to monitor progress. Other respondents felt that the lack of coordination may result in a duplication of effort, or

non-comparable research results that are not of value to risk assessment. To enable better coordination, several respondents suggested the establishment of a single high-level body to bring together key Government Departments and stakeholders, coordinate efforts and prioritise actions, for example in the form of a single cross-Government agency with sufficient budget for a focused and direct research programme.

The respondents also outlined other issues or challenges that are perceived to be not adequately coordinated;

- targeting relevant information to SMEs effectively;
- the classification of nanoparticles into different hazard categories based on their properties to aid risk assessments;
- the balance of research activity between toxicology/ecotoxicology and exposure assessment and life cycle analysis;
- European efforts to validate alternative (non animal) testing methods for toxicology, for example through European Centre for the Validation of Alternative Methods (ECVAM).

Quotes

"The complexity of the challenges to be addressed is not backed up by the necessary scale of funding nor even a single body with sufficient clout to coordinate efforts." – **Dr Chris Jones, RCUK Nanosciecne Programme (in a joint response on behalf of the Research Councils)**

"European efforts to validate alternative testing methods seem to be inadequately funded. ECVAM needs to take a new approach to speed up the development of new tests." – **Dr John Malcolm Wilk, Kirkstall Ltd**

5. Are the views of the full range of stakeholders given adequate consideration through the existing structures? Please explain your answer

Respondents were evenly split on whether the full range of stakeholders' opinions are currently given adequate consideration. Some respondents suggested issues of 'survey fatigue' and the need for better engagement with the public, non-Governmental organisations (NGOs) and regulatory enforcement bodies. Of the respondents that answered positively, there was a spectrum of comments ranging from one respondent rating the Department for the Environment, Farming and Rural Affairs (Defra) and the Department for Business, Innovation and Skills (BIS) exemplary in their initiatives compared to other countries, to another respondent stating that current efforts are "enough".

A range of views were given by the respondents that do not feel the stakeholders' views are adequately considered. These include;

- the issue of 'survey fatigue', where stakeholders regularly provide feedback to similar surveys and consultations, resulting in the feeling that their views are not being acted upon or effectively shared between different Departments, agencies and countries;
- the need for better public engagement. One respondent commented that the public engagement initiatives have been limited in scope and it is not clear whether they have influenced Government policy. It is suggested that more active media involvement is needed to access the real public voice;
- the engagement of non-industry stakeholders, including NGOs, who may not be willing to express their concerns in the Nanotechnology Stakeholder Forum (NSF);

- the need for active involvement from enforcement bodies in policy discussions, such as the Trading Standards or the Local Authorities Co-ordinators of Regulatory Services (LACORS), since the enforcement of legislation relating to nanotechnologies is likely to be technically complex and potentially expensive.

Quotes

"Bodies, or individuals with an agenda in this area e.g NGO's and industry have certainly had plenty of opportunity and many have taken advantage of this. We are not convinced that the voice of the general public has really taken advantage of this opportunity, nor been entirely aware of this issue […]. Those who seek an active participation in a forum such as this do not necessarily represent the view of the man in the street." – **Christopher Seaman, GlaxoSmithKline**

"I don't think increased involvement of unknowledgeable stakeholders is likely to be helpful. Knowledgeable stakeholders rather need to know that the consequences of not complying with the spirit as well as letter of existing regulations is not going to be acceptable." – **John Shaw, Tyco Safety Products**

2.3. Innovation and Business Climate

Updated SWOT Analysis

Strengths
The UK has a good research base, has invested strongly and now has many of the elements for successful innovation such as a strong academic base. Technology Strategy Board (TSB) programmes complement this and target funding to support the pull-through ideas from academia to industry.

Weaknesses
The UK needs to be more focused on exploiting research and innovation developed in this country. SMEs are often unaware of the support that the TSB's joint partnership programmes can provide to them. Other companies that might benefit from using nanomaterials do not have easy access to information about nanotechnologies.

Opportunities
There is an opportunity for more cross-sector technology transfer which could be facilitated by the KTNs. The UK could pioneer responsible innovation in globally important sectors including alternative energy sources, energy efficiency and environmental remediation.

UK industry has the opportunity to influence and inform the direction of UK activities on nanotechnologies, to work with Government to develop measures (voluntary or mandatory) to identify and manage risks in a way which maintains the pace of innovation.

The development of specific financial risk analysis tools would provide UK entrepreneurs with an ability to manage risk exposure in concert with CSR. The UK could become the centre of excellence for business and investment advice on nanotechnologies.

Threats
There is a serious shortage of suitably qualified graduate technicians to support research and manufacturing. Where nano-related skills and awareness are available, they tend to be concentrated in those companies that develop and manufacture nanomaterials but not in the businesses that buy and apply the nanomaterials to products. Manufacturing in the UK may not be able to pull-through developments because the relevant businesses may not exist. The UK will need to be more assertive about exploiting its research and innovation, or they will lose the competitive edge against the international market and the UK manufacturing base will decline further.

Questions and Summaries of Responses

1. Do you consider that the UK's research efforts are correctly targeted and prioritised? If not, please suggest how it might be improved.

Most respondents felt that greater direction was needed in the UK's research efforts, either to assist in delivery of product pull-through or to achieve research priorities set following independent reports such as EMERGNANO on underpinning subjects such as H&S and metrology.

Many of the respondents felt that the UK has lost focus in pushing through key priorities. One stated that there is a reliance on large companies or universities to progress nanoscale innovation and thought that this has led to UK research being inconsistent between many areas of nanotechnologies. One respondent felt that interdisciplinary opportunities are being missed because targeted, large scale funding is currently very prescriptive in its application areas. However, another contributor thought that the Research Councils Grand Challenges have been an excellent idea but went on to say that outputs from this research must be properly supported to translate into real products and services. One respondent called for continued horizon scanning mapped onto UK strengths and capabilities to ensure that a pro-active rather than reactive approach is employed. Several comments were received on the lack of support for innovation to be developed through to market, while others felt that research was being correctly managed.

There was a call for a much clearer strategy for delivery of the Government's key priorities on nanotechnologies. It was felt by some respondents that the UK's current research effort is too heavily weighted towards scientific innovation and product development at the disadvantage of research into EHS impacts. Two respondents commented that the Government sets priorities for this type of research without detailing a plan for fulfilment of those priorities.

Quotes

"I think UK research in the Nano area is patchy: some esoteric fields have become traditionally embedded but could develop in interesting different ways." – **Prof. Jeremy J. Baumberg, University of Cambridge**

"At this stage in the development of this technology there are many horses that need to be ridden and it is not possible to know which is the most likely to succeed." – **Howard Hopwood, HARMAN Technology Limited.**

2. Do you consider that the knowledge transfer and equipment-sharing initiatives are proving effective? If not, how might they be improved?

There was a mixed response to this question, ranging from no comment from those who were not aware of these initiatives to those who do not rate them very highly and those who were positive about the value they currently provide. Overall, there was a call for these initiatives to be promoted more widely across the industrial community and to ensure public funding provided added value.

One of the respondents, who came from an academic background, felt that the UK has overinvested in new nanotechnologies related equipment which was not well supported by personnel, or well used for novel science or solid development. None of the industry respondents reported using the equipment sharing initiative.

Open access centres were considered by one respondent to be a good idea, if their independence from the agenda of other organisations was assured. Several respondents commented that the micro/nano technology (MNT) centres were positive, but that they needed to expand their profile and user base and prevent regional rivalries from affecting their performance.

Respondents commented that whilst a number of good initiatives had been put into place to make quality information resources and facilities for research and development available to the nanoscience community, there remains insufficient

visibility for such facilities in some cases, and as a result they are often overlooked. Similarly, one comment was received from an academic respondent that it was difficult for the nanotechnologies community to communicate with each other as there were so many forums available that there was not significant coverage offered by any one. They went on to say that they believed the KTNs did not offer value for money. However, another respondent, an industry association, commented that their members engaged with the KTNs and the TSB and supported the provisions they currently made. It was felt that a strategy to make the wider community aware of the opportunities available should be implemented, including adequate provision for effective advertising of opportunities for knowledge and equipment sharing to the nanotechnologies community.

Quotes

"From my perspective knowledge sharing initiatives work well but they do, and should, require active research/involvement from users. I have no experience on the equipment sharing field." – **John Shaw, Tyco Safety Products**

"A strategy to make the wider community aware of the opportunities available should be implemented, including adequate provision for effective advertising of such opportunities to the nano community." – **Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin & Sheona Peters, Safenon/IOM**

3. Government provides a variety of support activities and bodies (TSB, KTNs and Knowledge Transfer Partnerships (KTP) etc). Which of these activities are you already aware of and engaging with? How would you rate these activities for meeting expectations?

Most of the respondents were aware of and engaged with one or more of the activities mentioned above. Opinion on their impact, however, varied greatly. There was thought to be significant overlap between schemes available. There was criticism that the activities were not always aligned with business needs and that there can be a high administrative burden associated with some schemes.

Most respondents were aware of the TSB and many were engaged with projects run by them. Two respondents commented that the role of the TSB with respect to nanotechnologies was not clear, (although these comments were made before the launch of their Nanoscale Technologies Strategy). Several commenters, mainly from academic backgrounds, felt that TSB calls could to be restrictive while there was a suggestion for more jointly funded EPSRC/TSB projects.

KTNs were seen by several contributors to offer useful services, but these were seen to vary between the individual KTNs. Another respondent felt that the KTNs activities did not add value.

One problem cited in this area by several respondents was the amount of paperwork for a full KTP. It was also felt that short KTPs may not provide adequate funding for a post-doctoral position. The number of active KTPs related to nanoscience was reported by one respondent to be very low.

Quotes

"As a large company, we are aware of these schemes. However, our needs and interests are rather specialised, and don't necessarily fit UK or government priorities" – **Kim Travis Syngenta.**

"We have an active participation in the Nanotechnology, Knowledge Transfer Network. On the whole it is effective, but rate of progress is stifled by a plethora of other strategy groups." – **Christopher Seaman, GlaxoSmithKline.**

4. Do you consider that the UK is developing the necessary nano skills? Please explain your answer.

Most respondents suggested that the UK was developing some of the necessary skills for nanotechnologies, especially at the pre-manufacturing level and post-graduate level. There was, however, some indication of a lack of continuous professional development and technician level skill for engineering and integration roles.

The majority of respondents gave the impression that the UK was developing the necessary skills for nanotechnologies successfully. However, this was thought to be mainly at the post-graduate level. Several suggested that there was not sufficient investment in the technical skills required for manufacturing. It was suggested that if this issue was not addressed then the Intellectual Property Rights (IPR) from UK funded research and innovation could be sold overseas, thus jeopardising manufacturing jobs. This was thought by one respondent to be partially because of low level of uptake of science and engineering degrees by UK based students and because overseas students who take them often choose not to remain in the UK after their degree.

It was stated by several respondents that the toxicology area has seen a notable increase in training opportunities available at the PhD level. Separately, it was suggested by one respondent that the National Measurement System was aiding in the development of the necessary nanometrology tools, equipment, procedures and skills.

The recession was considered by one respondent to have adversely affected science recruitment due to companies cutting back on research and development.

Quotes

"The number of UK students applying to science and engineering courses is too low; there must be a greater focus on enthusing children into studying the basis subjects for a nanotechnology career." – **Mark Morrison, Institute of Nanotechnology**

"This field in particular is in need of strengthening if the H&S issues surrounding the use of nanoparticles are to be fully addressed. In seeking to address this, the Integrative Toxicology Training Partnership (ITTP), led by the Medical Research Council (MRC) Toxicology Unit in Leicester, will start to build up capacity in integrative toxicology research through awards of approx. 25 PhD studentships and 1 Career Development Award to Universities in the UK." – **Chris Jones RCUK Nanoscience Programme (a joint response on behalf of the Research Councils)**

5. Do you consider that the UK nanotechnologies businesses are attracting sufficient investment (whether from the UK or elsewhere)? Please explain your answer.

The responses suggested that a small number of UK companies working on nanotechnologies developments were attracting investments, some of it from abroad.

However, the great majority of respondents indicated that UK nanotechnologies businesses were not attracting sufficient investment.

The majority of respondents were of the opinion that UK nanotechnologies businesses were attracting a certain amount of investment but possibly not in line with industry in other countries. There were some suggestions that where there was investment being secured, it may be coming from abroad and may not be consistent.

Two respondents proposed that the recession had limited the available funds for businesses to support technology development across the board. One respondent commented that UK companies may have to sell IPR due to lack of funding to develop and exploit ideas.

Another respondent suggested that there was a need to balance the investment in innovation and research to understand the EHS and social implications of nanotechnologies developments.

A further respondent indicated that it was difficult in the UK to find funding to take potential business ideas through to the demonstrator stage. They commented that the EPSRC follow-on scheme provided too small a sum to be effective.

Quotes

"Possibly […] I do know companies who are receiving external funding albeit from abroad." – **John Saffell, Alphasense Ltd**

"No. Even though I have engagement with >25 companies related to the Nano research and development space, I find that they only fund piecemeal (maybe with the exception of Nokia at Cambridge). Very few seem to funding strong linked centres with >10 researchers, which is needed to really focus on Nano developments." – **Prof. Jeremy J. Baumberg, University of Cambridge**

"No. Compared to other countries, investment is not as great. Government funding in the area is essential because of the high cost of fundamental research especially directed at more long-term commercial opportunities." – **Michael Adeogun, National Physical Laboratory (NPL)**

6. Is there sufficient information available on other countries' research strengths, priorities and regulatory environments, or is there more which could be provided (for example by the UK Science and Innovation Network)? What are the most important pieces of information which need to be more readily available?

Most of the respondents were of the opinion that there was information available on other countries in terms of research strength, priorities and the regulatory environment. Others were either not aware of information or did not comment. There was some suggestion that it was not always in the most suitable format for business to make use of.

Most of the respondents were from academic, technology support organisations, trade associations or larger research companies and indicated that there was information available from many sources on nanotechnologies, including on other countries' management of nanotechnologies. It was felt, however, that it was not always easy to filter the information and find what was required.

There were thought to be some gaps in available information; some respondents would like to see the following;

- a coherent and realistic independent single source of analysis on countries' SWOTs;
- a comparative benchmarking exercise with other economies;
- a consolidated European view with guidance on what is being done across the union and elsewhere;
- information on funding calls in other countries;
- technology roadmaps would be extremely valuable across the value chain;
- market assessments.

Quotes

"I am not aware of information being available." – **Howard Hopwood, HARMAN Technology Ltd**

*"*There is already a lot of information available from various sources but what would help is the availability of a independent single source analysing countries' strengths and weaknesses and where the UK could become more competitive, innovative and take a lead in various market sectors. Certainly a coherent (and realistic) market assessment and technology roadmaps would be extremely valuable across the value chain." – **Michael Adeogun, NPL**

7. Are there any other issues that might prevent UK businesses from deriving maximum commercial advantage from nanotechnologies?

The following points were raised as issues which hinder UK businesses; (1) regulation or the threat of regulation preventing potential investment in scaling up products from research; (2) the ability to access finance; and (3) the negative perception of public opinion on nanotechnologies products.

The responses on this question were similar for industry and academia alike, with the lack of clear regulation and standardisation, availability of finance and negative public opinion thought to make it difficult for business to maximise commercial advantage from nanotechnologies.

Respondents felt that the issues around regulation were whether any new regulation would be robust enough to allay concerns of the public while allowing industry/academia to develop and safely exploit nanotechnologies without being overregulated. There was concern that media reporting concentrates on the negative perceptions over consumer safety and environmental concerns without balancing with the positives of advances in nanotechnologies, especially in areas like healthcare.

It was recognised that although there was a lot of information available, there was no central source which could guide academia and industry to accurate and comprehensive information. A central point was also mentioned as a way to bring academia and business closer together, thereby increasing the likelihood of commercial exploitation.

Funding, again, was raised as an issue by several respondents, because of the inability of companies to access finance due to the current economic climate. This was not thought to be unique to nanotechnologies, but is considered severe in this

area. One respondent commented that companies too large to be considered an SME found it particularly difficult to access support.

Quotes

"The regulatory environment is a key issue, both for universities and companies. Too strict and everything will be overrun by safety people, who do not exist in the same way in other countries. It is mainly in the way the safety culture works within institutions within the UK, rather than the legislation itself that is particularly a UK problem." – **Prof. Jeremy Baumberg - University of Cambridge**

"Public and non-specialist misunderstanding about potential risks to health and the environment from nanotechnologies, driven by inappropriate/ill-advised advertising and media exposure presents a very real risk to the commercialisation of nanotechnologies." – **Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin & Sheona Peters, Safenon/IOM**

"In general, access to funding for follow-on projects is difficult to secure and is not available in sufficiently high quantities to lead to genuine progress." – **Dr Chris Jones, RCUK Nanoscience Programme (in a joint response on behalf of the Research Councils)**

8. Are there currently any constraints impeding the transfer of research from the lab to a marketable product?

Respondents commented that while the UK is globally recognised as leaders in academic research, there are often failures to pull through ideas to full scale commercialisation due to lack of relevant financing, taxation and uncertainty around future regulation.

Almost all respondents highlighted that although the UK was well placed in the area of research and development, there was a big gap between research and the scaling up to full commercial exploitation. The main reasons given for this lack of movement between research and commercialisation were a lack of finance, the UK's manufacturing disadvantages (high energy costs & taxation), regulatory uncertainty around nanotechnologies usage, risk aversion and a perceived lack of co-operation between academia and companies. In particular, lack of funding to support the pull through of products to commercial viability was raised again as a significant issue. There was also concern from an academic respondent that companies would not look beyond their niche areas and that there was a lack of technological competence amongst CEOs, which is a disadvantage for early-stage spin-offs.

Company responses were mixed; one stated that current regulatory frameworks allowed them to continue to develop nanomaterials products, one said that their company hadn't identified how nanotechnologies could improve their product and another highlighted the problem of attracting investment for nanotechnologies.

Quotes

"Statistics consistently point to the UK and Europe being leaders in academic research, but followers to US and Japan in terms of commercialisation, despite there being a number of mechanisms in place." – **Mark Morrison, Institute of Nanotechnology**

"No – We are of the opinion that an adequate regulatory framework exists for our

product types." – **Christopher Seaman, GlaxoSmithKline**

9. Who (e.g. research base, industry, general public) or what (e.g. environment) might:

(a) Benefit from nanotechnologies; and/or

(b) Be adversely affected by them?

Please explain what the effects might be and when they might be felt.

All respondents thought that nanotechnologies will benefit all of the groups mentioned in the question, including many fields of industry, in the long term. Although responses were positive, there were concerns that it must be ensured that nanomaterials were used innovatively but safely in order to prevent the adverse effects outweighing the beneficial ones.

Respondents felt that there are wide ranging and significant potential benefits offered by nanotechnologies and nanomaterials. As a result, it was thought that, for example, better healthcare and consumer products, improved energy generation and storage technologies and enhanced environmental remediation technologies will all impact on the public's quality of life. However, it was stated that unless the EHS and social implications of nanomaterials are satisfactorily determined, the potential exists for such materials to adversely affect health and the environment. There were also concerns that although the academic research sector will exploit the science of nanotechnologies, it might not be effectively transferred into mainstream use due to the adverse effects of "bad news stories" or lack of responsible manufacture and disposal.

Quotes

"The potential positive effects of nanotechnologies on all stakeholders could be wide ranging with advances having the potential to revolutionise the healthcare, energy and electronics sectors through new products and revenue generation." – **Chris Jones, RCUK Nanoscience Programme (in a joint response on behalf of the Research Councils)**

"All could benefit if valuable desired products are produced. Research base will probably benefit whatever the outcome but industry and public may suffer from disappointment with hyped nano advantages distorting investment." **John Shaw – Tyco Safety Products**

10. Will the new products or technologies be developed and exploited in the UK or in other countries?

Responses suggested that some UK developed products will be exploited in this country, but that the majority will be exploited elsewhere, either through licensing to other countries or through manufacturing abroad. There were suggestions that this could result in a loss of value added for the UK.

Almost all respondents felt that exploitation of new technologies or products will be largely in other countries, particularly emerging economies in Asia and in Russia, where there will be greater financial incentives and access to infrastructure. The UK was expected by contributors to undertake a reasonable amount of development, given our academic research base. However, exploitation in this country will be impeded by lack of commercial research and development and links to manufacturing capacity.

Respondents felt that the UK is currently not proactive in encouraging the exploitation of nanotechnologies, and suggested that there are risks associated with this. Some stated that the UK is capable of successfully using its considerable research knowledge, but needs to be creative at a product and system level to feel the benefit. There was concern about the lack of enthusiasm in the UK to exploit research, which has led to it being exploited abroad. It was thought that the UK must address this by learning how to harvest good ideas for creating new business wherever it is generated. There were concerns expressed that this country's research output may be developed overseas and that we will, therefore, only see the benefits from nanotechnologies when products are sold back to the UK.

Quotes

*"*Some UK developed products will be exploited here, but we must accept that the majority will be exploited elsewhere either through corporate ownership from abroad or through manufacture abroad" – **John Saffell, Alphasense Ltd**

"In general, much development and exploitation will occur outside the UK simply because of the greater investment that is available in USA, Japan etc. and the strength of their core industries. Therefore it is vital that the UK focuses on its strong industries such as materials, organic electronics, biotech, including the greater move into nanobiotechnology while scanning ahead to see where future commercial opportunities may also lie." – **Michael Adeogun, NPL**

"A reasonable amount of development may be expected in the UK given the developed academic research base; however the exploitation in the UK will be impeded by lack of commercial R&D and links to manufacture." – **John Shaw, Tyco Safety Products**

11. If you have any other comments or feedback about this, please use the box below:

There were only a few responses to this question - the main points raised were that there should be greater cross-sector application of nanotechnologies and better transfer between research and business exploitation.

Quotes
"The future lies in increased integration of historically discrete technologies. The US appears to have grasped this, but I would assert that in the UK (research at least) people still prefer to focus on niches rather than try to collaborate/integrate their work to neighbouring technologies." – **David Cumming, Glasgow University**

*"*The UK and Syngenta, would benefit from more read-across of common issues between different sectors, e.g. human exposure resulting from use in the pharmaceutical, cosmetic and food sectors." – **Kim Travis, Syngenta**

2.4. Public and Stakeholder Dialogue

Updated SWOT Analysis

Strengths
The UK has been one of the first countries to engage in public dialogue over nanotechnologies and the issues they raise. It has learned much from the public dialogue on nanotechnologies and is using that knowledge both to inform policy decisions and to improve future methods of dialogue. Its open, collaborative approach, for example through the Nanotechnologies Stakeholder Forum, has also helped to avert major campaigns against the use of nanotechnologies in the UK.

Weaknesses
The slow progress on understanding (and managing) potential risks makes informed assessment and discussion of potential risks difficult. As does the lack of information about what the industry is developing and what the benefits and concerns might be. Because public dialogue is very expensive, it is unlikely that individual businesses and decision makers will be able or willing to undertake it on an ongoing basis.

Opportunities
The UK has already demonstrated innovative ways of engaging in dialogue with the public and stakeholders but there is scope for improving and innovating further. In particular, there is scope for industry to generate public confidence (and thus market share) by engaging (perhaps collectively) in genuine dialogue about product development. Food security would be a good area to do this.

Threats
A lack of public confidence could hinder our ability to use nanotechnologies to deal with major societal challenges such as climate change or to market certain products. Uncertainty over the methodologies and approaches could also limit the value of, and confidence in, the outcomes of public engagement.

Questions and Summaries of Responses

1. Are you able to easily access the information you need? If not, what improvements would you like to see?

Many respondents suggested that whilst information is available, this is from a number of disparate sources, causing a degree of confusion. There was a strong desire for a consolidated source of information or portal to the various outlets, with Government suggested as the provider of this central source.

One respondent also highlighted a desire for more information about which existing products have nanomaterials in them, and what the likely developments are in the short and medium term.

Quotes

"There are possibly too many outlets of information and this leads to confusion and fragmentation of the information. The observatoryNANO provides a central focus for information gathering within the EU, and something similar, targeted to UK business would be a great advantage." – **Mark Morrison, Institute of Nanotechnology**

"Information is available at a number of websites (e.g. http://www.safenano.org/), though a single point of coordination and increased public awareness about where to find information would be very welcome. Government and Government agencies potential have an important role to play as a trusted source of information on matters such as health and safety." – **Dr Chris Jones, RCUK Nanoscience Programme (in a joint response on behalf of the Research Councils)**

2. Do you consider that information in the UK (not just by Government) is being shared in a way that meets the needs of all stakeholders, including the public? If not, how could this be improved?

Many respondents felt that information could be shared better and that the public constituted the most disengaged community. The desire for a central source of information, to optimise information sharing and dissemination of information, was reiterated.

Some respondents highlighted the importance of reporting of nanomaterials in products, and research to inform risk assessments as being vital sources of information which could be improved. These should be fed into a central source of information to allow easy access for the public.

Quotes

"The information available is not being shared in a manner which is integrated or optimised. A UK nano portal, similar to that already available from SAFENANO (www.safenano.org) in the EHS area, but encompassing more general issues such as the SAFENANO, Nano&Me and Nanoforum initiatives, UK based research programmes (Framework Programme 7 [FP7] and other), the latest activity from UK Government departments, educational resources, regulatory and legislative guidance, and business tools would provide an ideal way to increase visibility of those resources already available and make improve access by stakeholders and the public to the information they require. This would require in reality little effort to implement; SAFENANO would be prepared to take an active role in development of such an initiative." – **Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin & Sheona Peters, SafeNano/IOM**

3. What do you consider to be the challenges or barriers to sharing information?

Many respondents cited intellectual property protection and commercial sensitivities as the main barriers to industry sharing information, however a significant number of respondents felt that it had become habitual to avoid sharing information, sometimes without good reason.

Several respondents felt that by incentivising and facilitating businesses to share information, using a central focal point and by demonstrating the benefits of communicating with the public, some of the reluctance to share information could be overcome.

Another challenge highlighted was the need to go beyond simple communication of information about nanomaterials. It was thought that communication without taking on board feedback from the public, and demonstrating as such, can undermine trust in new technologies.

Quotes

"I would be interested to get to the bottom of what is really the barrier to companies sharing information and being more transparent about their work. I am unconvinced by the 'competitiveness' thing in many areas, but also think it could just be habit and not really knowing how to do it and when. I would like to see more work done on that and look forward to the long promised DEFRA/Cardiff BRASS [Centre for Business Relationships, Accountability, Sustainability and Society] report. 25 years in communication and latterly corporate responsibility shows me that many of the barriers are habit, insecurity, timidity and the herd mentality. I am sure with a number of carrots and sticks we could start to change that." – **Hilary Sutcliffe, Responsible Nano Forum**

"Whilst fully supporting the principles behind the sharing of information, there are a number of challenges or barriers to overcome for enabling this. We will be the first to admit that the chemical industry is not particularly good at communicating the benefits that chemicals bring to society, yet without the chemical industry we would not have today's high standard of living and health benefits. This together with commercial confidentiality issues can often lead to situations where industry is mistrusted and in some cases targeted specifically by campaigning groups. We are currently working with our European partners on a communication campaign on the risks and benefits of nanomaterials." – **Dr Anne-Gaelle Collot, Chemical Industries Association**

4. Do you consider that the UK is deriving any advantage (commercial or otherwise) from seeking to develop and manage nanotechnologies in an open and collaborative way? Or from seeking to understand and address the aspirations and concerns of the public at an early stage?

Many respondents felt that early dialogue on nanomaterials should help avoid downstream public rejection of new technologies, and this would be of benefit to the UK. This was tempered by the belief that public "backlash" against a new technology is inherently unpredictable.

It was felt that benefit could be maximised by better collaboration between business, Government and the research community to deliver a concerted engagement effort. It was proposed that early engagement activity had a dual role in preparing the ground for new technologies, and also in informing research and policy on nanotechnologies. This latter function was seen as an important aspect of a successful engagement campaign.

Some respondents highlighted international collaboration on nanotechnologies as key to securing benefit to the UK.

Quotes

"The transparent approach being adopted helps to re-assure the public and minimises the risk of a non-science based backlash. But as the GM [Genetically Modified] crop story shows, a backlash could still happen at any time." – **Kim Travis, Syngenta**

"Certainly, the public engagement exercise that informed the nanoscience Grand Challenge in healthcare was a first for the UK; potentially the world, and informed the

investment of around £15M of public funding. The exercise has received many plaudits from diverse sections of the academic community. Engaging the public at an early stage can certainly help to limit the negative issues that might have arise during future technology deployment but also to focus the minds of the researcher on the key issues of acceptability at an early stage. Time will tell whether the UK will derive a competitive advantage from this approach. It is fair to note that to undertake this type of consultation on a wider scale would require a significant increase in staff effort." – **Dr Chris Jones, RCUK Nanoscience Programme (in a joint response on behalf of the Research Councils)**

5. If you have any other comments or feedback about this, please use the box below:

There were limited comments on Question 5. Issues raised included the use and effectiveness Nanotechnologies Stakeholder Forum and the leadership role that the UK plays in public dialogue on science and technology, and nanotechnologies in particular.

2.5. Measurement and Standards

Updated SWOT Analysis

Strengths
The UK Government attaches great importance to the development of measurement expertise and equipment. As well as funding work in the UK National Measurement System, it supports the development of underpinning skills and equipment for academic research. The UK's leading role in international standardisation enables it to maintain a position at the leading edge of technical and commercial developments and to represent and defend UK interests.

Weaknesses
The UK has not invested in a focused programme of work to address the many EHS concerns that have been raised and as a result progress is limited and erratic. The UK spends less than its principal competitors such as the USA and Japan and the capacity and availability of qualified nano-metrologists is limited in key areas. If industry is to be able to measure and characterise nanomaterials, the pull-through of expertise to industry needs improving.

Opportunities
Investment in measurement and standards will provide an environment and international markets where commercialisation of UK developed nanotechnologies products can flourish. The UK has a strong instrumentation sector that is well placed to take up and successfully exploit developments in the detection and monitoring of nanomaterials.

By maintaining our position at the forefront of nanotechnologies standardization, the UK should be well placed to take full advantage of anticipatory standards developments, recognised as being an effective tool for, and enabler of innovation. The UK should also be well-placed to help secure critical opportunities to compete effectively in an increasingly aggressive global market.

Threats
Possible reductions in UK Government support for measurement research could have an impact on the UK's leading role in nanotechnology standardisation.

There is strong competition from the USA, Germany, China and Japan and UK businesses could become uncompetitive if the industry fails to develop the expertise to measure and characterise nanomaterials. Without standardised measurements, we will not be able to implement an efficient and effective regulatory regime.

Questions and Summaries of Responses

1. Do you consider that the UK's work on nano-measurement and metrology is correctly targeted and prioritised? If not, please suggest how it might be improved.

A majority of respondents thought that the UK's work on measurement and metrology was correctly targeted and prioritised. Work related to EHS related measurement research was generally considered to be a priority.

However, a significant minority noted the need for publication of a UK nanometrology

strategy from the National Measurement Office (NMO). On the whole there was strong support for a focus on EHS related measurement research but some respondents thought that the public visibility of the outputs of current projects could be improved. Investment in other areas of nanometrology also generally received support but without a clear set of non-EHS measurement priorities there were some questions asked about direction, responsiveness and speed of delivery.

A few other key points that were raised included;

- the need for research into both;
  - fundamental metrological studies associated with traceability of nanoscale measurements;
  - measurement and characterisation of nanomaterials and nanotechnologies enabled products;
- measurement of nanoparticles in air and water is important;
- difficult to get Research Council funding for underpinning metrology;
- essential to continue support for the UK lead in the development of nanotechnologies standards through ISO TC229 and CEN TC 352;
- the effectiveness of the NRCG is limited due to inadequate resourcing.

Quotes

"In view of current uncertainties regarding health and environmental impacts of exposure to nano-objects, clear priorities must be: the development of metrological tools for the determination of exposure; the identification, ideally in real time, of the chemical nature and physical structure of nano-objects; the development of metrological tools in support of toxicology testing; agreement on physico-chemical characteristics that could impact toxicology and validated measurement methods for their determination; and development of robust and reliable in vitro metrological methods for toxicological investigation." – **Peter Hatto, IonBond Ltd**

"Further and sustained dialogue between the UK's nanometrology expertise and the wider nanotechnology sectors should be encouraged." – **Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin & Sheona Peters, SAFENANO/IOM**

2. Do you consider that the UK's work on developing standards for nano is correctly targeted and prioritised? If not, please suggest how it might be improved.

International and national standards were seen as vital to the future development of nanotechnologies based industries and regulation by virtually all respondents. Many responses expressed concern about potential plans to reduce support for international standards work.

There was a view that as standards were very much a horizontal activity, cutting across the interests of many different stakeholders it was difficult to find financial support from one source. Many of the respondents expressed concern about reduced support for standards work, in particular the UK's leadership of TC229. One respondent suggested that support for ISO TC229 activities should be ring-fenced for a period of 5 years to ensure that the foundation standards for nano were established.

Quotes

"The role of the NPL in agreeing international standards is vital. This must not just be

to regulate the industry but to also encourage the development of the benefits that will flow from the technology." – **Kim Travis, Syngenta**

"Word is that the UK government is seriously considering slashing support for standards work. This is short-sighted and will have a negative impact on UK industry." – **Mark Morrison, Institute of Nanotechnology**

"The UK has been taking a leading role on the development of standards. This is important work, but it is a very slow process and is now lagging behind the need to implement effective regulation." – **Rob Reid, Which?**

3. Do you consider that the knowledge transfer and equipment-sharing initiatives for nano measurements and standards are proving effective? If not, how might they be improved?

Respondents felt that both knowledge transfer and equipment-sharing initiatives could be improved, especially outreach to industry. There was a perception that many nanotechnologies events failed to attract broad industry participation.

In general, respondents expressed the view that both knowledge transfer and equipment-sharing initiatives could be improved, especially links across to industry. There was a perception from some commentators that the events organised by KTNs and others mainly attracted academic participants and related organisations and did not attract broad industry participation. A similar picture emerges for the equipment sharing initiatives where there was seen to be good take up by academics for RCUK supported initiatives but limited visibility of facilities set up by the TSB and RCUK outside of the research community.

Quotes

"KTNs appear to be doing their best to engage with industry and academia but sometimes it is difficult to identify the direction and benefit of knowledge transfer as many of the meetings organised are largely attended by academics and support organisations, with minimal attendance by industry." – **Peter Hatto, IonBond Ltd**

"Whilst good initiatives recently have been put into place to make available to the nanoscience community high quality facilities for measurement and characterisation (such as some of the MNT Centres and the NERC [Natural Environment Research Council] funded FENAC [Facility for Environmental Nanoparticle Analysis and Characterisation] at Birmingham University), there remains insufficient visibility for such facilities, and these are often overlooked as a result. A strategy to make the wider community aware of the opportunities available should be implemented." – **Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin & Sheona Peters, SAFENANO/IOM**

4. Do you consider that the UK is developing the necessary skills for nano-measurements and standards? If not, what needs to be done?

The majority opinion expressed was that not enough was being done to support the development of training in measurement and standards. A suggested solution was to include appropriate modules in all science courses.

A respondent noted that NPL were strongly pushing this but questioned if funding levels were appropriate. Several respondents suggested including appropriate

modules as part of broader science or technical training. One commentator felt that this lack of training was due to the fact that metrology was not sufficiently appealing and that there was a tendency for students to use instruments that provided numbers directly without requiring understanding of the problems or limitations of the measurement technique.

Quotes

"There is some good work in […] and other research institutes that is developing expertise in nanomeasurements and standards. Most of the major professional societies in the sciences such as the Institute of Physics, the Institute of Materials Mining and Minerals and the Royal Society of Chemistry have groups and committees that aim to foster awareness in nanotechnology. This does not seem to be supported by courses in universities or schools. Even the introduction a modest content on nanotechnology in University courses would help to provide a positive culture for nanotechnology innovation." – **Prof Mark Gee, NPL**

"There is insufficient consideration given to this in university courses and so little consideration in the 'real world'. Perhaps short courses, or inclusion of lectures within university courses would underline the importance of standards." – **Dr Mark Morrison, Institute of Nanotechnology**

5. Is the UK deriving commercial advantage from its work on measurement and standards for nanotechnologies? Please explain your answer.

The majority of respondents felt that the UK does derive commercial benefits from nanotechnologies related measurement research and standards. It was felt that measurement and standards were more horizontal activities, enabling product innovation and development.

The general consensus was that the UK does derive commercial benefits from measurement and standards for nanotechnologies, although no real assessment has been completed to quantify benefits for UK nanotechnologies industries. Sectors as diverse as instrumentation, personal care products, medical diagnostics and structural materials were given as examples where measurement and standards had provided commercial advantage. However, it was generally felt that measurement and standards were more enabling and cross cutting, facilitating the development of nanotechnologies applications and products where the commercial benefits accrued.

Quotes

"The implementation of measurement and nanostandardisation is key to providing an environment where nanotechnology commercialisation can flourish. Innovation and quality control cannot take place effectively until robust, reliable tools are in place that give consistent results with high information content. The UK has historically had a large instrumentation sector which is underpinned by the investment made in the UK's National Measurement System and supported by the activities of the TSB." – **Prof Mark Gee, NPL**

"It is not possible to comment on whether or not commercial advantage has been gained from UK measurement work on nanotechnologies, though it is known that the SMEs involved in BSI [British Standards Institute] committee NTI/1 have all gained considerable benefit by their association with the national metrology institute." – **Peter Hatto, IonBond Ltd**

6. What do you consider to be the challenges facing this sector?

EHS issues were felt to represent the immediate technical challenges. The limited financial support along with lack of continuity and rapid changes in staff within Government were thought to be the major non-technical challenges facing the sector.

The immediate technical challenges were thought to be those related to EHS issues. However, substantial challenges were seen in getting suitable levels of financial support for measurement and standards. Although measurement and standards underpin most aspects of everyday life they were thought to be effectively invisible to the majority of people. As this area of science was less glamorous than other areas of nanoscience this meant that budgetary support was difficult to find and maintain even though measurement and standards bring substantial, cross-sectoral economic benefits and are essential for effective regulation. The lack of international agreement in this area was raised by one industry respondent and another commentator also highlighted the lack of stability in terms of changes to key Government Departments (Department of Trade and Industry (DTI), followed by the Department for Innovation, Universities and Skills (DIUS) and Department for Business, Enterprise and Regulatory Reform (BERR), which were merged in 2009 to become BIS) and the rapid changes in personnel responsible for nanotechnologies in Defra and other Government Departments as factors that have hampered the development of nanotechnologies in the UK.

Quotes

"The chemical industry is actively involved in the development of standards for nanomaterials both in the UK, Europe and within the OECD programmes. We recognise that additional data is crucially needed to better understand the health, safety and environment impacts of nanomaterials." – **Dr Anne-Gaelle Collot, Chemical Industries Association**

"Standards are essentially 'invisible' to most people, however we could not live in a world without standards. As a result most do not see their utility. There needs to be strong government support in this area […]" – **Mark Morrison, Institute of Nanotechnology**

"Whilst the situation in DEFRA has not been as structurally challenging as that in DTI/TSB/DIUS/BIS, there has been a serious lack of staff continuity, with something like four or five complete changes of staff over the same period. This has not only had an impact nationally, for example on the Nanotechnology Stakeholders Forum, and to some extent on the NRCG, it has also impacted the UK's engagement with international structures, in particularly the OECD Working Party on Manufactured Nanomaterials." – **Peter Hatto, IonBond Ltd**

3. Sectors

Questions and Summaries of Responses

1. Do you agree with this description of how and why nanotechnologies are currently being used in this sector?

The descriptions provided a good summary of many of the areas where nanotechnologies have applications across the various sectors consulted. However, a significant number of the respondents from these sectors felt that more applications could have been included. Conversely, in the agriculture sector the respondent felt that the description overstated how much nanotechnologies were being used in this sector. Some felt that safety concerns with nanomaterials, such as nanosilver were not well-addressed.

With respect to the **chemicals/formulated products sector,** respondents felt that it could be made clearer that the chemicals industry is key to applying the promise of nanotechnologies to almost all sectors. There is also a need to be clearer about how and why nanotechnologies are being used to improve formulation.

One person responding to the **cosmetics sector** commented that the description on the website implies that there is insufficient knowledge regarding the safety of some nanomaterials used in cosmetics. They noted that in practice, unless a manufacturer has sufficient data to be able to be sure of the safety of a nanomaterial used in its products, it would not be in a position to carry out the product safety assessment before placing a product on the market, as required by law. One respondent noted that in addition to the purposes mentioned on the website, they had identified that there are claims that nanomaterials are used in some toothpastes and shampoos.

Additional ways identified through the evidence gathering that nanotechnologies could have a role in the **energy sector** included nanofluid technologies (to manage heat transfer), surface engineering to improve the efficiency of land transport (and machinery more generally); thermoelectric power generation technologies (to make use of waste heat); and energy saving nanotechnologies including insulation and solid state lighting.

One respondent to the **food sector** commented that although nanotechnologies will offer nutritional benefits such as those outlined in the nutrition section of the website, applications of nanotechnologies in food appear to be limited. Particularly in relation to food additives, one respondent stated that there is currently no food additive produced using nanotechnologies, when taking into account the definitions proposed in European Food Safety Authority's (EFSA) 2009 opinion on nanotechnologies and the definition proposed by the European Parliament further to their first reading of the Commission's proposal.

Another respondent commented that they are not aware of any food products incorporating nanotechnologies or processes on the UK market but in the absence of an international agreement on a definition of nanomaterials, this is a somewhat grey area. In relation to nanofoods being on the UK market, one respondent highlighted the need to differentiate between naturally occurring nanoparticles and those that have been engineered to behave differently to their conventional counterparts. One respondent felt that it is difficult to determine the extent to which manufactured nanomaterials are being used in food and that there is a lack of understanding on the status of developments. One respondent commented that in addition to the two

supplement products mentioned on the website, a range of other products are available via the internet.

Respondents felt that there are more efforts and a wider span of approaches being expended towards drug delivery than is the impression given in the description for the **healthcare sector**.

In the **materials sector,** respondents felt that one of the areas not described in sufficient detail on the website is structural materials, where nanostructuring technologies have impacted on the strength and durability of materials. Another area is functional materials where many of the newer developments in the area make use of nanoscale phenomena that have the potential for major improvements in performance in applications such as electronics, actuators and sensors.

It was felt by one respondent that the description in the **packaging sector** does not cover more immediate applications of nanotechnologies in packaging such as their use of food and drink packaging. It should be noted that the use of nanomaterials in food packaging is covered in the food section of the website.

Although mentioned in the **sensing and instrumentation sector** pages of the website, one respondent felt that hybrid sensors that marry nanostructured metal oxide active sensing layers with a conventional sensor system represents most opportunity in the near to mid-term.

Quotes

"Yes, [I] broadly [agree], although I believe that the opportunities are wider than suggested, both technologically and market / economy wise." **Hilda Coulsey – Yorkshire Forward**

"The description provides a good summary of many of the areas where nanotechnology has the potential to improve energy generation and efficiency. However, an additional area that should be added under fuel efficiencies is the potential for surface engineering, either by the use of low friction coatings or by surface nanopatterning, to increase the fuel efficiency of land transport and engineering machinery in general." **Professor Mark Gee – NPL**

2. Do you agree with this analysis of the UK's strengths, weaknesses, opportunities and threats? Please explain your answer.

In general, there was a high degree of agreement that the SWOT analyses reflected the sectoral status although there were with some additional proposals for improving them in each sector, which have been reflected in the SWOTs given here.

Aerospace and Defence Sector

Strengths

Strong UK aerospace and defence industry, especially in the design and production of aircraft equipment, engines, systems and frames. The UK is a major exporter of defence systems. Good UK research base and materials production expertise geared toward aerospace and defence applications (e.g. QinetiQ, Rolls Royce, BAE Systems).

Weaknesses
Aerospace industry conservatism, stringent testing and qualification procedures and long-product cycles may prohibit introduction of widespread nanotechnologies solutions. Structural use of nanotechnologies requires significant testing and accreditation to enter and gain confidence of the market. End-user awareness and confidence and immature recycling infrastructure may also prevent wider adoption of nanotechnologies in aerospace applications. Therefore, the areas of characterisation tools and measurement standards needs immediate attentions.

Opportunities
Industry need to continue to reduce costs and meet environmental and safety legislation will drive the need for high-performance material technologies, such as nanotechnologies-based paints and coatings, metal matrix and ceramic matrix nanocomposites. Defence applications are good proving ground for advanced material technologies. Good opportunity for UK to take a lead in sustainable aviation developments.

Threats
Overseas head start in some aspects of aerospace/defence-based nanotechnologies, especially in USA (e.g. Boeing and NASA).

Agriculture Sector

Strengths
Nanotechnologies have the potential to help us meet increasing demands for sustainable agriculture and the plentiful supply of food. Growers stand to benefit, as do the industries which supply the products. Consumers are ultimately the downstream beneficiaries.

Weaknesses
Societal concerns over the changing nature of agricultural practices have the potential to elicit the same issues as were raised in the GM debate.

Opportunities
Considerable potential for sustainable and environmentally beneficial agricultural practices, with producer, industry and wider societal benefits.

Threats
Further research is needed into the effects of nanomaterials on human health and the environment.

Automotive Sector

Strengths
Good UK research base and materials production expertise in the UK. UK has a mature automotive sector, with an established infrastructure coupled with a large aftermarket (largest in Europe). UK automotive sector comprises many hundreds of companies and employs over 800 000 people (Society of Motor Manufacturers and Traders (SMMT) data). Automotive manufacturing contributes around £10.3 billion value-added to the UK economy.

Weaknesses
Current cost of nanotechnologies solutions (price/performance ratio is key driver), industry conservatism and long-product cycles may prohibit introduction of widespread nanotechnologies solutions. Structural use of nanotechnologies requires

significant testing and accreditation to enter and gain confidence of the market. Lack of end-user awareness and confidence and an immature recycling infrastructure may also prevent wider adoption of nanotechnologies in automotive applications.

Opportunities
The automotive industry's need to continue to reduce costs and meet environmental and safety legislation will drive the demand for high-performance material technologies.

Threats
Various automotive companies around the world are developing and/or implementing automotive-based nanotechnologies. Toyota first began research into polymer nanocomposites in the 1980s. Import competition, especially Far-East automotive companies' increasing expansions.

Chemicals/Formulated Products Sector

Strengths
The UK has a strong base for delivering novel high added value chemical and formulated products including pharmaceuticals, agrichemicals, catalysts, fuel lubricants and additives, healthcare, home and personal care and coatings. The UK hosts R&D and manufacturing centres for several leading multinationals and a significant number of SMEs. There are also well established connections with the underpinning value chain and knowledge base in the UK e.g. ingredient supply, analytical services/technologies and academic expertise/capabilities. The UK also has a strong knowledge transfer base.

Weaknesses
The UK pipeline for public R&D funding (through from Technology Readiness Level 1 to 9) is not particularly well aligned, strategically or mechanistically. There is also a major gap in funding available for development/demonstration at pilot scale. Adoption and registration of new materials in formulated products is generally limited due to the time, cost and risk involved. For nanomaterials the barriers are exemplified as there is limited availability/awareness of regulatory guidance and knowledge/tools for robust risk management. As a result, time to market is likely to be slower than other countries and the opportunity may be missed.

Opportunities
Nanotechnologies could provide UK industry with added value novel formulated products that address global challenges and in turn enable leverage of a large share of a £1,000bn global market. In turn, a greater share of the associated ingredients and enabling instrumentation/process equipment market could also be captured. Much of the relevant technology is highly transferable and exploitable across several formulating sectors. Significant value could be gained from investment in this area.

Threats
In terms of investment in nanotechnologies, USA, Japan and other European Countries are making the largest investments and provide the largest threats. However., there is also significant competition from Brazil, Russia, India and China all of whom are making major investments in chemical R&D/manufacturing. Public perception of nano is also perceived to be a critical barrier.

Construction Sector

Strengths

Good UK research base and materials production expertise in the UK.

Weaknesses

Current cost of nanotechnologies solutions and industry/client structure may prohibit their introduction. Structural use of nanotechnologies requires significant testing and accreditation to enter & gain confidence of market.

Opportunities

Sustainability agenda and present/planned regulation on the sector will provide great emphasis on both the energy/carbon performance of both new and existing buildings.

Threats

Strong overseas head start in construction nanotechnologies in USA and Northern Europe. Import competition.

Cosmetics Sector

Strengths

The UK cosmetics industry is already using nanomaterials in cosmetic products and in researching future uses; examples include sunscreens, anti-ageing product and deodorants.

Weaknesses

There is at present insufficient knowledge regarding dermal absorption and uptake via inhalation of some nanomaterials used in cosmetics. Further research may be necessary to quantify an EHS risk associated with the use of these products.

Opportunities

Nanotechnologies offer enhanced cosmetic properties that can lead to better products. Use of nanomaterials can mean that products are easier to apply and have increased function and efficacy.

Threats

To maintain and improve consumer confidence in the use of nanomaterials in cosmetic products, the Commission must administer the new requirements in the Cosmetics Regulation in an effective and transparent way.

Electronics Sector

Strengths

Good research base and materials production expertise in the UK. The UK electronics industry is already embracing nanotechnologies.

Weaknesses

Hype over the performance of nanomaterials in real applications (e.g. carbon nano-tubes), long time to market, cost of nanomaterials, scaling issues, process compatibility of nanomaterials with existing electronics manufacturing infrastructure.

Opportunities

Nanotechnologies will impact on every industry because electronics are ubiquitous. Hybrid integration with existing semiconductor materials and processes most likely in

near to mid term. Carbon nano-tubes or graphene-based transistors are unlikely to emerge commercially for 5-10 years.

Threats
Conventional materials and manufacturing processes: Silicon will not be easily displaced and other materials have been touted as potential replacements without significant success in mainstream applications. Significant competition from major USA, Japanese and South Korean electronics companies that have taken the lead in many nanoelectronics developments.

Energy Sector

Strengths
Work to develop improved energy efficiency through nanotechnologies is already well underway, and there are encouraging indications that nano-science can be an enabler to the energy agenda in the future. The development of fuel additives using nanotechnologies are already helping London buses, for example, to achieve greater fuel efficiency. In the longer term the use of nanotechnologies will hopefully contribute to the development of improved renewable sources of energy such as solar power. Some UK universities have particular expertise in nano thermal fluids.

Weaknesses
Although many of the ideas for harnessing nanotechnologies to achieve sustainable energy generation have been developed in the UK, in certain areas (e.g. automotive) we lack the manufacturing base to capitalise on these ideas.

Opportunities
The application of nanotechnologies to enable the development of clean and renewable energy and reduce our dependency on fossil fuels could significantly reduce carbon emissions and thereby help to mitigate the effects of climate change.

Threats
Research is ongoing into the potential health impact of free nanoparticles in diesel exhaust gases, there is a possible threat if the research shows that there are adverse heath impacts. As in other areas, the continued development of using new technologies in the energy sector is dependent on consumer acceptance which is likely to be a major factor in its success.

Environmental Remediation Sector

Strengths
Nanotechnologies offer unique opportunities for novel environmental sensing and monitoring approaches, as well as possibilities for cleaning up contaminated land, water and air

Weaknesses
The Royal Society and Royal Academy of Engineering recommended in their 2004 Report “Nanoscience and Nanotechnologies: Opportunities and Uncertainties” that, given the uncertainties over the environmental impacts of nanoparticles, their release into the environment should be avoided. The UK currently has a moratorium in place. Early commercialisation of nanofiltration and nanomembranes, nano-based sensors and nanocatalysts is therefore currently occurring outside the UK.

Opportunities
Natural nanomaterials already exist and could provide a wealth of data to help address some of the uncertainties

Threats
Before many of these technologies - especially the use of nanomaterials in remediation applications - reach fruition, their performance and EHS impacts require verification. More research is necessary to determine any negative effects that the release of nanomaterials into the environment may have. For example, research is still needed into any potential side effects of nanomaterials on bacterial cultures used in secondary treatment of waste water, as well as the effect treatments such as ozonation may have on nanomaterials themselves (and therefore on the environment).

Food Sector

Strengths
UK has a strong research base in the food area, which facilitates the development of innovative products and new technologies. The UK also has a well-developed market for processed foods.

Weaknesses
There is at present insufficient knowledge about the behavior of engineered nanomaterials in food and in the body, so that their safety can only be assessed on the basis of detailed case-by-case testing. There is a perceived failure on the part of regulators to understand the status of developments in addition to inadequate guidance on how specific pieces of legislation relate to nanofood products may be perceived as weaknesses. Also, in common with cross cutting areas, a lack of standard definitions and tools to identify engineered nanomaterials at trace levels in a complex background may be perceived as weaknesses for the food sector.

Opportunities
Improved packaging could contribute to better shelf life of pre-packed foods (less wastage) or to reductions in packaging waste.

Threats
The introduction of new technologies in the food sector is strongly dependent on consumer acceptance and this is likely to be a major factor for the success of products of nanotechnologies.

Consumer acceptance may be directly influenced by other factors including transparency or engagement. Consumer organisations are concerned about a lack of openness by industry about ongoing research and development and inadequate public engagement.

Healthcare Sector

Strengths
Good UK research base in materials, medical engineering, biosciences, clinical research. Over 400 Biotech/Pharma companies and 2000 healthcare technology companies with established infrastructure (such as supply chains) are part of the large National Health Service (NHS) market. The pharmaceutical sector in the UK employs around 73,000 people directly and generates another 250,000 jobs in related industries. Pharmaceuticals and biotechnology contributed to 4% of total UK value added in 2007: worth £25.7billion or £130,024 per employee. For healthcare

technologies the UK employs around 55,000 people. In terms of 'Value Added' the industry contributed around £47,000 per company employee.

Weaknesses
Current cost of nanotechnologies solutions, conservatism amongst the larger pharmaceutical companies and long-product development times may prohibit their widespread introduction. The multidisciplinary nature of the area means that collaboration is important between academia, clinicians and industry; this could be a potential obstacle.

Opportunities
Increasing burden of disease and cost of healthcare provision mean novel, costs-effective solutions are needed for disease prevention, diagnosis and advanced treatments.

Threats
Many countries are investing heavily in healthcare research and the drivers to move R&D capability overseas mean opportunities could be lost in developing nanotechnologies solutions into products within the UK. There are concerns that there is currently insufficient information about the lifecycle and toxicity of nanomaterials for use in medical and healthcare applications.

Materials Sector

Strengths
Good UK research base and materials production expertise in the UK, especially in plastics and coatings.

Weaknesses
Overhype, current cost of nanomaterials, uncertain EHS effects, lack of standards, quality issues plaguing some nanomaterial manufacturers and poor materials property data may prohibit introduction of widespread nanotechnologies solutions and cloud public perception. There is a need for improved characterisation and manipulation tools, measurement standards and reference materials.

Opportunities
Engineering materials by design (tailor-made, multifunctional materials) using bottom-up manufacturing processes (e.g. self-assembly) for specific application requirements.

Threats
Strong import competition of nanomaterials from Europe, USA and Japan: IPRs may play a role in determining who wins out. Strong competition from existing material and manufacturing technologies in various applications and market sectors.

Printing & Packaging Sector

Strengths
Good research base and materials production expertise in the UK. UK electronics industry already embracing nanotechnologies and organic electronics with many SMEs active in printed electronics R&D and commercialisation.

Weaknesses
Performance of nanomaterials (e.g. electron mobility is often much lower in printed electronic devices than in corresponding silicon devices) and product consistency

(scaling issues still need addressing for high-volume manufacture; surface tension and fluid flow issues for conventional inkjet printers occur at smaller printing dimensions); long time to market; cost of nanomaterials especially for disposable items (like product packaging); process compatibility with existing electronics manufacturing infrastructure.

Opportunities
High-throughput printing processes will dramatically reduce the cost of fabricating electronic devices. Lightweight, flexible substrates will provide design freedom, enabling the use of organic electronic devices in applications that are impractical for rigid devices (e.g. packaging and clothing). Opportunity for manufacturers of high-end products to embrace printed electronics and target low-end, disposable product markets. For example, providing necessary components for smart packaging could contribute to end-users not only providing improved products but also enhanced consumer experiences and brand recognition.

Threats
Conventional materials and manufacturing processes: Silicon will not be easily displaced. Numerous SME activity and significant competition from major USA, Japanese, German and South Korean electronics and materials companies that have taken the lead in some printed electronics developments, including printing materials, printable solar cells and displays.

Sensing & Instrumentation Sector

Strengths
Increased miniaturisation, ability to create nanoarrays for multivariate detection, increased sensing and specificity, low energy consumption, smaller size and lightweight. UK has a very strong research base. Most of the academic institutions are involved in exploiting nanoscale properties for sensing.

Weakness
While there is an active research community there are concerns about:
- the main focus being on biosensing;
- a highly fragmented sensing market;
- challenges in integrating nanoscale devices into existing platforms;
- high manufacturing costs; and
- a lack of standards for sensors and instrumentation.

Opportunities
This sector market is valued at $15 million per year. The technology developed for one application can be used interchangeably for another application. Need for improved sensitivity, unprecedented strengths, which cannot be offered by other competitive technologies, lowering costs of nanomaterials, increased security, defence and health concerns.

Threats
A conservative industry and potentially restrictive regulations.

Textiles Sector

Strengths
The UK is strong in textile design, dyeing and finishing. Europe is world leading in textiles and clothing manufacture.

Weaknesses
For consumer goods there is always the consideration of cost and how much the consumer is willing to pay for better performance, especially in the current economic climate. End-user awareness and confidence in nanotechnologies may prevent wider adoption of nanotextiles, thus requiring the need for better characterisation tools and measurement standards.

Opportunities
Consumer applications (clothing and apparel) offer significant opportunity for nanotechnologies because of the large sales volumes involved. Intense competition and manufacturers' need for high-performance products, greater product differentiation whilst reducing costs and meeting environmental and safety legislation will drive the need for high-performance material and process technologies. There are also opportunities for the UK to take a lead in transitioning from the use of passive to active nanotechnologies in smart textiles (increased performance and functionality, such as dynamic climate control), adding value and benefits to consumers.

Threats
Strong overseas head start in nanotechnologies surface treatments, especially in USA and Germany. Import competition could become extremely significant, especially from low-wage countries such as China and India. Consumer confidence in "nanosafety" will be important.

3. In which part(s) of this sector are nanotechnologies or nanomaterials most likely to be used in the future? Please explain your answer.

In general respondents felt that nanotechnologies and nanomaterials would have a positive impact, and be used in all areas of each of the sectors because of the advantages that can be offered by more effective, novel products. However, several specific areas were highlighted for some of the sectors.

In the **aerospace/defence and automotive sector**, respondents noted that in particular in this sector nanomaterials such as polymeric composites will be used for light weighting vehicles.

Respondents to the **chemicals/formulated products sector** suggested many ways that nanomaterials would be used including in catalysts, industrial products, pharmaceuticals and consumer products. It was suggested that nanomaterials use would be ubiquitous across the sector.

Similarly, it was noted by one respondent that nanotechnologies will remain underpinning technology for all **electronic** systems and electronics will be an enabler for many other sectors. Other suggested uses for nanotechnologies in this sector are in transparent conductive electrodes and quantum well lasers for CD and DVD players.

One respondent to the **environmental remediation sector** suggested that in the future, nanotechnologies would likely be used in water purification (nanofiltration and nanomembranes), environmental gas sensors and catalysts.

Several respondents felt that **food** packaging was one area where nanomaterials are most likely to be used in the future. One respondent specifically identified nano-coatings and barriers, intelligent packaging and improved printing inks as the most likely areas of future use. One respondent felt that, unlike packaging applications, unknown risks and possible media scare tactics will mean that direct food applications are unlikely to be acceptable to consumers.

One respondent suggested that although opportunities in the food additive area are presently limited, use of nanotechnologies/nanomaterials in carrier and delivery systems can be envisaged in the future. One respondent felt that nano-encapsulation of flavourings and other ingredients, cleaning applications (although not precisely specified, a possible example might be easy clean utensils) and equipment in processing facilities offer the most promise for the future. One respondent felt that nanotechnologies/nanomaterials will most likely be used in processed foods, food supplements and as general preservatives. One respondent also viewed that the convergence of nanotechnologies with other technologies will result in further innovations that will impact on production, processing, storage, transportation, traceability, safety and security of food, for example, nano-diagnostic tools for detection and monitoring in food production.

For **healthcare**, respondents suggested that future areas where nanotechnologies are likely to be used could include drug delivery and drug discovery, medical diagnostics, contrast imaging agents, medical coatings and implants, tissue engineering, nanopharmaceuticals, diagnostics and regenerative medicine.

A respondent suggested that a likely use of nanomaterials in the **materials sector** was in nanostructured materials and coatings with radically improved performance.

A respondent to the **printing and packaging sector** suggested that the in this sector, nanomaterials are most likely to be used as inks that provide semi-conductive layers and printed display electrolytes that provide low voltage but high output properties.

A respondent felt that gas or chemical (including biochemical) sensors would be a key future use in the **sensing and instrumentation** sector. It was also suggested that the robustness of non-contact optical sensing methods may increase their involvement in a number of the applications and this may be helped by the application of nanotechnologies in light source design.

Reflecting the view of respondents to most of the sectors, respondents suggested that nanomaterials or nanotechnologies would be used in all parts of the **textiles sectors** from fibre manufacture to post production treatment of finished articles. A respondent also felt that it is conceivable that additional products will be developed specifically for the home treatment of garments.

Quotes

“Nanomaterials have potential for use in all areas of the healthcare industry.” – **Christopher Seaman, GlaxoSmithKline**

“Areas of interest include direct application in food, e.g. nano-encapsulation of flavourings and other ingredients; packaging applications, e.g. nano-coatings and barriers, ‘intelligent’ packaging, improved printing inks; cleaning applications and equipment in processing facilities.” – **Keneth Chinyama, Food and Drink Federation (FDF)**

4. What difference will nanomaterials or nanotechnologies make to the products or processes that are used in individual sectors (and what are the properties or functionalities that will make the difference)?

In general, respondents felt that nanomaterials and nanotechnologies could have many effects. In particular, a respondent to the chemicals/formulated products sector suggested that nanomaterials will impact on all areas of our daily lives and bring significant benefits across many sectors. In addition, there were a few key themes that have emerged including the opportunity to reduce the amount of materials required for a product making them smaller and cheaper; enhanced functionalities and physical properties and addressing societal challenges, e.g. clean water and climate change.

A respondent to the **electronics** industry sector suggested that using quantum effects and electronic and optoelectronic properties, will potentially allow new circuit materials, processors and storage devices (amongst other things) to be designed.

In addition to the comment highlighted in the introductory section, another respondent to the **chemicals/formulated products sector** noted that production costs will be reduced by using fewer active ingredients. The same respondent noted that further into the future, nanotechnologies products could be introduced with systems that change functionality depending on external stimuli.

In the **healthcare sector**, one respondent suggested that nanomaterials and nanotechnologies may be used to improve drug efficacy by more efficient targeting. Other particular functionalities that may impact in this area were suggested by another respondent including fluorescence and biocompatibility.

For the **food sector**, there were different products or functionalities suggested. Specifically, one respondent suggested that nanotechnologies will improve the appearance of a range of products by facilitating the production of clear emulsions and could also improve the delivery of products into food matrices. One respondent suggested that the main differences will be to reduce packaging weight and increase packaging strength. They also highlighted that the properties or functionalities will be changed according to the intended use of the nanomaterials and the difference that nanotechnologies will make will depend on a particular application. Respondents by and large did not explain which nanomaterials or properties of nanomaterials have the potential to make the differences they have referred to.

One respondent to the **sensing and instrumentation sector** suggested several ways in which sensors could be improved by nanotechnologies including improved sensitivities and responsiveness.

Quotes

“Nanotechnologies permit the design of sensors that are smaller and more sensitive, stable, specific, responsive and selective.” – **Michael Adeogun, NPL**

“Nanomaterials developed by the chemical sector have the potential to help enable existing and future technologies to revolutionise virtually every aspect of our daily lives, bringing societal, environmental and economic benefits across many sectors (e.g. healthcare, aeronautics, electronics, transportation).” – **Dr Anne-Gaelle Collot, Chemical Industries Association**

5. Who (e.g. research base, industry, general public) or what (e.g. environment) might;

(a) benefit from these developments; and/or
(b) be adversely affected by them?

Please explain what the effects might be and when they might be felt.

In general, respondents to this section felt that nanotechnologies are likely to bring benefits across all of society from industry to the consumer. Developments also have the potential to benefit the wider environment. Nanotechnologies will also help manufacturing sectors to become more sustainable and reduce their impact on the environment. The healthcare sector was thought to present a very positive picture of the benefits of nanotechnologies to patients and the healthcare system as a whole. In contrast, the construction sector has a great fear of a repeat of incidences such those created by the health impact of asbestos.

Nanotechnologies were thought to be key to helping sectors such as **aerospace, defence and automotive** to become more sustainable and reduce their impact on the environment. Consumers may benefit from improved functionalities of the materials and products they use. For example, in the **cosmetics sector,** the use of nanoparticles in sunscreen may result in more effective protection against UV radiation than conventional sunscreens. Many industry players will also benefit through improved manufacturing and formulation processes and through added functionalities increasing the retail value of products and the potential benefit of new markets such for **environmental** management and environmental technologies.

The environment also may benefit from more targeted **agricultural** chemicals, encapsulation and slow release pesticides and herbicides that reduce the number of applications made, for example.

In the **electronics sector**, one respondent suggested that consumers and manufacturers will benefit, but not necessarily be aware of the fact that they are utilising nanomaterials, just that the products have 'enhanced' capability. One respondent suggested that the **healthcare sector** has the most to gain from safe and responsible development of nanotechnologies, and in turn the patients will benefit. In particular by more efficient drug development and targeting and non -drug therapies.

In the **energy sector**, one respondent noted that the main benefit of nanotechnologies would be to help energy generation become sustainable with reduced environmental impacts. No comments were received regarding those adversely affected.

In the **food sector**, respondents generally took the view that there would be several groups who could benefit from these developments. They were thought to potentially provide most benefit for the environment, the food industry, research base and the public in the following ways;

- environment – certain respondents felt that the main environmental benefits would be derived as a result of reduced packaging and consequently less packaging waste;
- food industry – some contributors felt that nanotechnologies will benefit the food industry. One of these respondents felt that nanotechnologies will provide industry with options to meet the challenges of innovation and competitiveness in a time where there are limited resources and global economic pressures. Certain respondents stated that production of improved

products (for example products with improved stability and shelf life) would be the main benefit for the food industry;
- research base – one respondent felt that the research base will benefit by gaining a better understanding of nanomaterials in terms of behaviour which in turn will lead to improvements in products and processes;
- public – certain respondents felt that the public would benefit from developments in this area. Others felt that the main benefit for the public would be derived from improved products, for example, products with increased shelf-life or improved stability. One respondent felt that nanotechnologies will offer the general public an increased choice of products on the market (when any safety concerns or regulatory uncertainties have been ruled out).

Whilst in all sectors there was a general focus on the benefits rather than the adverse effects, respondents did highlight that these exciting developments need to be managed responsibly. In particular, there was acknowledgement that there are potentially some health risks associated with some nanomaterials.

For example, one respondent suggested that the impact of using nanosilver in **textiles** and clothes is not well understood and that, going forward, other functional clothing could also impact on the environment.

There was concern about the use of nanotechnologies products in **construction** from one respondent. In particular, they noted that it was not yet known what possible health effects there could be associated with nanomaterials, particularly in light of the fact that some nanomaterials could potentially have a similar effect as asbestos particles.

In the **healthcare sector**, one respondent noted that the MHRA considers current legislation governing medicine and medical devices as being sufficient to cover nanomaterials. However, DG SANCO, the Royal Society and the EMEA have expressed the opinion that existing regulations may need to be re-drafted with nanotechnologies taken into consideration. There was a need for guidance documents specifically addressing the regulation of nanotechnologies in medicine.

A respondent to the **food sector** considered that developments may pose a risk to consumers particularly if there is not a good understanding of the behaviour of ingested nano-constituents.

A respondent to the **printing and packaging sector** noted that the environment could be adversely impacted if nanomaterials that are used in packaging are sent to landfill and suggested that there could also potentially be effects on water as nanosilver from consumer products 'leaches' from products into the environment.

Quotes

"The whole supply chain from research labs through to production, retail and the consumer could benefit from improved sustainability, enhanced functionality, reduction in costs and consequent higher returns on investment." – **Dr Neil Harrison, NPL**

"Patients and the healthcare system as a whole have the most to gain from safe and responsible development of nanotechnology in the medicines sector." – **Rob Reid, Which?**

"Union of Construction, Allied Trades and Technicians (UCATT) is very concerned about the use of nanotechnology products in construction. There is an overwhelming ignorance by workers that nanotechnology products exist and that they could already be using them. Others have expressed a strong fear that nanotechology products could be "the new asbestos", in the sense that the particles could have a similar effect as asbestos particles." – **Dorthe Weimann, UCATT**

6. Will the new products or technologies be developed in the UK or in other countries?

Responses to this question were heavily sector dependent, with the aerospace, defence, automotive, healthcare and energy sectors thought to have high potential for development in the UK while environmental remediation and electronic sectors could be developed most strongly in other countries.

Respondents felt that the UK has major capability in some key areas, such as **aerospace** structures and propulsion systems, and has a major presence in the **defence sector**. The UK is strong in the development of lightweight materials for the **automotive sector** and for actuators, engines and other aspects of the drive system. A respondent to the **chemicals/formulated products sector** believed that the UK has great potential to develop nanotechnologies and to remain one of the key global players. In terms of **environmental remediation**, respondents felt it was too early to tell whether technologies would be developed in the UK. Respondents felt that, to some extent, the scope for technologies in the **food sector** to occur in the UK depended on the public perception.

The UK also has a strong **healthcare** and personal products industry and one respondent suggested that a wide range of nanotechnologies based therapeutics and diagnostics devices will be developed in the UK. However, they noted that the uptake of such technology, and potentially its ongoing development in the UK would be dependent on Government policy and other factors such as the medical insurance industry.

Both respondents to the **electronic sector** suggested that products will continue to be developed as now (both in the UK and outside the UK). However, one of the respondents noted that the UK has strong research and early commercialisation base in organic electronics and that in this sector, it would be likely for more to be done in the UK.

In the **energy sector**, it was considered by a respondent that with continued support, capabilities areas such as fuel cells and gas turbines could be exploited successfully in the UK.

Quotes

"We believe that the UK has a great potential to develop nanotechnologies to remain one of the key global players." **– Dr Anne-Gaelle Collot, Chemical Industries Association**

"The UK has major strengths in materials. It is important that these strengths are maintained and indeed strengthened through appropriate targeted investment. The recently published TSB nanosciences strategy gives a good description of the relevant priority areas." – **Prof Mark Gee, NPL**

7. What do you consider to be the challenges relating to this sector?

Most respondents felt that the main challenge facing nanotechnologies sectors was misinformation to the public. Other issues raised included measurement, characterisation, standards, and the burden of regulation which could be a barrier to innovation.

In the aerospace/defence and automotive sector respondents felt that measurement and characterisation were key to solving many of the issues association with the application of nanotechnologies. For example, it was suggested that the characterisation of the dispersion of nano-objects in polymeric nanocomposites is a key factor where the development of characterisation methods will lead to the capability for robust manufacture of high quality polymeric nanocomposites.

Several different challenges were raised by different respondents in the **chemicals/formulated products sector,** including lack of regulation, lack of public support, lack of clear and consistent regulatory guidance and competitiveness of emerging economies.

In the **cosmetics sector** respondents felt that the challenge would be to reassure the consumer both by being transparent and maintain their confidence in safe products in the face of misinformed comments.

Conversely, in the **electronic sector** it was suggested that the challenge would be overcoming the hype, particular in relation to carbon nanotubes. Another respondent highlighted a challenge around developing the tools required to assess the long term effects of using nanomaterials on human health and the environment.

A challenge identified in the **energy sector by** one respondent related to skills and the need to retrain existing engineers to ensure that they could make use of the technology. In addition, it was suggested that there is a requirement for a strong capability in measurement and characterisation.

Respondents to the **environmental remediation sector** stressed that the clear societal opportunities offered through fighting pollution and improving human health could not be evaluated without mentioning the potential risks of using nanomaterials or without verifying their efficacy, safety and environmental and health impacts.

Respondents felt that the **food sector** faces a number of challenges which are summarised below;

- consumer acceptance – certain respondents felt that consumer acceptance was the greatest challenge. One of these respondents noted that consumers tend to be distrustful of new technologies applied to food and drink manufacture. This situation may be exacerbated if consumers find the technology difficult to understand or react to alarmist media tactics;
- developing a suitable legislative framework – one respondent stated that the main challenge will be to develop a legal framework that controls the technology without creating unnecessary barriers, for example as already exists in the additives area;
- cost and time period required to bring new products to the market – one respondent suggested that the immense cost of bringing new products to the market could deter all but the largest manufacturers. It was also highlighted that the time periods required to bring new products to the market can be lengthy in the EU compared to the USA or Australia for example;

- developing interesting applications – one respondent felt that developing interesting food-related applications would be the biggest challenge;
- ensuring that industry is open and engaging – one respondent felt that one of the biggest challenges will be to ensure that industry is open and engaging about what is being done;
- understanding the risks – one respondent suggested that developing an understanding of any risks associated with this sector was the main challenge. It was highlighted that other challenges centre around having appropriate measurement and characterisation tools and having a research infrastructure in place that is capable of delivering innovation.

In the **healthcare sector** respondents felt that poor industrial academic communication would be a challenge. Also that if products are not developed responsibly, there would be challenges around public perception. A respondent noted that an increasing amount and complexity of regulation could be a barrier to efficient development of these technologies.

Challenges that were highlighted by respondents to the **materials sector** were capitalising on a quickly progressing and developing research base. As highlighted in other sectors, a respondent to this sector also mentioned measurement and characterisation as being key to solving many of the issues.

One respondent mentioned the need to develop scientific tools to assess the long-term impact of nanomaterials in **printing and packaging** on the environment as well as understanding how these materials may enter and interact with the human body.

Sensing and Instrumentation

Respondents to the **sensing and instrumentation sector** noted the following challenges;

- the cost/performance ratio of the nanosensors will be nanomaterials dependent, which will therefore determine whether commercialisation and uptake is successful in a particular market;
- a lack of standards and standardisation, sensor testing and calibration facilities would be a challenge;
- a lack of traceable calibration of nanomaterials: since their properties are strongly dependent on size, new metrological capabilities are required in order to ensure consistency in quality and innovation;
- advances in precision engineering, optics, electronics, materials technology and molecular biology are placing increasing demands on nanometrology;
- a need to maintain sufficient local manufacturing to provide outlets for R&D.

Textiles

It was noted that a key challenge for the **textile sector** is having the measurement tools that can underpin future research and development – this reflects the view that was felt across many sectors that issues around measurements will be a key challenge.

Quotes

“lack of regulation, characterisation/analytical capability, scare mongering,” – **Simon Lawson, University of Leeds**

“Public perception and antagonism if products are not developed responsibly and ethically. Increasing amount and complexity of regulation could be a barrier to efficient development of these technologies. Development of characterisation

methods for nanomaterials. It is a requirement of the pharmaceutical manufacturing process that we have a rigorous understanding of the process and materials.“ – **Christopher Seaman, GlaxoSmithKline**

“Consumers need to have confidence in the technology and the benefits it delivers whilst being aware of the risks; the challenge lies in the communication of this.” – **Dr Anne-Gaelle Collot, Chemical Industries Association**

8. If you have any other comments or feedback about this, please use the box below:

A respondent to the **chemicals/formulated products sector** noted that the chemical industry is an important and valuable industry in the UK (contributing £18billion to the economy) and that because of the existing industry infrastructure nanotechnologies offer a real and valuable opportunity for the UK. Another respondent noted that there needs to be sustained Government focus to support industries and enable them to grow in this area.

One respondent to the **electronics sector** made the point that *“nanotechnology is just a term, it is not a magic bullet.”* They go on to note that it is not a sector in its own right or a specific business opportunity.

A respondent to the **food sector** said that there were opportunities for consumer benefit in the food area and that is would be regrettable if such advances were not taken advantage of because of fears about nanotechnologies or a failure to convince consumers of their safety.

4. Appendix A – Glossary

BERR	Department for Business, Enterprise and Regulatory Reform
BIS	Department for Business, Innovation and Skills
BRASS	Centre for Business Relationships, Accountability, Sustainability and Society
BSI	British Standards Institute
CIA	Chemicals Industry Association
CLP	Classification, Labelling and Packaging
CNT	Carbon Nanotube
COSHH	Control of Substances Hazardous to Health
CSR	Corporate Social Responsibility
Defra	Department for the Environment, Farming and Rural Affairs
DIUS	Department for Innovation, Universities and Skills
DTI	Department of Trade and Industry
ECVAM	European Centre for the Validation of Alternative Methods
EFSA	European Food Safety Authority
EHS	Environmental, Health and Safety
ENI	Environmental Nanoscience Initiative
EPSRC	Engineering and Physical Sciences Research Council
FDF	Food and Drink Federation
FENAC	Facility for Environmental Nanoparticle Analysis and Characterisation
FP	Framework Programme
GM	Genetically Modified
H&S	Health and Safety
HPA	Health Protection Agency
HSE	Health and Safety Executive
IPR	Intellectual Property Rights
ITTP	Integrative Toxicology Training Partnership
KTN	Knowledge Transfer Network
KTP	Knowledge Transfer Partnership
LACORS	Local Authorities Co-ordinators of Regulatory Services
MHRA	Medicines and Healthcare products Regulatory Agency
MNT	Micro/Nano Technology
MRC	Medical Research Council
NERC	Natural Environment Research Council
NGO	Non-Governmental Organisation
NHS	National Health Service
NMO	National Measurement Office
NPL	National Physical Laboratory
NRCG	Nanotechnology Research Coordination Group
NSF	Nanotechnology Stakeholder Forum
OECD	Organisation for Economic Cooperation and Development
R&D	Research and Development
RCUK	Research Councils UK

REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
SERS	Surface Enhanced Raman Spectroscopy,
SME	Small and Medium-sized Enterprise
SMMT	Society of Motor Manufacturers and Traders Ltd
SWOT	Strengths, Weaknesses, Opportunities, Threats
TSB	Technology Strategy Board
UCATT	Union of Construction, Allied Trades and Technicians

5. Appendix B – List of Respondents

Name	Organisation
John Saffell	Alphasense Ltd.
Seamus	AB World Foods
Ian Phillips	ARM Ltd
Stephen bysouth	Automaxion Ltd
Dr Anne-Gaelle Collot	Chemical Industries Association
Philip Cooper	De La Rue Ltd
Mark Priest	Dispersia Ltd
Stephen Williamson	DVC (Research and Innovation) University of Surrey
Donald Bruce	Edinethics Ltd
Joy Hardinge	FAIA
Keneth Chinyama	FDF
David Cumming	Glasgow University
Christopher Seaman	GlaxoSmithKline
Howard Hopwood	HARMAN technology Limited
Chris Howick	INEOS Vinyls UK Ltd
Thanate Kitisriworaphan	Institute for Population and Social Research, Mahidol University
Mark Morrison	Institute of Nanotechnology
Christopher Jones	International Underwriting Association
Peter Hatto	IonBond Ltd
Dr John Malcolm Wilk	Kirkstall Ltd
Matthew Thornton	Materials KTN
Prof. Mark Gee	NPL
Dr Neil Harrison	NPL
Michael Adeogun	NPL
Dr Craig Murphy	NPL
Dr Chris Jones	RCUK Nanoscience Programme (a joint response on behalf of the Research Councils)
Hilary Sutcliffe	Responsible Nano Forum
John A. Hoskins	Royal Society of Chemistry
Rob Aitken, Bryony Ross, Lang Tran, Steve Hankin & Sheona Peters	SAFENANO / IOM
Kim Travis	Syngenta
Dr Christopher Flower	The Cosmetic, Toiletry and Perfumery Association
John Shaw	Tyco Safety Products
Dorthe Weimann	UCATT
Prof. Mike Eaton	UCB & board member ETP Nanomedicine
Prof. Jeremy J. Baumberg	University of Cambridge
Ken Donaldson	University of Edinburgh
Bonny Umeadi PhD	University of Greenwich/NanoMind IDC
Simon Lawson	University of Leeds
Prof.Terry A Wilkins	University of Leeds, Nanomanufacturing Institute
Rob Reid	Which?
Hilda Coulsey	Yorkshire Forward