



COUNCIL FOR
SCIENCE AND
TECHNOLOGY

Strategic decision making for technology policy

A report by the Council
for Science and Technology

November 2007

THE COUNCIL FOR SCIENCE AND TECHNOLOGY (CST) IS THE UK GOVERNMENT'S TOP-LEVEL ADVISORY BODY ON SCIENCE AND TECHNOLOGY POLICY ISSUES.

CST's remit is to advise the Prime Minister and the First Ministers of the devolved administrations on strategic issues that cut across the responsibilities of individual government departments. CST organises its work around five broad themes (research, science and society, education, science and Government, and technology innovation) and takes a medium to long term approach.

CST's past work profile includes reports on 'Pathways to the future: the early career of researchers in the UK', 'Nanoscience and Nanotechnologies: A Review of Government's Progress on its Policy Commitments', 'Health Impacts – A Strategy Across Government', A 'Better Use of Personal Information: Opportunities and Risks'; 'An Electricity Supply Strategy for the UK'; and 'Policy Through Dialogue: informing policies based on science and technology'. The Council has also provided advice to Government on improving interactions between academia and the services sector, and how procurement can drive innovation.

The members of the Council are respected senior figures drawn from across the field of science, engineering and technology. The current membership of the Council:

Professor Sir John Beringer CBE
Professor Geoffrey Boulton OBE FRS FRSE
Professor Peter Davies
Professor Janet Finch CBE DL AcSS (co-chair)
Professor Alan Gilbert
Professor Wendy Hall CBE FREng
Dr. Hermann Hauser FREng CBE CPhys FInstP
Professor Alan Hughes
Dr. Sue Ion OBE FREng
Sir David King KB ScD FRS (co-chair)
Sir Paul Nurse FRS FMedSci
Sir Keith Peters FRS PMedSci
Dr. Raj Rajagopal FREng CEng FIEE FIMechE FIE FCMI
Dr. Philip Ruffles CBE
Professor Michael Sterling FREng
Professor Kathy Sykes CPhys FInstP
Dr. Mark Walport FMedSci

CONTACT

Council for Science and Technology
Kingsgate House, 66-74 Victoria Street
London SW1E 6SW
+44 (0)20 7215 2876
cstinfo@dius.gsi.gov.uk
www.cst.gov.uk

Contents

• Executive Summary	3
• Summary Recommendations	6
o A framework for technology priority-setting	6
o A specific application	6
o The priority technology areas	7
1. Introduction	9
2. A Framework for Technology Priority-Setting	10
o Stage 1: The initial process	10
o Stage 2: Compiling a 'long list' of technology areas	10
o Stage 3: Sifting the 'long list'	10
o Stage 4: Detailed assessment of short-listed technologies	11
o Stage 5: Narrowing down the list and getting agreement	11
o Stage 6: External 'road testing'	12
3. Priority Technology areas	13
o Summary	13
o Rationale for the Selected Technologies	15
– Carbon Capture and Storage	15
– Disaster Mitigation Technology	18
– Low Carbon Distribution Networks for Electricity Supply	21
– Medical Devices	24
– E-Health	27
– Plastic Electronics	29
o Platform/Enabling Technologies	31

4. Evaluation of the Process	32
• Annex A: Information Gathering Questions	34
• Annex B: Organisations Consulted	37
• Annex C: Definition of Short Listed Technology Areas	39
• Annex D: Note of the Road-Testing Workshop 22 June 2007	47
• Annex E: Plastic Electronics – developing a new industry in the UK	53

Executive Summary

The Challenge

A major challenge for the UK is to ensure that the substantial investments in science and technology, skills and education that Government has made over the last ten years translate into innovation and wealth creation by business in the UK. Government asked the Council for Science and Technology (CST) to advise on what would be the best areas to focus resources for science, technology and innovation which could lead to applications with commercial or social benefits in around five years time¹.

Making choices between different technologies is both challenging and complex, particularly for Government which must look across the full spectrum of technologies and decide where and how to make its interventions. Currently, UK innovation policies spread public sector finance much more thinly than the US – typically by a factor of five². For Government to have a robust set of technology policies it needs to take hard decisions, and in order to make those decisions effectively Government needs a systematic mechanism.

CST therefore used its remit to achieve two objectives:

- a narrower list than is currently available of key technology areas that CST considers Government should be focusing extra resources on within the five-year window
- a priority setting framework for decision-making that could be developed by Government in the future to make better choices between competing areas for technology funding

Approach

We should emphasise we did not start from scratch. We collated a long-list of over 100 technology areas from a variety of sources³ and assessed them first against the five-year timeframe and then against six criteria we developed: UK Technological Competitiveness; Market Size; UK Capacity to Deliver; Potential Societal Implications; Risks; and Government Interventions Needed. CST then made the final technology selection during a day-long facilitated workshop.

Our priority setting framework was developed over a short – three month – time period. We found there were a core set of questions and issues that must be addressed by Government when it makes decisions about priorities for support. Although we recognise that the framework needs to be developed further, we believe it is sufficiently adaptable that it could be developed for use in a wide variety of contexts where Government needs to identify science and technology priorities. It thus forms a starting point for discussion for when Government is next seeking to identify such priorities.

1 Interpreted as the technology having proven commercial feasibility within five years, with major market impact within ten. This means that the basic science will usually have already been completed.

2 UK Plc: Just How Innovative are we? Findings from the Cambridge-MIT Institute International Innovation Benchmarking Project, available from http://www.cbr.cam.ac.uk/news/160206_Report_only.htm; CST Barriers to Growth in SMEs Workshop March 2005

3 UK horizon scanning activities, the Technology Strategy Board; Dstl. EPSRC and S&T attachés overseas. Additional information on short listed technologies was collected from a wide variety of organisations and may be found at Annex B..

Technologies

In applying its priority-setting framework the CST considers that the technology areas in which a larger-scale focus by Government could accelerate the real returns for the UK within a five-year timeframe are:

- Carbon Capture and Storage
- Disaster Mitigation Technologies
- Low Carbon Distribution Networks for Electricity Generation
- Medical Devices
- E-Health
- Plastic Electronics

Of these six technology areas, we see Plastic Electronics and E-Health as being high risk/high reward. In other words, there is greater uncertainty compared with the other technology areas on whether the high rewards associated with these technologies can be delivered.

We also highlight four further platform or enabling technologies:

- Bandwidth Telecommunications
- Cell and Tissue Therapies
- Pervasive Systems
- Simulation and Modelling

The UK has great strengths in each of these four areas, which themselves underpin many other current or future technologies and sectors. They are currently receiving substantial investment which we firmly believe should continue.

The ten technology areas that we have highlighted are broad ranging and disparate, underlining the versatility of our priority-setting framework. It is not biased in any one direction and in particular delivers outcomes which span the whole UK economy – both in manufacturing and services sectors. This is important as the services sectors cover over 70% of the economy and comprise some of the highest value-added businesses.

Next Steps

The UK has great expertise across a very broad range of technologies. CST is clear that in prioritising certain technologies now Government should not divert resources into these technology areas at the expense of others, but rather should provide additional resources and remove barriers that might otherwise impede progress.

CST considered a wide variety of means by which Government could support each technology. These include: procurement mechanisms; regulatory and fiscal interventions; facilitating international collaborations and links between academia and industry; R&D investment; funding demonstration projects; and promoting public engagement. However, the work to identify these additional mechanisms was conducted during a necessarily short time frame and we recommend that a more in-depth study, including value chain analyses,

be carried out. This will optimise the choice and maximise the effectiveness of intervention in each area of technology. The appropriate bodies to carry out these analyses may include the Technology Strategy Board and Energy Technologies Institute.

We have road-tested our conclusions with senior figures from Government, business, academia and learned societies. We received strong support for both the priority setting framework and the choice of technology areas that it generated. We therefore have great confidence in the approach we have taken and the conclusions we have reached.

Summary Recommendations

CST's six recommendations fall into two categories:

- recommendations concerning the development of a priority-setting framework for decision making
- technologies that CST has identified where a greater focus by Government could accelerate the real returns for the UK within a five-year timescale

A Framework for Technology Priority-Setting

Recommendation 1: Government should make strategic decisions on setting technology priorities by means of a systematic priority-setting framework.

Recommendation 2: The following should be core elements of a systematic priority-setting framework:

- Clarity around the ultimate objective
- Consideration of whether the issue would be best approached by starting from a wide range of technology areas in a bottom-up approach; or a more top-down, systems approach (for example identifying grand challenges and considering the technologies required to meet them); or both
- A set of core criteria against which to measure the technology areas
- Clarity around the most appropriate breadth and scope of each technology being considered, and the utility of clustering cognate technologies prior to evaluation
- Access to high quality information for each of the short-listed technologies against each of the criteria
- A method for in-depth assessment of each of the technologies against each criterion
- A robust outcome capable of being road tested by key stakeholders
- Mechanisms to identify the most effective form of intervention in each case

Specific Application

CST has used the priority-setting framework to identify technologies where a greater focus by Government could accelerate the real returns for the UK within the five-year timescale⁴. This serves as a concrete example of how the framework can be applied in practice. Although it would need to be modified to suit different circumstances, we believe it is sufficiently adaptable so that a similar framework could be developed for use in a wide variety of contexts where Government needs to identify science and technology priorities.

⁴ CST interpreted this to mean that the technology must have proven commercial feasibility within five years, with major market impact within ten

We took a bottom-up approach involving:

- compiling a long-list of technologies identified from a variety of sources including UK horizon scanning activities, the Technology Strategy Board (TSB), dstl, Research Councils and FCO S&T attachés overseas.
- using three *go/no-go* criteria – (i) meeting the five-year timescale; (ii) a large potential market; and (iii) world-class technological expertise within the UK – to reduce the long-list down to a short-list of 24 technology areas.
- obtaining detailed information for each of the 24 technologies.
- assessing the 24 technologies against six key criteria: UK Technological Competitiveness; Market Size; UK Capacity to Deliver; Potential Societal Implications; Risks; Government Interventions Needed.
- finalising the technology selection by CST in plenary at a day-long facilitated workshop⁵.
- road-testing the conclusions with key stakeholders.

Priority Technology Areas

Recommendation 3: In applying its priority-setting framework the CST considers that the technology areas in which a larger-scale focus by Government could accelerate the real returns for the UK within a five-year timeframe are:

- **Carbon Capture and Storage**
- **Disaster Mitigation Technologies**
- **Low Carbon Distribution Networks for Electricity Generation**
- **Medical Devices**
- **E-Health**
- **Plastic Electronics**

Of these six technology areas, we see Plastic Electronics and E-Health as being high risk/high reward. In other words, there is greater uncertainty compared with the other technology areas on whether the high rewards associated with these technologies can be delivered.

Recommendation 4: There are four further key technologies which CST would highlight as platform/enabling technologies:

- **Bandwidth Telecommunications**
- **Cell and Tissue Therapies**
- **Pervasive Systems**
- **Simulation and Modelling**

⁵ There were some occasions in which one or more CST members had a declared interest in a technology under consideration. In such cases members did not take part in discussions where a decision was being made about a technology where they had a declared interest. A register of interests of CST members may be found at <http://www.cst.gov.uk/cst/about/interests.shtml>

The UK has great strengths in each of these four areas, which themselves underpin many other current or future technologies and sectors. They are currently receiving substantial investment which we firmly believe should continue.

Recommendation 5: We recommend that Government commission value chain analyses to identify the best forms of intervention in each of the chosen technologies. The appropriate bodies to carry out these analyses may include the Technology Strategy Board and Energy Technologies Institute.

This is a critical step since it involves identifying which are the critical parts of the value chain that the UK should aim to retain and the mechanisms that can be used to do so, in order to maximise the benefits to the UK. It would also identify whether the need for access to key complementary assets controlled by other firms affects where value added can be extracted/appropriated for the UK.

Recommendation 6: Government should set in place mechanisms to repeat this process at appropriate intervals, likely to be approximately every three years. The decision on which technologies to focus upon would be made on the basis of these periodically updated reviews.

1. Introduction

Government asked the Council for Science and Technology (CST) to advise on what would be the best areas to focus resources for science, technology and innovation which could lead to applications in around five years time⁶.

CST and Government both recognise that making choices between different technologies is both challenging and complex, particularly given the real strength and breadth of science and technology expertise that exists in the UK. Government must look across a very broad range of technologies and decide where and how to make its interventions. But if Government is to have a robust set of technology policies it needs to take tough decisions, and in order to make those decisions effectively requires a systematic mechanism.

CST therefore used its remit to achieve two objectives:

- a narrower list than is currently available of key technology areas that CST considers Government should be focusing extra resources on within the five-year window.
- a priority setting framework for decision-making that could be developed by Government in the future to make better choices between competing areas for technology funding.

This report begins by describing the development of the priority setting framework and how CST applied it to identify the technology priority areas in which a focus of Government resource is likely to produce the most significant results within the five year time scale. It then moves on to deal with each technology priority area in turn, detailing the rationale and specific recommendations for interventions for each. The report concludes with an evaluation of how the framework could be further improved, including feedback given to CST by stakeholders.

A case study on Plastic Electronics, one of the technologies selected as a priority area, is included as Annex E to the report. The case study builds on the work of the main report, focusing particularly on how Government has supported the development of the technology in the UK and what interventions might be necessary to support the technology further.

⁶ CST interpreted this to mean that the technology must have proven commercial feasibility within five years, with major market impact within ten. This means that the basic science will usually have already been done.

2. A Framework for Technology Priority-Setting

Stage 1: The initial process

CST consulted with a number of organisations on how they selected which technologies to support:

- The Technology Strategy Board, which funds projects through a variety of means, including Collaborative R&D programmes and Knowledge Transfer Networks.
- Research Councils, which fund Integrated Knowledge Centres to support research and industry in areas of emerging technology.
- The Department of Innovation Universities and Skills' Horizon Scanning Centre which has established the Wider Implications of Science and Technology (WIST) programme to anticipate the impacts of future technologies.
- MoD's Defence Science and Technology Laboratory (dstl), which identifies technologies that may be of interest to MoD.
- The Foreign & Commonwealth Office's Science and Technology attachés in the USA, Japan and Singapore, who were asked how each of these countries approached this issue.

This round of discussions allowed CST to develop a process for the prioritisation of technologies, which was used for this project. CST found this process to be a flexible and powerful means for the assessment of technologies. CST recommends that the process itself is one of the important outcomes of this piece of work that may be useful in the future to the Government and others interested in the evaluation of technologies.

The key steps in the process are described below, with our evaluation of the process being given on page 32.

Stage 2: Compiling a 'long list' of technology areas

Each of the organisations consulted above provided a set of technology areas that they had considered for funding, or in the case of the Horizon Scanning Centre, had identified for consideration of their future impacts. After common technologies were amalgamated, a 'long list' of over 100 technology areas was drawn up. These were clustered under six major themes: biosciences, advanced materials, advanced manufacturing, energy and environment, information and communications technology and security.

Stage 3: Sifting the 'long list'

Small teams of CST members were brought together to assess technologies on the long list according to three *go/no-go* criteria which Government had made clear were important:

- i. the technology would be likely to deliver applications within the five-year timescale
- ii. the technology would have a potentially large market size
- iii. world class technological expertise existed in the UK

Out of the 100-plus technology areas, twenty-four were short-listed on the basis of these criteria. A description of each of the short-listed technologies is given at Annex C. CST provided feedback to those who had put forward technologies that were not included in the short-list and no objections were raised.

Stage 4: Detailed assessment of short-listed technologies

Based on the remit given to it by Government, and from consultation with other bodies (TSB, Dstl, EPSRC and the CBI), CST developed a set of criteria on which to assess each of the 24 short-listed technologies:

- i. UK Technological Competitiveness
- ii. Market Size
- iii. UK Capacity to Deliver
- iv. Potential Societal Implications
- v. Risks
- vi. Government Interventions Needed?

CST framed a set of questions around each criterion (see Annex A). These criteria and questions were sent to a wide range of organisations (see Annex B) asking for detailed data for each of the twenty-four technologies. Desk research supplemented the exercise. The information for each technology was compiled, with sources referenced.

Stage 5: Final selection of technologies

A facilitated workshop was held with CST members to develop a list of technologies for recommendation to Government. Using the evidence from the information gathering exercise, members ascribed a rating of *high/medium/low* to each criterion for each technology. To give consistency across the resulting matrix, the guidance for a *high* marking against each criterion was defined as:

- i. UK technological competitiveness
UK has a scientific and technological competitive advantage in both the science base and private sector R&D activities, relative to other countries, on which commercialization could build
- ii. Market size
Estimated world market in ten years greater than £100 billions, with a clear indication of possible products and services that would result. (Medium was market size between £10 billions and £100 billions; low under £10 billions.)
- iii. UK capacity to deliver
UK has the necessary commercial infrastructure, in the form of businesses, structures and people, to develop leading market shares in the markets identified

iv. Potential societal implications

The technology has strong, positive implications for one or more important societal areas related to the Government's five Comprehensive Spending Review (CSR) challenges⁷: demographic and socio-economic change; the intensification of cross-border economic competition; the rapid pace of innovation and technological diffusion; continued global uncertainty with ongoing threats of international terrorism and conflict and the continued imperative to tackle global poverty; increasing pressures on our natural resources and global climate.

v. Risks

The technology has comparatively low risks associated with the UK being able to develop a leading market position in this area. A technology considered to be high risk was not necessarily ruled out – the risks were considered in context with the rewards and strengths (as demonstrated by the other criteria) in making the final selection.

vi. Government interventions needed?

There exist key constraints or market failures that are preventing the technology from reaching its potential in the UK and the constraints must be of the form that justify and could be effectively addressed by Government intervention.

On completion of the matrix, members selected the technologies which had scored most favourably for inclusion on the list to recommend to Government. The results of the workshop were collectively agreed by CST⁸.

Stage 6: External 'road testing'

The outcomes in terms of the process itself and the chosen technology areas were road-tested at a series of meetings with high-level stakeholders – senior business representatives, academics and officials. The aims of the meetings were to test whether the invitees were confident in the priority-setting framework by which CST reached its conclusions and to seek their opinions both on how it might be improved and how it could be best embedded within Government. A note of CST's road-testing meeting is at Annex D.

Stakeholders were rightly challenging about various aspects of the priority-setting framework and technologies and contributed a number of valuable points on how the process could be improved. There was strong agreement that the next steps should be a more in-depth study of each of the chosen technologies, including a value chain analysis.

Overall, stakeholders expressed very strong support for the project. Confidence was expressed that the criteria and sub-criteria considered were appropriate and that the process worked well as a systematic framework for priority-setting.

There was also considerable support for the technology areas that CST had selected. No-one identified any gap that CST had missed.

7 See http://www.hm-treasury.gov.uk/spending_review/spend_csr07/spend_csr07_longterm.cfm

8 There were some occasions in which one or more CST members had a declared interest in a technology under consideration. In such cases members did not take part in discussions where a decision was being made about a technology where they had a declared interest. A register of interests of CST members may be found at <http://www.cst.gov.uk/cst/about/interests.shtml>

3. Priority Technology Areas

Summary

It is very clear that there is a real strength and breadth of expertise within the UK across a very broad range of technologies. This is a necessary complement to the strength of the UK's Science Base. In identifying a small number of technology areas we would like to emphasise that this does not mean that resources should be diverted into these technology areas at the expense of others currently being supported. Indeed, the areas CST has identified are already the subject of significant amounts of Government support. CST is therefore proposing that where further resources become available, they should be focused on the technology areas that CST has identified.

Nor are we suggesting that devoting extra resources should merely be thought of in monetary terms. It is clear that there are a range of interventions other than financial that Government could make: for example regulatory improvements, better use of public procurement or improving connectivity across the technology sector. A key next step is to carry out value chain analyses – at a fairly granular level – in the chosen technology areas. This is a critical step since it involves identifying which are the critical parts of the value chain that the UK should aim to retain and what mechanisms can be used to achieve this, in order to maximise the benefits to the UK. It would also identify whether the need for access to key complementary assets controlled by other firms affects where value added can be extracted/appropriated for the UK. Appropriate bodies to carry out this analysis may include the Technology Strategy Board and the Energy Technologies Institute.

CST considers that the technology areas where a larger-scale focus of Government resource could accelerate real returns for the UK and thereby produce the most significant results within the five-year timeframe are:

- **Carbon Capture and Storage:** technologies which allow fossil fuels – especially coal and gas – to remain as major components of the power generation mix without adding further to atmospheric CO₂ emissions.
- **Disaster Mitigation Technologies:** measures designed to prevent, predict, prepare for, respond to, monitor and/or mitigate the impact of disasters such as earthquakes, tropical cyclones and flooding.
- **Low Carbon Distribution Networks for Electricity Supply:** the development of new grid technologies is vital for enabling and stimulating large-scale, local electricity generation by renewable and other low carbon technologies as well as stimulating consumer participation.
- **Medical Devices:** technologies, devices and combined systems to provide for improved healthcare, targeting prevention, diagnosis, treatment and rehabilitation.
- **E-Health:** health services, information and research delivered or enhanced through the internet and related technologies.
- **Plastic Electronics:** a new generation of materials and products which have applications in a large range of areas, including computer and sensing technologies, displays, photovoltaics and communication systems.

Of these six technology areas, we see Plastic Electronics and E-Health as being high risk/high reward. In other words, there is a greater uncertainty compared with the other technology areas on whether the high rewards associated with these technologies can be delivered.

The list is very heterogeneous, which is perhaps not surprising given the broad range of technological expertise across the UK.

In addition, the Council wishes to highlight four further technologies as being platform or enabling technologies. All four technologies are areas in which the UK has great strengths and which underpin many other current or future technologies/sectors – our view is that the UK needs to maintain or enhance its strength in these four areas:

- **Bandwidth Telecommunications:** massively increasing bandwidth in the home, workplace and on the move.
- **Cell and Tissue Therapies:** advances in biology that allow the generation of new tissue types to replace damaged tissues and organs or the production of advanced biopharmaceuticals for human healthcare. This is very much at the upper time-limit of the Council's five-year timescale; however, continued investment now is vital as it will be a platform for many of the future developments in medical science.
- **Pervasive Systems:** an environment with billions of intelligent or preprogrammed devices in a networked environment, providing people with services and information.
- **Simulation and Modelling:** development of hardware, underpinning mathematical algorithms and software to model complex physical, chemical, biological, societal, financial and other systems.

These technologies are all vitally important for many sectors of the economy. They are currently receiving substantial investment which CST firmly believes should continue; however, it is not immediately clear what additional interventions – beyond maintaining the current support and investment – should be made.

Government should continue to support all of these technologies at least at current levels, and monitor carefully to ensure their continued development.

Rationale for the Selected Technologies

Carbon Capture and Storage

Definition

Carbon Capture and Storage (CCS) may allow fossil fuels – especially coal and gas – to remain as major components of the power generation mix without adding further to CO₂ emissions. Carbon capture is the removal of CO₂ from fossil fuels either before or after combustion. Carbon storage is the long-term storage of carbon or CO₂ in the forests, soils, ocean, or underground in depleted oil and gas reservoirs, coal seams and saline aquifers. An example of CCS technology is carbon sequestration whereby gases that are contributing to climate change are captured from power stations, separated and stored in suitable porous rock layers deep underground. Due to the five-year time scale being considered, this technology is considered to be limited to CCS from electricity generation, not from smaller scale applications such as vehicle emissions.

Rationale

The UK market in 2012 is estimated at £2 billions with a world market of £150 billions⁹. The UK has a clear potential to be a world leader with strong academic and commercial sector expertise. Fourteen Universities and the British Geological Survey (BGS) are organised together to form the Carbon Capture Storage Consortium to coordinate activities on CCS in the UK whilst the Scottish Centre for Carbon Storage Research between the University of Edinburgh and Heriot-Watt University with the BGS combines expertise in Scotland.

The commercial sector is actively pursuing research, demonstration and commercial deployment of CCS. UK industry has proposed a number of large-scale demonstration projects in the UK for power generation with CCS, all of which are currently in the study/evaluation phase. Collaborative R&D is supported by the Technology Strategy Board, with BERR providing some additional funding for smaller demonstration projects under its Hydrogen, Fuel Cell and Carbon Abatement Technologies Demonstration Programme.

The UK has a vibrant offshore oil industry with a strong supply chain and so is well positioned to realise offshore CCS demonstration projects. A large proportion of the value to the UK is most likely to be in the contracting services businesses. Industry players in the UK have formed the Carbon Capture and Storage Association which now has 45 companies in manufacturing & processing, power generation, engineering & contracting, oil, gas & minerals as well as a wide range of support services to the energy sector such as law, banking, consultancy and project management.

CCS is widely regarded as a critical technology in reducing CO₂ emissions to combat climate change, given the predicted significant role for fossil fuels throughout this century. It is therefore a core element of UK Energy policies. CCS would also have positive implications for international relations and pressure on resources. Coal is more abundant and its supply less politically sensitive than gas. CCS offers the UK a unique opportunity to build on its leadership position internationally, particularly with China and India, two of the most important countries to influence on reducing emissions to solve the climate change problem. The UK is already involved in a demonstration programme in China.

⁹ Edinburgh University and the UK Energy Research Centre, see http://www.geos.ed.ac.uk/ccs/Questions_and_Answers/Business_questions.html.

There is a clear role and justification for Government intervention. Representations to CST have made clear that the current price for carbon in emissions trading schemes does not give a sufficiently stable or long-term signal to facilitate medium-range investment planning for CCS; and that in the short term other incentives – such as funding for a range of demonstration projects – would need to be established to sustain the UK's leadership position in this area¹⁰.

Other nations are investing heavily in CCS. In the US, the Department of Energy is providing substantial support for Carbon Sequestration Research and Demonstration activities including over \$800 millions (£400 millions) for the Futuregen CCS demonstration project and \$100 millions (£50 millions) for the next phase of the Carbon Sequestration partnerships which will include a range of demonstration projects. In addition demonstration and deployment of clean coal technologies in USA, including CCS, will be supported under the US EACT through tax credits (\$1.6 billions (£800 millions)), loan guarantees (\$9 billions (£4.5 billions)) and direct grants. In Europe the EC has announced a goal of up to 12 demonstration projects by 2015, although it is not clear at present how these will be achieved. Australia, Norway and Canada have all announced their intentions to support large scale demonstration projects.

Actions Needed

CST considers there are two major areas where Government intervention is required: first there is a need to establish the long-term regulatory and fiscal environment to enable demonstration and deployment of large-scale CCS projects; and second, Government funding to support large-scale system demonstrators.

On regulation, CST is encouraged by Government's commitment in the Energy White Paper to developing the regulatory framework, including its previous establishment of the CCS Taskforce to examine the regulatory framework that will facilitate CCS. The Task Force is clarifying existing UK regulation and its application and is identifying the need for new regulation, including the licensing of carbon dioxide storage sites and the decommissioning and long-term liabilities associated with storage facilities. There is also a need for work on risk assessment of long-term storage of the sequestered CO₂.

Significant progress has been made recently, including the amendment in December 2006 of the 1996 Protocol to the London Convention and the amendment in June 2007 of the OSPAR Convention, which help to enable the storage of carbon dioxide in sub-seabed geological formations. Primary legislation is planned by BERR this autumn to lay the framework for CCS on the UKCS. CST commends Government for its actions so far and encourages it to continue its commitment to establishing the regulatory frameworks for the implementation of CCS.

On demonstrators, the Energy White Paper announced Government's intention to launch a competition to develop the UK's first full-scale CCS demonstration. CST considers this to be a positive step but considers that if the UK is to be a global leader in CCS the focus ought to be on system demonstrators i.e. showing that the technology works through a continuous cycle 24 hours a day seven days a week. It will be important that the outcomes

¹⁰ This need has been recognised by Government in the Energy White Paper (June 2007). Section 5.4 – Cleaner Coal and Carbon Capture and Storage for Fossil Fuels, acknowledges that 'it is likely that CCS would not be commercially viable unless costs fell substantially relative to the cost of other cheaper forms of generation, or unless the carbon price rose sufficiently to provide a larger financial incentive...the UK and the EU are working towards commercial-scale demonstration and deployment of CCS, in order to bring down the costs and to help make the technology commercially viable.' See <http://www.dti.gov.uk/energy/whitepaper/>.

from Government-funded demonstrators should be made as widely available as possible. There is a case for supporting multiple demonstrators as there are a range of technologies (including different capture systems, transport systems, geological storage systems) that require developing – for example post-combustion or pre-combustion extraction, coal or gas, building new power stations or retrofitting existing ones. We recognise, however, that demonstrator projects are very expensive, typically around £1 billion. We would therefore propose that the initial focus should be on pre- and post-combustion and that financial clawbacks or similar mechanisms should be built in.

Given the costs of demonstrators, this is an area where international collaboration may be important. However, Government should not underestimate the time and effort needed to get agreement between collaborative partners; this may be a less attractive option given the need for the UK to move quickly. In addition, in many collaborative projects of this nature the majority of benefits are likely to be captured by the host country and so, before entering collaborations, Government should be clear about where and how benefits are likely to accrue to the UK.

The window of opportunity in which Government action can secure the UK's lead on CCS is, therefore, narrow. Heavy investment by other nations means the Government must act with urgency if the UK is to sustain a position of leadership. A cross-Government approach involving BERR, Defra, and the Energy Technologies Institute will be important.

Disaster Mitigation Technology

Definition

Disaster mitigation covers measures designed to prevent, predict, prepare for, respond to, monitor and/or mitigate the impacts of disasters, such as earthquakes, tropical cyclones, volcanic eruptions, major storms and coastal and inland flooding. It requires a range of soft technologies including a monitoring/predictive component: for example earth monitoring from satellites and earth-based stations (e.g. geophones) and predictive modelling of surface events and their physical and social consequences, both to estimate prior vulnerability to disaster as a basis for planning and to provide real time assessments of impacts in any disaster. It requires planning and implementation of response systems, including disaster resilient communications systems and logistics algorithms. It greatly benefits from inter-agency and inter-governmental agreements. It also involves the hard technologies of engineering-based mitigation systems such as earthquake-proof buildings and tsunami deflectors. Knowledge-based consulting, financial services including risk consultancy and insurance are vital support processes¹¹.

Rationale

The UK possesses world class capability in many areas of disaster mitigation technology including earth observation, meteorology, oceanography, seismology, volcanology, hydrology, earth system modelling, risk assessment and communications. Its leading private sector finance and insurance companies give it expertise in disaster resilience and risk, with networks including the Willis and Lighthill Research Networks. EPSRC provides funding of £50 millions per year. Natural hazards will be one of NERC's research themes when it announces its strategy in October 2007. A recent *Universities UK* report proposes a national scheme for coordinating university and humanitarian charitable work in disaster relief¹². The insurance sector has begun to engage with the science and technology of disaster risk, rather than merely using the pattern of past risk as a guide to premiums. Major disasters such as Hurricane Katrina and recent English flooding have reinforced this trend.

The UK's position as a world leader in finance and insurance with a strong civil and military technology base gives it an excellent capacity to deliver. The UK has world-class facilities in communications, earth observation and climate and weather research; focused support for Disaster Mitigation Technology will at the same time build on and stimulate UK niche strengths in the area of Advanced Satellite Technologies. The UK is also extremely well-placed in international networks including the World Health Organisation, World Meteorological Organisation and Global Seismological Network, with the Department for International Development (DfID) providing approximately £15 millions a year to support the work of such organisations.

There are two components of the market. The first is one of primary demand for forecast, mitigation, rescue and recovery technologies, which may not be as large as for the other technologies recommended. However, the secondary market for knowledge as a basis for insurance is large and growing. The global impacts of disasters are already exceeding \$100 billion (£50 billion) in some years and have been increasing exponentially¹³, with the potential impacts of climate change measured in the trillions¹⁴. Mitigation and resilience is

11 CST description. Technology initially identified in Japanese Council for Science and Technology Policy 3rd Basic Plan.

12 See <http://www.glos.ac.uk/faculties/ehs/sciences/ukdrp.cfm>

13 Location and Timing Knowledge Transfer Network.

14 Stern Review Report on the Economics of Climate Change available at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

a multibillion pound market and similarly increasing exponentially¹⁵. The same technologies and capabilities used to respond to natural disasters can also have applications in responding to and mitigating the effects of man-made disasters.

In addition, CST found that the very high societal benefits make this technology a priority area. Benefits accrue in all 5 areas of the 2007 Comprehensive Spending Review challenges, including the prevention of disaster and refugees from climate change. There are also direct benefits to the UK in the areas of flooding and coastal defence, where there will be a substantial home market with billions of pounds at risk.

Disaster mitigation technology is likely to become increasingly important, particularly as an ever-greater proportion of the global population lies in areas at risk of disasters and disasters are being predicted to continue to increase in frequency with climate change. More development and leadership by the UK will improve our world standing and help build international links.

Actions Needed

Disaster mitigation technology is an area which CST considers that moderate Government interventions could have significant impact. These should have two dimensions: stimulating better connectivity across the sector in the UK, and developing the UK's engagement in international systems.

CST recommends that the Government consider the establishment of a Disaster Resilience Knowledge Transfer Network (KTN) to improve commercial connectivity within the sector. This would facilitate the rapid movement of existing technologies from research and small-scale applications to, in particular, the engineering export sector and the financial sector¹⁶, as well as the aid/charity sector¹⁷. The KTN's role in promoting knowledge transfer and innovation would be highly complementary to the current coordinating work of the Cabinet Office. Transfers of knowledge would be accelerated through the provision of easy and cheap access to fundamental data that provides the underpinning infrastructure for an expanding market, including information generated by the Ordnance Survey, Met Office, Environment Agency, satellite observation and public sector research establishments.

Internationally, Government should increase its efforts to promote UK engagement in developing international systems. This would build on the UK's existing strong links into international networks including the World Health Organisation, World Meteorological Organisation and Global Seismological Network. The Government could also consider a more determined effort to embed disaster mitigation in its aid for developing countries, where natural disasters have the capacity to seriously set back the development process. The Department for International Development's paper *Reducing the Risk of Disasters* (2006)¹⁸, makes clear that disaster mitigation is an integral part of that department's agenda – a very encouraging move.

15 Location and Timing Knowledge Transfer Network

16 See CST's work on improving connectivity between the university and services sector. (2006) <http://www.cst.gov.uk/cst/reports/>

17 The UK HE Disaster Relief Project (July 2007) similarly calls for greater connectivity between the UK Higher Education sector and humanitarian agencies, see <http://www.glos.ac.uk/faculties/ehs/sciences/ukdrp.cfm>

18 *Reducing the Risk of Disasters – Helping to Achieve Sustainable Poverty Reduction in a Vulnerable World: A Policy Paper*; see <http://www.dfid.gov.uk/pubs/files/disaster-risk-reduction-policy.pdf>

There is a role for Government in regulation and policy, including in standardisation, promoting the interoperability of systems and safeguarding radio spectrum availability. One of the challenges is ensuring these regulations are implemented and monitored and Government must continue to provide support to other nations in this area. Government also has a role promoting activities that might not be a priority for commercial organisations (e.g. targeted warnings for flooding incidents), encouraging military-to-civil technology transfer (e.g. sensors, communications) and promoting and coordinating use of new technology by the emergency services.

Government leadership will be needed to coordinate and implement prevention and resilience activities on a national scale. A strong policy announcement that disaster mitigation technology is a priority area across Government as a whole, will help drive an expansion of UK capability to both relieve suffering and to place the UK at the forefront of capitalising on the opportunities that the expanding threats from disasters and climate change provide.

Low Carbon Distribution Networks for Electricity Supply

Definition

The existing Grid is based on large central power generators with passive distribution networks that have very little in-built intelligence and are designed for 'one-way' power flows. This acts as a significant blocker for new, low carbon, small-scale technologies coming on stream – resulting in 'reverse flows' on the networks. Reinvigorating the grid would facilitate the development of microgeneration technologies including solar and micro-wind turbines¹⁹, as well as fuel cells, combined heat and power (CHP) and heat pumps. This technology is considered to include the IT, software and control systems required for active network management technologies, including advanced controllers, power electronics and communications.

Rationale

Low carbon distribution networks are vital for enabling large-scale, local electricity generation by renewable technologies to combat climate change. They also allow greater flexibility for local generation by conventional means. The development of the Grid will stimulate the development of renewable technologies including solar and wind, as well as by fuel cells, CHP or heat pumps. Other benefits include increasing the efficiency and flexibility of electricity generated by conventional power station generation and reducing losses through transmission.

The IEA 2006 World Outlook figures suggest global expenditure on transmission and distribution networks of \$20 trillions (£10 trillions) from 2005 to 2030 (this is an increase of \$3 trillions (£1.5 trillions) over the 2005 estimate). This is based on the reference scenario (business as usual) for energy supply, of which about 60% relates to electricity generation and supply. UK expenditure on transmission and distribution networks over the current five year price control period will amount to £10 billions²⁰. Establishing world leadership position in network development would reap substantial rewards for the UK as countries around the world begin to follow a pathway to a low carbon economy.

The widespread adoption of low carbon distribution networks will enable energy consumers to become energy producers, with potentially significant implications on energy awareness and behaviour. Customer participation in energy delivery and management could provide substantial societal benefits including:

- Overall demand reduction
- Increased efficiency of energy usage
- Lower network electrical losses
- Increased awareness of energy (and carbon) cost
- A potential cultural/behaviour change driver as the population increasingly seek engagement and participation in measures to protect their environment

¹⁹ An electricity supply strategy for the UK (May 2005) <http://www.cst.gov.uk/cst/reports/#9>

²⁰ Ofgem figures

The UK has a very strong technological competitiveness and capacity to deliver. It is already respected as a 'thought' leader in this area; in particular innovation in technical applications, commercial and regulatory models, and environmental impact analysis. The UK university research base is strong with an effective culture of collaboration. There has also been a significant increase in private investment in research in the last two years.

The design and development of a UK low carbon distributed network (technical) architecture is unlikely to become reality in the timescales required if left to market forces alone. Government is arguably the only agent that can facilitate such a major development of the electricity network and its intervention is needed now if the UK is to achieve global leadership.

Government has acknowledged this need in the Energy White Paper (June 2007). *Chapter 3 – Heat and Distributed Generation* states that Government's role is to ensure that "new market opportunities are identified, that the market and regulatory environment is 'user-friendly' for smaller participants, that potential barriers are identified and addressed, and that genuine market failures are resolved." CST agrees with this statement and is pleased to see that the White Paper echoes the recommendations made by CST in May 2005²¹ that development of the distribution and transmission networks, their protection mechanisms and metering systems to facilitate distributed and diverse generators – ranging from commercial to domestic units – and addressing the regulatory issues arising from this form of generation should be an urgent priorities for Government.

Actions Needed

The primary interventions that have been recommended to CST concern regulation, standards and continued R&D investment. Many of these issues are discussed in the Energy White Paper; CST highlighted them in its earlier report,¹² where we pointed out that urgent reinvigoration of the Grid should be made a priority, including moves to actively managed distribution networks to enable low carbon generation to be successfully brought on-stream. If Government is to deliver the low carbon commitments of the Energy White Paper it will need to be a major customer in this technology as well as a thought leader.

There is therefore a need for a consistent 'joined-up' Government policy framework combined with light touch regulatory instruments. This would require a coherent approach between the Government and the Regulator to ensure consistent, predictable support that the sector can make plans around, to provide the required direction and incentives.

As discussed in paragraph 3.42 of the Energy White Paper, smart metering will be key to the overall development of this technology, in particular in enabling the use of sophisticated, dynamic tariffs. Smart and decentralised networks may need specific attention by Ofgem, as currently there is a break point in the regulatory frameworks for generation less than 50MW. CST considers it likely that regulatory intervention will be required if wide-spread use of smart meters is to be adopted. CST also considers that planning and building regulations will play a significant role in driving the adoption of distributed networks, as acknowledged in the Energy White Paper. In addition to these actions, CST supports Government's statement that "the public sector has a role to play in promoting [distributed energy]" and considers that Government procurement in this area could help to drive the development of this technology.

²¹ An electricity supply strategy for the UK (May 2005) <http://www.cst.gov.uk/cst/reports>

There is also a role for additional targeted Government support for R&D – for example through the Energy Technologies Institute – in order to generate the required pull-through environment that would accelerate the development of the market and in providing incentives for commercial players to invest. Network innovation is unusual in that new technology has to be proven on the ‘live system’ so network company engagement from an early stage is a prerequisite for success. Government also has a role in covering risk as more innovative technologies are trialled, just as it did when the grid was initially established.

Overall, CST commends the commitment to low carbon distribution networks in the Energy White Paper: in particular the plans to improve awareness, introduce more flexible market and licensing arrangements, provide clearer export rewards for smaller generators and to facilitating connections for distributed generators.

If the UK is to achieve global leadership in this technology, a clear Government commitment and focus on this area is necessary now. Technology-proving and accelerated commercialisation will require the engagement of the network companies and other parties; Government will need to signal the priorities and ensure adequate incentives and risk mitigation measures.

Medical Devices

Definition

Medical biotechnology and medical devices include technologies, devices, and combined systems to provide for improved healthcare targeting prevention, diagnosis, treatment, and rehabilitation. Such technologies increasingly need multi-disciplinary solutions encompassing biology, physics, materials, engineering, mechanics, and IT. New technologies can act as enablers to deliver novel medical device products, to support new treatments for specific disease morbidities and enable a higher quality of life for all.

Key technology priorities identified by the medical device industry include: converging technologies encompassing intelligent implants, remote sensing, functional imaging; diagnosis and screening technologies for targeted therapies, early health monitoring compliance; regenerative medicine for tracking cells, tissue/organ engineering, advanced biomaterials; assistive technologies to include wearable diagnostic tools, wireless technology for home monitoring and human equipment interface²².

Rationale

The global market for medical devices is £120 billions plus a further £23 billions for the diagnostics market. The UK market, at £5.4 billions (2004)²³ is the fourth largest market in Europe, behind Germany, France and Italy²⁴. Healthcare markets are growing at 7-12% per year and medical devices are identified as high value added products with potential for good margins²⁵. The estimated market by 2015 is £240 billions²⁶. The technology offers direct societal benefits in better treatment and improving health for all, and also contributes strongly towards active aging by enabling the disabled and elderly to continue working/enjoying a high quality of life.

The UK benefits from a broad base of academic excellence in many of the fields on which medical devices depend including biomaterials, biomedical engineering, bionanotechnology, tissue engineering, biosensors, microsystems, manufacturing, regenerative medicines and photonics. Particular world-leading strengths lie in imaging, diagnostics, orthopaedics and innovative interdisciplinary devices. Industrial funding for R&D was over £250 millions in 2005/2006²⁷.

The Government has been strongly supportive of the area, with activities including establishing the Knowledge Transfer Network (and Faraday Partnership previously) and calls on Regenerative Medicine, Sensors and Bioactives. Funding in 2006/07 was around £120 millions from EPSRC and £8 millions from BBSRC. The Research Councils fund Interdisciplinary Research Collaboration in Medical Imaging and Signals and in Tissue Replacement and Regeneration. The Technology Strategy Board is launching an Innovation Platform in assistive technologies. Two funding streams in the NHS fund medical device research – New and Emerging applications of Technology (NEAT) and Healthcare Technology Devices (HTD).

22 Technology Strategy Board Key Technology Area: Bioscience and Healthcare

23 Innovation for Health: Making a Difference (Report of the Strategic Implementation Group of the Healthcare Industries Taskforce, March 2007)

24 Technology Strategy Board Key Technology Area: Bioscience and Healthcare

25 Technology Strategy Board: Bioscience and Healthcare Key Technology Area

26 Health Technologies Knowledge Transfer Network.

27 Innovation for Health: Making a Difference (Report of the Strategic Implementation Group of the Healthcare Industries Taskforce, March 2007)

The UK has a strong medical device and diagnostics sector that benefits from world players with R&D bases in the UK (Smith & Nephew, Johnson & Johnson, GE Healthcare); world players that have activity in the UK (Guidant, Medtronic, Smiths Industries), medium size indigenous companies that are in growth areas of the market (Gyrus, Bepak) and a large number of innovative small companies that offer a route to de-risk new and exciting technologies, such as Oxford Biosensors and Oxford BioSignals. Overall, in 2005 there were approximately 2000 medical devices manufacturers in the UK. The UK also has a well-regarded legislative landscape and one of the most trusted medicines control agencies globally. CST's view is that medical devices are the lowest risk of all the biomedical technologies we have considered, with risks primarily centring around the size of UK companies compared to their US competitors. By comparison, these are SMEs and not large companies, with the consequence that the UK industry is much more fragmented.

The potential of the NHS to act as an intelligent market to stimulate innovation is also a potential UK strength; however, this potential is currently not being fulfilled, to the detriment of the UK medical devices sector²⁸. The Wanless report (2002)²⁹ emphasised that the NHS was a "late and slow adopter of medical technology, lagging behind comparator countries in both pharmaceuticals and "big ticket" items such as scanners and radiotherapy equipment": The challenge is to get a culture of innovation and early adoption of technology embedded within the NHS as a whole. If the situation is to improve, there must be a recognition that the medical devices sector is substantively different from the pharmaceutical sector. In particular, innovative medical devices companies, many of which are small, currently face difficulties in entering the NHS market. This lost opportunity caused by current NHS procurement practices must be overcome and the major challenge is to find ways of doing so.

Actions Needed

CST's view is that medical devices is an area where significant benefits could be gained with only moderate financial Government interventions. One important intervention would be the use of Government procurement by the NHS to stimulate innovation and development. CST's paper on public procurement (2006)³⁰ describes in more detail the type of action that would be needed. We would like to see the Department of Health/NHS pilot a procurement process in medical devices.

It is important to recognise the distinction between DH and the NHS. Although there is some recognition within DH of the importance of the innovation agenda with a number of enablers having been put in place to support innovation at the national level, within the NHS there is little sign yet of material positive impact on attitudes and behaviours. Realising the potential benefits of the NHS will require major initiatives in objectives, reward structures and practice behaviours, as well as in procurement.

Government has a valuable role in improving connectivity throughout the sector. This could include improving the linkages between academia and industry, as well as improving linkages between companies and the market. We would reinforce the TSB's approach of Innovation Platforms as an important means of bringing together key players in business, universities and Government. We also support the Healthcare Industries Task Force's call³¹

28 Discussions with Sir Chris O'Donnell, Chair of the Health Industries Task Force

29 Securing our Future Health: Taking a Long-Term View, available at http://www.hm-treasury.gov.uk/consultations_and_legislation/wanless/consult_wanless_final.cfm

30 <http://www.cst.gov.uk/cst/reports/>

31 See Innovation for Health: Making a difference (March 2007), available at http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_072655

for a stock take of existing support mechanisms for SMEs with a view to publicising these more effectively and reviewing the need for any additional measures. Other interventions that have been suggested to CST include assisting industry to diversify into new areas by supporting skills development, sharing risk, and higher investment in developing infrastructure and increasing the sector profile to attract private venture investment.

CST considers that more work is needed on clarifying the precise form of interventions. A starting point should be a value chain analysis to identify exactly where the benefits to the UK lie.

E-Health

Definition

E-Health is an emerging field at the intersection of medical informatics, public health and business, and covers health services and information delivered or enhanced through the internet and related technologies. The concept is a network using information and communication technology to improve health care locally, regionally, and worldwide. The focus has been taken to be on the *Connecting for Health* agenda; however, there are many other significant technologies encompassed by E-Health, including including telemedicine, design and delivery of advance information acquisition and management systems, patient monitoring, treatment validation and interface system.

Rationale

The potential of E-Health is large: the European E-Health market was worth approximately \$3.2 billions (£1.6 millions) in 2005 and is predicted to double to \$6.3 billions (£3.2 billions) by 2010³². It is important to emphasise that the value of E-Health lies not only in the size of the market. The societal benefits are also significant, with improvements in clinical care for and the improved safety of medical interventions. Successful implementation of E-Health could, by enabling the monitoring of the entire population's reaction to new treatments (essentially clinical trials on a national scale), contribute strongly to making the UK a more attractive place for the pharmaceutical industry – an industry which is of great importance to the UK economy. E-Health also acts as an enabler for medical research.

UK skills in a wide spectrum of IT fields should help to stimulate many areas of E-Health, including telemedicine, design and delivery of advance information acquisition and management systems, patient monitoring, treatment validation and interface system. There are also strong synergies with Medical Devices, with the wiring up of devices and diagnostics in the community potentially leading to new care pathways at the Medical Devices/E-Health interface.

The NHS gives the UK a unique opportunity to develop and exploit this technology. There are few countries in which a single organisation holds the entire nation's medical records. Currently the UK has a competitive edge in the development of a national E-Health programme that can be developed to allow the appropriate use of the information to improve patient health and safety.

The Department of Health and NHS *Connecting for Health* have been working with the UK Clinical Research Collaboration (UKCRC) to investigate the potential for achieving significant benefits for UK research activities through the NHS Care Records Service. The MRC has invested £21 millions since 2000; EPSRC invests around £10 millions per annum. E-health has been a major research activity supported within the EU Framework Programmes where €500 millions (£350 millions) has been provided within the last two decades in support of the development of a European eHealth Action Plan³³. The Technology Strategy Board is launching an Innovation Platform in assistive technologies in which areas such as telemedicine are relevant to E-Health.

32 <http://www.e-healthexpert.org/node/105>

33 See: 'Clinical trials will suffer if electronic system is delayed' BMJ 2007;334:1132; http://ec.europa.eu/information_society/activities/health/index_en.htm

Actions Needed

The Council sees significant risks in at least three areas. First, there are concerns over how quickly it will be possible to embed this technology within the NHS. Second, there are risks that UK businesses – largely SMEs – will be unable to compete in the global market with the larger multinational IT solutions' providers. This does not only apply to software for the NHS – major companies including Google and Microsoft are currently vying to win a share of the online E-Health market. Third, a number of concerns have been raised around security of data; anonymity; privacy; the type of data being sought; and the perceived relevance and potential benefits of the research. These concerns must be managed and overcome if the technology is to reach its full potential.

If the UK is to maintain its world leadership in E-Health then Government, and in particular the Department of Health, must continue to ensure that the necessary infrastructure and governance arrangements are in place, and that researchers and clinicians are fully engaged as the process is developed.

One key requirement to enable patient record linkage and improve data quality and patient safety is to mandate the use of the NHS Patient Number. A unique identifier is seen as a major factor in the success of any linked electronic record system.

Building on existing initiatives such as Connecting for Health, the government should identify areas and platforms for procurement-led innovation in this area. For those areas of e-Health that will be driven by individual procurement, the government needs to provide standards for integration etc. to enable individuals to buy with systems with confidence that they will work together.

Integral to the developments should be a programme of appropriate access to enable biomedical research and development. A major challenge is ensuring public support and confidence in an electronic system of medical records particularly when the information is used for purposes, such as research, not directly linked to their care. There is thus a considerable piece of public engagement work that must be done to ensure the public are supportive of the use of electronic technology in their care and for research. CST made recommendations to Government in its report *Better use of personal information: opportunities and risks*³⁴.

We are clear that more work is needed on clarifying the precise form of interventions needed: a starting point should be a value chain analysis to identify exactly where the benefits to the UK could lie.

³⁴ <http://www2.cst.gov.uk/cst/reports/files/personal-information/report.pdf>

Plastic Electronics

Definition

Plastic electronics has applications in a large range of computer and sensing technologies, displays and communication systems through the introduction of new low cost, flexible molecular and macromolecular materials. These materials, which encompass polymers, advanced liquid crystals, and nanostructures, including carbon and silicon nanowires, are predicted to have a disruptive impact on current technologies not only because of their cost/performance advantages, but also because they can be manufactured in more flexible ways, provide more functionality and be engineered for a wider range of applications.

Rationale

The UK has real world-class strengths in plastic electronics, a disruptive new technology with good market potential. We have a strong technical position in an early stage market, with a number of companies beginning to invest. The academic position is very strong, with EPSRC funding of £20 millions per year. Business has also invested more than £65 millions in R&D, and private equity more than £140 millions. There are over 30 companies with benchmarked world-class R&D in plastic electronics, including Plastic Logic, Cambridge Display Technologies, Innos, Oxford Instruments Xaar, together with multinationals such as DuPont Teijin Films, Dow Corning, Epson, HP, Kodak and Merck. UK organisations hold much of the knowledge and critical IPR.

Government has also supported the development of the technology: £10 millions for the PETeC centre to provide a focus to help companies develop manufacturing facilities; £10 millions through the Technology Strategy Board; and UK organisations have secured £40m from the EU Framework VI programme. The EPSRC Integrated Knowledge Centre at Cambridge provides a key link between PETeC and academic research whilst NPL provides a focus for metrology issues. The UK Display and Lighting KTN and the Micro and Nanotechnology KTN also act as networks across the technology area.

The 2006 market was £71 millions and the predicted world market is £3 billions by 2009; £12 billions 2011; £15 – 30 billions by 2015 and between £100 and 250 billions between 2020 and 2025³⁵ with value to the UK most likely to be in materials, device designs/structures and process knowledge.

Plastic electronics is a high risk/high return business for the UK. The risk is that key parts of the value chain move outside the UK, or that spin-out companies are bought up by major IT multinationals at such an early stage that the plastic electronics industry never fully develops a manufacturing and product infrastructure in the UK. It is crucial not to underestimate the importance of electronics design to plastic electronics manufacture. Currently, the UK is a knowledge hub in plastic electronics; the trick is to find ways in which Government can intervene to help ensure the knowledge base is successfully commercialised within the UK.

However, if these risks can be avoided the potential rewards are high. Existing markets include advertising posters, and in phones and other handsets. As a disruptive technology plastic electronics may create entire new industries. Major likely production areas over the next five years include electronic paper, RFID tags and smart sensors, retail signage, and lighting. It is anticipated that, within 7 years, samples of full-colour video capable displays printed on flexible substrates will be available with consumer electronic devices and large

³⁵ Reports by ID TechEx, UKDL members; and Nanomarkets

digital signage moving into high volume production. Furthermore, by focusing upon Plastic Electronics this would help to stimulate other technologies including solar photo-voltaics, RFID and active packaging.

Actions Needed

The first action necessary is for a comprehensive value chain analysis of the sector to identify where the value will lie, and what the key elements of the supply chain are. Such an analysis will allow Government to take a strategic view of where to concentrate any support such that the UK captures as much value as possible.

It will be important for Government to help promote strategic links and collaborative projects between businesses, universities and other research organisations to encourage knowledge transfer between the science base and business. Government should consider how it can bring the key players together most effectively: whether a new mechanism, such as appointing a ministerial or private sector individual to co-ordinate and drive forward UK capability is required, or whether existing systems are sufficient. One suggestion that has been made to us is to establish a national strategy to address the interdisciplinary nature of many of the manufacturing and materials challenges and to enhance the capability of the entire supply chain around a big theme such as large area displays³⁶.

It will be important for Government to use procurement to encourage marketable products and services, as well as addressing the wider skills issues, ensuring that training is in place at the right time to meet the demands of a growing industry. It is also vital to continue support for those interventions that have already been made, such as PETeC and the Cambridge IKC. They must be allowed to carry out their mandate, and be further supported as they meet their objectives. Rapidly scaling-up their facilities, or the setting-up of similar facilities in other locations, if they are seen to be working, should be an option.

A case study on Plastic Electronics, one of the technologies selected as a priority area, is included at Annex E. The case study builds on the conclusions described here, focusing particularly on how Government has supported the development of the technology in the UK and what interventions might be necessary to support the technology further.

³⁶ By the UK Displays and Lighting KTN; Micro and Nanotechnology KTN; EPSRC; Cambridge Integrated Knowledge Centre; PeTEC centre

Platform/Enabling Technologies

Bandwidth Telecommunications

This technology has huge market and high societal benefits, particularly amongst the elderly and disabled. UK technological competitiveness and capacity to deliver are high. There are currently large numbers of research grants, commercial investment, and the industry base is strong. Current levels of support should be maintained and the development of the technology monitored to ensure that future issues can be rapidly addressed. Improvements in bandwidth telecommunications are a vital enabling technology to business and the economy as a whole, across all sectors including the services sectors.

Pervasive Systems

To implement pervasive systems high capability bandwidth telecommunications will be required – hence the strong linkages between the two technologies. Technologies around pervasive systems have a huge market, high societal benefits and there is high UK technological competitiveness and capacity to deliver. Indications are that there is no immediate and obvious market failure – the required support from Government, KTNs and Research Councils is happening. Current levels of support should be maintained and the development of the technology monitored to ensure that future issues can be rapidly addressed.

Cell and Tissue Therapies

Cell and tissue therapies is one of the UK's major technological strengths and is crucial to underpinning many new advances in medical sciences, including in orthopaedics, biological healing technologies, stem cell science, cell culture technology, matrix technology and scaffold technology. The current worldwide market is estimated at approximately \$150 millions (£75 millions). The total market by 2015 is predicted to be about \$2.1 billions (£1.1 billions)³⁷. Hundreds of millions of dollars have been spent to commercialize products – though the returns will mainly be realised beyond the timescale CST is considering. The societal benefits are also huge: for many diseases, this is the only technology that offers potential cures. It is crucial to continue sustained investment in this area to maintain UK strength and underpin many other medical developments.

Simulation and Modelling

The UK has great strengths in Simulation and Modelling, both in academia and business, where many major companies across all sectors are investing heavily. The societal benefits are large. Simulation and modelling technologies stimulate markets across almost all sectors of the economy, including in the services sectors. At present, it is hard to identify additional Government interventions beyond maintaining the sustained investment in Simulation and Modelling – specific interventions would best be considered when addressing a specific technology or sector.

³⁷ <http://www.mediligence.com/PR/PR04-05.htm>

4. Evaluation of the Process

CST is conscious that it is in the vanguard of those developing techniques for systematically prioritising technologies across the full spectrum of disciplines. Given this, and the short – three month – timescale which CST set to deliver advice, we are conscious that there are a few areas where the process could be further refined:

Information gathering on short-listed technologies

The short timescale for this work meant that organisations had very little time – about three weeks – to respond with the information CST had asked for. They did a tremendous and thoroughly professional job. Whilst sufficient data were received to allow the comparison of technologies to a large extent, there were inevitably some areas where there was a lack of consistency of data between technologies (eg. non-comparable market size data related to UK, EU or world), disagreement between sources, or missing data. Therefore, a further iteration (including some peer review) at the detailed evaluation stage would help to develop the quality of the data.

Sensitivity to ‘time to market’

Government had asked for technologies that could lead to applications in around five years’ time. This had two consequences: first, in fields such as medicine, the time taken to pass regulatory tests (several years) meant that the five year horizon gave little room for meaningful intervention from Government; second, uncertainties over the rate of development of a technology and its subsequent potential market could be significant, particularly at the bottom end of the innovation adoption curve, so imposing a short timescale could mean some technologies were unjustly missed. Re-running the exercise with a ten or fifteen year horizon would produce a different (and arguably larger) set of technologies that could still bring much economic and societal benefit to the UK. Exactly how the time to market is interpreted needs to be agreed right at the outset and should perhaps be based on the stage that the technology is in the innovation cycle rather than on a strict timescale.

Risk

Assessment of risk is a difficult process. Although CST had asked respondents to assess various types of risk as *high*, *medium* and *low*, it remained challenging to compare assessments across different technologies. CST did not explicitly consider all types of risk – for example, risks around gaining planning permission – but questions on technical, commercial and regulatory risks, as well as on key constraints facing each technology, were asked of respondents. Risk assessment is an area which needs strengthening with due account being taken of possible risk mitigation measures.

‘Government intervention’ criterion

To score highly on the *Government Interventions Needed?* criterion, there must be identified constraints or market failures that are preventing the technology reaching its commercial and economic potential for the UK and the constraints must be of a nature that Government intervention could effectively address them. However, the sub-criteria

for 'Government intervention' gave responses from organisations that were often difficult to compare between technologies. The questions sent to organisations would need to be more focused in a future exercise. The need for more detailed consideration of specific interventions is an important recommendation we make to Government.

International Cooperation

CST did not explicitly consider the possibility of international co-operation (as opposed to international competition) when assessing the UK's technological competitiveness. Incorporating this aspect could improve the framework.

'Grand challenge' approach

The CST process was essentially bottom-up, starting from a wide range of technology areas. An alternative would be to take a systems approach, beginning with a set of *grand challenges* and considering the technologies required to meet them. Stimulated by CST's work, the CBI conducted an exercise using this method with representatives from over twenty of their member companies. The broad outcomes from the CBI debate were presented at CST's road-testing event; it is reassuring to note that there are strong overlaps with the priority technologies identified by CST.

Annex A: Information Gathering Questions

UK's Technological Competitiveness

In this section we are interested in establishing the extent to which the UK has a scientific and technological competitive advantage *in both the science base and private sector research and development activities*, relative to other countries, on which commercialization could build.

- Is the UK already a world leader in this technology area?
- Does the UK have the potential to be a world leader in this technology area in the next five years?
- How strong is the university and commercial sector research base relevant to this technology area?
- Are there clusters of expertise (world-class research groups; spin-outs; mature companies)?
- What Government action or programmes has there been to date to support this technology?
- What in the next five years will be the most critical factors affecting the UK's technological edge in this area?
- Any other comments?

Market Size

In this section we are interested in establishing the potential market size accessible by the technology area. Since there may be a variety of markets/products the first question in this section relates to the range or the pervasiveness of applications. In subsequent questions it will in that case be helpful to specify and concentrate on the one or two most significant applications in terms of market size.

- What are the potential applications and products?
- Which of these do you consider the most significant in terms of the potential market size?
- Will there be proven commercial feasibility in these areas within the next five years?
- What is the potential world market size in 5/10/20 years in these areas?
- Where is the value to the UK likely to lie in these areas (for example, might the value lie in manufacturing/ design/other areas)?
- What are the feasible commercialisation routes in these areas (Licensing/partnering/independent start-ups/growth)?
- Are there complementary technologies that successful commercialization will rely on?
- Any other comments?

UK Capacity to Deliver

In this section we are interested in establishing the factors which will enhance or constrain the capacity of the UK commercial sector to develop leading market shares in the potential markets identified in the previous section

- Who are the key commercial players (customers/suppliers/ rivals) in the UK and abroad and where is the most significant non-UK competition likely to come from in the next five years?
- How much are companies investing in the UK in developing this technology area?
- Does the UK have the necessary skills base to support commercialisation in this technology area?
- Are there particular management strengths or weaknesses which might help or hinder UK private sector competitive ability in exploiting this technology area in the next five years?
- Are there structures (firms, industry organisations or other networks) in place to facilitate a rapid expansion of commercialisation in this technology area across firms, including customers and the supply chain?
- What is the UK's potential share of markets in this area in the next 5/10/20 years and which of the above (or other) factors will be most critical in affecting UK capacity to establish commercial production feasibility in the next 5 years and maximise market share in the medium and longer term?
- Any other comments?

Potential Societal Implications

In this section we are interested in the broader societal implications (positive or negative) of developing this technology. This includes potential direct and indirect positive and negative impacts linked to the Governments Comprehensive Spending Review Challenges. We are also interested in any attitudinal or socio-economic factors which may be critical in hampering or encouraging the development of new product markets based on this technology.

- Which product market developments linked to this technology, if any, offer direct or indirect potential benefits or impacts upon health or the environment?
- What are the implications of the direct and indirect effects in relation to the five Comprehensive Spending Review Challenges³⁸
 - Demographic and socio-economic change
 - Globalisation
 - Technological change
 - Global uncertainty
 - Pressure on natural resources and global climate
- Which socio-economic and regulatory trends do you consider most important in affecting the development and use of products based on this technology (e.g public sector business and consumer attitudes to sustainability issues and to risk and social

³⁸ http://www.hm-treasury.gov.uk/media/298/55/csr_longterm271106.pdf

responsibility; regulatory issues; health and safety issue; standards setting; public and private sector expenditure and population patterns; patterns of leisure, work, and household behaviour; global distribution of spending power and production)

- Any other comments?

Risks

In this section we are interested in the variety of risks which will be faced in developing this technology area. It would be helpful if you could use the following scale Very High, High, Medium, Low in summarising your answers.

- What is the degree of technical risk in developing a leading market position in this area?
- What is the degree of commercial risk in developing a leading market position in this area?
- What is the degree of regulatory risk in developing a leading market position in this area (including health/environmental/regulatory risks)?
- What are the risks of overseas competition capturing a leading position in relevant markets?
- What is the risk for exploiting the UK's medium and long term potential if production capacity in this area is not established within the next 5 years?
- Any other comments?

Potential Government Interventions Needed

In this section we are interested in identifying the case for public sector support for this area, its likely form and cost and the chances of success.

- In the light of your answers to the previous sections what are the key constraints on the technology reaching its commercial and economic potential for the UK?
- What is the scale and nature of public sector support in addressing similar constraints abroad and what policy methods and level of support does this suggest would be needed in the UK?
- Can the UK constraints you identify be addressed within the next five years and what immediate Government action, if any, is needed?
- What is the scale of Government funding that you would consider appropriate for any intervention you identify?
- What would the risks of policy failure in making such intervention and how might they be addressed?
- What would be your overall recommendations for immediate action by Government to affect outcomes within the next 5 years and in the medium and longer term?
- Any other comments?

Annex B: Organisations Consulted

CST is very grateful to the following organisations and individuals who provided information on short-listed technologies:

- British National Space Centre
- Chief Scientist's Advisory Committee
- Department of Health
- Department of Trade and Industry
- Foresight
- Home Office
- Horizon Scanning Centre
- Horizon Scanning Centre Future Analysts' Network
- Integrated Knowledge Centres (IKCs)
 - Cambridge IKC (Advanced Manufacturing Technologies for Photonics and Electronics)
 - Cranfield IKC (Ultra Precision and Structured Services)
- Knowledge Transfer Networks (KTNs)
 - Cyber Security KTN
 - Displays and Lighting KTN
 - Electronics KTN
 - Electronics Enabled Products KTN
 - Health Technologies KTN
 - Industrial Mathematics KTN
 - Location and Timing KTN
 - Low Carbon and Fuel Cell KTN
 - Nanotechnology KTN
 - Resource Efficiency KTN
- Met Office
- Ministry of Defence: Defence Science and Technology Laboratory
- Research Councils
 - Biotechnology and Biological Sciences Research Council
 - Economic and Social Research Council
 - Engineering and Physical Sciences Research Council
 - Medical Research Council

- Technology Strategy Board
- Royal Society
- Royal Academy of Engineering
- Institution of Engineering and Technology
- Institute of Mechanical Engineers
- Institute of Materials, Minerals and Mining
- BP
- Professor Chris Browitt
- Carbon Trust
- Confederation of British Industry
- DTI/Ofgem Distribution Working Group members
- Lord Julian Hunt
- International Energy Agency
- Professor Brian Lee
- Sir Rob Margetts
- National Grid
- Sir Chris O'Donnell
- RWE NPower
- Shell
- Surrey Satellite Technologies Ltd
- UKSpace
- Mike Walker, Vodaphone
- Wellcome Trust

Annex C: Definitions of Short-Listed Technology Areas

The 24 short-listed technologies are:

- Active Packaging
- Advanced Battery Technologies and Micro-generation
- Advanced Satellite Technologies
- Bandwidth Telecommunications
- Biometrics
- Carbon Capture and Storage (CCS)
- Cell and Tissue Therapies
- Cognitive Therapies
- Disaster Mitigation Technology
- E-Medicine
- Fuel Cells
- Low Carbon Distributed Networks for Electricity Generation
- Medical Devices
- Millimetric Radar
- Off-shore Wind
- Optoelectronics and High Performance Lasers
- Pervasive Systems
- Personal Information Management Systems
- Plastic Electronics
- RFID Technology and Applications
- Simulation and Modelling
- Smart materials for the Automotive and Aerospace Industry
- Solar
- Surveillance Technologies

Definitions

Active packaging

Active packaging covers a range of technologies, including new pigments for paint and other coatings, which will enable materials to be self-heating or cooling, or to change colour. It will also be possible to incorporate radio direction-finding or similar devices into packaging, which will help transform logistics and supply chains³⁹. With the continual development of smart materials and systems and their application to innovative package design and construction, additional communication and sensing functionalities will become possible via photovoltaic, photochromic, piezochromic and hydrochromic materials, applied as inks during the printing/decoration process.

Advanced Battery Technologies and Micro-generation

Advanced Battery Technologies are designed to develop modern alternatives to the classic lead-acid battery, such as lithium-ion. They have the potential to replace fossil fuel use in transport – helpful in cutting CO₂ emissions if batteries can be charged using electricity from low-carbon sources.

Micro-generation is the production of heat and/or electricity on a small scale. Most micro-generation technologies are low-carbon. They may require modifications to the nation's power transmission infrastructure if they are to be deployed on a large scale.

A number of energy technologies can be applied at the micro-generation level. They include (at various stages of development and take-up): solar photovoltaics (the direct conversion of solar radiation into electricity by the interaction of light with the electrons in a semiconductor device or cell); solar thermal hot water systems (that collect solar heat and transfer this heat to create hot water); micro-wind turbines; and combined heat and power systems (CHP) that take the heat by product from generating electricity and uses it to heat water for heating systems⁴⁰.

Advanced Satellite Technologies

Satellite technologies have commercial applications in astronomy, environmental science, telecommunications, navigation, and the exploitation of Earth observation data. Government space policy has traditionally been to identify clear scientific and commercial objectives for which space activities are the most effective tool, rather than considering the development of space technology as an end in itself⁴¹. The UK has a strong reputation in many areas including satellite platforms and payloads, instrumentation, software, components, testing facilities, remote sensing applications, antennae and signal simulators, digital processing, RF technology, system validation and satellite operators⁴².

Bandwidth Telecommunications

Massively increasing bandwidth in the home and workplace, and to a lesser extent on the move, presents opportunities for reconfigurable 'clouds' that are, to all intents and purposes, limitless in terms of bandwidth and accessible on the move.

39 Horizon Scanning Centre WIST Workbook

40 Horizon Scanning Centre WIST Workbook

41 BNSC UK Space Strategy 2003-2006 and beyond

42 BNSC Introduction to the British Space Industry

Photonics is also key to the next generation of broadband communications systems. The backbone of the Internet is optical, and scaling with advances in lasers and switching technologies. The major challenges will be in developing cost effective components and architectures that will support the hundred-fold growth of bandwidth to the user that the market is likely to demand within the next decade⁴³.

Biometrics

Biometrics are automated methods of recognizing a person based on a physiological or behavioural characteristic. Among the features measured are face, fingerprints, hand geometry, handwriting, iris, retinal, vein, and voice. Biometric technologies are becoming the foundation of an extensive array of highly secure identification and personal verification solutions.

Biometric-based solutions are able to provide for confidential financial transactions and personal data privacy. The need for biometrics can be found in central, regional and local governments, in the military and in commercial applications. Enterprise-wide network security infrastructures, government IDs, secure electronic banking, investing and other financial transactions, retail sales, law enforcement and health and social services are already benefiting from these technologies.

Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS) may allow fossil fuels – especially coal and gas – to remain as major components of the power generation mix without adding further to CO₂ emissions. Carbon capture is the removal of CO₂ from fossil fuels either before or after combustion. Carbon storage is the long-term storage of carbon or CO₂ in the forests, soils, ocean, or underground in depleted oil and gas reservoirs, coal seams and saline aquifers. An example of CCS technology is carbon sequestration whereby gases that are contributing to climate change are captured from power stations, separated and stored in suitable porous rock layers deep underground⁴⁴. Due to the five-year time scale being considered, this technology is considered to be limited to CCS from electricity generation, not from smaller scale applications such as vehicle emissions.

Cell and Tissue Therapies

Advances in cell biology and particularly stem cell biology have led to the ability to change how cells differentiate and this allows different cell types to be made in large quantities – these cells can generate new tissue types which can be used to replace damaged tissues and organs which have occurred, for example, through wasting diseases or accidents. Technology priorities relating to cell and tissue therapy include stem cell science, cell culture technology, matrix technology and scaffold technology.

Biopharmaceuticals are defined as large molecule medicines for human healthcare that are produced by biological means, rather than by chemical means. Included in this definition are traditional products extracted from animal and human tissue, such as blood and blood products and viral vaccines, and modern products derived from new biotechnologies including cell and tissue therapies⁴⁵.

43 Technology Strategy Board Key Technology Area: Electronics and Photonics

44 Horizon Scanning Centre WIST Workbook

45 Technology Strategy Board Key Technology Area: Bioscience and Healthcare

Cognitive Therapies

Cognitive behaviour therapy (CBT) describes a number of therapies that all have a similar approach to solving problems, which can range from sleeping difficulties or relationship problems, to drug and alcohol abuse or anxiety and depression. CBT works by changing people's attitudes and their behaviour. The therapies focus on the thoughts, images, beliefs and attitudes that are held (our cognitive processes) and how this relates to the way we behave, as a way of dealing with emotional problems.

CBT is a combination of psychotherapy and behavioural therapy. Psychotherapy emphasises the importance of the personal meaning we place on things and how thinking patterns begin in childhood. Behavioural therapy pays close attention to the relationship between our problems, our behaviour and our thoughts⁴⁶.

Disaster Mitigation Technology

Disaster mitigation covers measures designed to prevent, predict, prepare for, respond to, monitor and/or mitigate the impacts of disasters, such as earthquakes, volcanic eruptions, major storms and coastal and inland flooding. It requires a range of soft technologies including a monitoring/predictive component: for example earth monitoring from satellites and earth-based stations (e.g geophones) and predictive modelling of surface events and their physical and social consequences, both to estimate prior vulnerability to disaster as a basis for planning and to provide real time assessments of impacts in any disaster. It requires planning and implementation of response systems, including disaster resilient communications systems and logistics algorithms. It greatly benefits from international inter-agency and inter-governmental agreements. It also involves the hard technologies of engineering-based mitigation systems such as earthquake-proof buildings and tsunami deflectors. Knowledge-based consulting, financial services including risk consultancy and insurance are vital support processes.

E-Health

E-Health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterises not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology. It will also improve research.

Fuel Cells

Fuels cells produce electricity and heat by an electrochemical process, usually involving hydrogen and air, with water as the only emission. Potential applications include stationary power generation and combined heat and power (CHP), transport (replacing the internal combustion engine) and portable power (replacing batteries in mobile phones). Hybrid technology using biofuels or hydrogen in fuel cells is a possibility.

46 MIND Website

Low Carbon Distribution Networks for Electricity Generation

The existing Grid is based on large central power stations with passive distribution networks that have very little in-built intelligence and are designed for 'one-way' power flows. This acts as a significant blocker for new, low carbon, small-scale technologies coming on stream – resulting in 'reverse' flows on the network. Reinvigorating the grid would facilitate the development of microgeneration technologies including solar and micro-wind turbines⁴⁷, as well as fuel cells, combined heat and power (CHP) and heat pumps. This technology is considered to include the IT, software and control systems required for active network management technologies, including advanced controllers, power electronics and communications.

Medical Devices

Medical biotechnology and medical devices include technologies, devices, and combined systems to provide for improved healthcare targeting prevention, diagnosis, treatment, and rehabilitation. Such technologies increasingly need multi-disciplinary solutions encompassing biology, physics, materials, engineering, mechanics, and IT. New technologies can act as enablers to deliver novel medical device products, to support new treatments for specific disease morbidities and to enable a higher quality of life for all.

Key technology priorities identified by the medical device industry include: converging technologies encompassing intelligent implants; remote sensing; functional imaging; diagnosis and screening technologies for targeted therapies; early health monitoring compliance; regenerative medicine for tracking cells, tissue/organ engineering; advanced biomaterials; assistive technologies to include wearable diagnostic tools; wireless technology for home monitoring; and human/ equipment interfaces⁴⁸.

Millimetric Radar

This allows the detection of objects at high resolution. Millimetric radars offer very high resolution at ranges of up to approximately 800m. These features can bring significant technical and operational benefits as well as low cost.

Currently it is used in missile guidance systems and for cloud observations. However, innovations in the fields of radar and digital signal processing have made use of the radar in low cost mass market applications possible. One of the most fruitful mass market for radars in the near future will be the automotive field. There are numerous potential applications such as Intelligent Cruise Control (ICC), speed-over-ground sensors, parking aids, height sensors for active suspension, blind spot warning systems and, in the longer term, obstacle detection systems. Other uses include use in surveillance – for example, by spacing millimetric radar heads at appropriate intervals around the airport, it is possible to provide 100% coverage and reduce shadowing or other problems associated with conventional radars – or in guidance systems for autonomous robots⁴⁹.

47 CST Energy Report

48 Technology Strategy Board Key Technology Area: Bioscience and Healthcare

49 Advanced Aviation Technology Ltd: Low Cost Surface Movement Radar

Off-shore Wind

Wind power is the conversion of wind energy into electricity using wind turbines. Offshore wind farms are built in the sea and are usually more expensive than onshore developments due to the more hostile environment⁵⁰.

Optoelectronics and High Performance Lasers

Optoelectronics is a combination of optical and electronics technology. This technology is evident in a range of commercial and domestic products including fibre optic communications, DVD/CD optical storage, phone and computer displays, laser printers and scanners, video and digital cameras and lasers used for a host of applications such as detection, cutting, welding and coding.

Photonic technologies in the form of lasers provide tools for precision engineering, inspection, marking and lithography. In healthcare, it is used in techniques such as laser surgery and photodynamic therapy. New developments include terahertz technologies and many of the recent approaches to genomics, proteomics, pharmaceutical screening and biomedical diagnoses also rely critically on photonic technologies. Lasers have become essential as part of the capillary electrophoresis systems used for DNA sequencing⁵¹.

Pervasive systems

Pervasive systems is used here to mean an environment with billions of intelligent or preprogrammed devices in a networked environment, providing people with services and information when, where and how they need it. Other terms used to describe this future include ambient intelligence, transparent computing and ubiquitous computing. The devices could be as small as a few square millimetres, operate independently of any user and may be parts of small sensors or be embedded in any type of physical object, from white-goods and traditional 'electronic' goods to bus-shelters and walls. Interaction will be through next-generation personal digital assistants, third and fourth generation mobile phones, set-top boxes, digital TV, clothing and doubtlessly a variety of other human-oriented methods as yet unforeseen.

In the longer term these interaction-devices will disappear and we will move into an 'attentive computing' environment in which user-interaction with devices will be through natural-language, gesture and body-language and in which the networked, intelligent, adaptive, context-aware devices will be able to pool their data and information to predict user needs and either deal with them 'invisibly' or be prepared for the possible user choices⁵².

Personal Information Management Systems (PIMS)

PIMS covers a range of areas including knowledge searching, data mining, pattern recognition and the automated interpretation of data (including 3D data mining). It also includes tools to capture tacit knowledge (knowledge which is only known by an individual and that is difficult to communicate to others) and agent-based analysis of information to identify key issues in an area of interest and to support decision making. Proactive and context-aware computer systems that anticipate users' needs and perform tasks in a timely and context-sensitive manner may begin to have an impact within the next 10 years.

50 CST Energy Paper

51 Technology Strategy Board Key Technology Area: Electronics and Photonics

52 Horizon Scanning Centre WIST Workbook

Plastic Electronics

Plastic electronics has applications in a large range of computer and sensing technologies, displays and communication systems with the introduction of new low cost, flexible molecular and macromolecular materials. These materials, which encompass polymers, advanced liquid crystals, and nanostructures, including carbon and silicon nanowires, are predicted to have a disruptive impact on current technologies not only because of their cost/performance advantages, but also because they can be manufactured in more flexible ways, provide more functionality and be “engineered” for a wider range of applications⁵³.

RFID Technology and Applications

RFID is a way to electronically control, detect and track a variety of items using FM transmission methods. A small tag, or transponder, affixed to or embedded into virtually any object (including livestock) individually identifies the object using a unique, factory-programmed, unalterable code.

RFID has a large number of applications and potential applications, including in retail to record items purchased or reduce shoplifting, to track animals, people or vehicles, or in security uses. As well as being attached to products, RFID tags can be implanted in clothing or in humans, with uses ranging from monitoring the whereabouts of criminals to maintaining a secure and reliable method of patient identification in hospitals.

Simulation and Modelling

The modelling and simulation of physical, chemical and biological systems is used to support, reduce and – increasingly – to replace experimentation in engineering. Simulation is especially beneficial when the product development cycle is costly and lengthy, such as in the aerospace and automotive industries. It is also relevant in modelling logistics and traffic flows, financial modelling, simulation as part of the computer games and other games industries and in architecture – all part of the UK’s burgeoning knowledge based economy. Simulations that take advantage of vastly increased computing power could be used more heavily in the social sciences, eventually becoming the more dominant means of analysis as a method of predicting human behaviour.

In addition to the software techniques simulation and modelling relies on possessing substantial computing power, including next generation supercomputers and grid computing⁵⁴. This area includes software, underpinning mathematical and hardware.

Smart materials for the Automotive and Aerospace Industries

Smart materials are materials engineered to perform specific tasks. The requirements for smart materials in the transport sector could cover materials with better functional properties such as piezoelectricity or shape memory effect, or which insulate against temperature change or maintain and repair themselves. The integration of smart materials to render the host structure ‘smart’ or intelligent is also important.

Applications in the automotive industry include, but are not limited to, electro-chromic materials used in automatic light and heat control (e.g. self-dimming mirrors and rear windows), the use of actuators as substitutes for small motors and the use of smart materials to reduce noise and vibration resulting in enhanced comfort and safety benefits, especially for professional drivers.

53 <http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/E023614/1>

54 Horizon Scanning Centre WIST Workbook

Applications in the aerospace industry include, but are not limited to, passive applications like health and usage monitoring systems (HUMS) for engine monitoring, structural HUMS and damage detection, vibration diagnostics, active blade contouring and active vibration control systems⁵⁵.

Solar

Solar photovoltaics is a technology in which light is converted into electrical power. It is best known as a method for generating solar power by using solar cells or solar photovoltaic arrays to convert energy from the sun into electricity. Such solar arrays have been used to power orbiting satellites and other spacecraft and in remote areas as a source of power for applications such as roadside emergency telephones, remote sensing, and cathodic protection of pipelines. Other potential uses include road signs, home power generation and even grid-connected electricity generation.

Surveillance Technologies

Ubiquitous, automatic scene analysis and identification of anomalous behaviour. They allow people to watch, listen to, or otherwise monitor and thus safeguard locations remotely. These technologies include video cameras and closed-circuit television systems, satellite surveillance systems, audio receivers and recorders, radar traffic enforcement devices, motion detectors, heartbeat detectors, "radar flashlights" to detect breathing and other vital signs, devices to "see" through walls and into enclosed spaces to locate and track concealed persons, and night vision and thermal imaging devices that detect infrared radiation or heat.

⁵⁵ Smart Materials for the 21st Century (Institute of Materials, Minerals and Mining)

Annex D: Note of the Road-Testing Workshop 22 June 2007

The note below sets out the main issues arising out of the Workshop. The list of participants is appended.

1. Priority-Setting Framework

The participants in the road-testing workshop provided clear and focused challenge on key elements of the priority-setting framework. They contributed a number of very valuable points on how the process could be improved. The meeting concluded with participants expressing strong support for the framework. There was real confidence that the criteria and sub-criteria considered were appropriate and that as a systematic framework for priority-setting it worked well.

Specific points were made in the following areas:

Clarity of Communication

Participants emphasised that it was important that CST communicated clearly a number of factors:

- Clear delineation of the process that had been gone through, including the wide variety of bodies consulted at various stages.
- The fact that CST defined the timescale of “applications within five years time” as meaning that the technology must have proven commercial feasibility within five years, with major market impact within ten.
- That the identification of priority technologies did not imply that CST was proposing reducing support for other areas – rather, it was recommending areas where specific focus could accelerate progress, given the timescales mentioned above.
- Interventions should be considered from a very broad perspective: for example they could involve regulation, public engagement and improving connectivity, and not simply provision of additional resources.

Complementary Technologies

Participants considered it important to specify complementary technologies that successful commercialisation of the selected technologies may rely on. The Workshop recognised that respondents to CST’s information gathering exercise had been explicitly asked to identify such technologies. The value chain analyses that are being proposed as the next step of this process should also identify such technologies. CST should also be clear in stating where a focus on one of the selected technologies would help to stimulate other technologies. It should also highlight any links or convergence between the selected technologies. CST will be taking forward all of these points.

International Cooperation

CST had not explicitly considered the possibility of international cooperation and global innovation systems (as opposed to international competition) when assessing the UK's technological competitiveness. CST acknowledged that including this aspect was a way in which the framework could be improved and will be reflecting this in its evaluation of the methodology.

Necessity for Intervention

CST was careful not to simply select a group of technologies which would succeed even without intervention. To score highly on the *Government Interventions Needed?* criterion, there must be identified constraints or market failures that were preventing the technology reaching its commercial and economic potential for the UK and the constraints must be of a nature that Government intervention could effectively address them. CST had also indicated which technologies it considered particularly high-risk/high-reward.

Relationship with the Technology Strategy Board

CST acknowledged the strong links between its Strategic Focus project and the work of the Technology Strategy Board. CST has maintained close links with the TSB throughout the project and Graham Spittle had indicated that he considered the approach and priority setting framework to be sound, with the criteria and sub-criteria systematic and thorough.

Risk

The meeting recognised that assessment of risk was a difficult process. It was important to recognise that interventions will often involve risk taking. CST had asked respondents to assess technical, commercial and regulatory risks, as well as whether there were other key constraints facing each technology. Participants recognised that comparing assessments of types of risk as "high", "medium" or "low" across different technologies was challenging, but were in agreement that a risk assessment, even if imperfect, was an important component of such a process. CST also acknowledged that it had not explicitly considered all types of risk, for example, the risks involving gaining planning permission, and would be reflecting this in its evaluation of the methodology.

CBI Exercise

The CBI had conducted a similar exercise on 21 June with representatives from over twenty of their member companies. They had considered the problem from a top-down "grand challenges" perspective – considering the technologies required to meet their challenges – rather than from a bottom-up technology-push perspective. The CBI are still finalising their conclusions, but there are strong indications of overlap with the priority technologies identified by CST.

2. The Technologies

There was broad support for CST's conclusions. Participants praised the overall quality of the data that had been assembled in such a short time, although inevitably there were places the data needed to be looked at again. CST will be doing that. All sides recognised that there were often no definitive answers and that exercises such as this involved making judgements. However, CST's systematic approach had striven to make that judgement as objective as possible. Participants strongly supported CST's proposal that the next step before intervention should be a more in-depth study of the chosen technologies, including a value chain analysis.

Specific points were made in the following areas:

Carbon Capture and Storage (CCS)

Participants considered that funding for demonstrators, an intervention likely to be necessary for CCS, would require significant Government support (several hundred million pounds). Participants also stressed the importance of establishing a regulatory and fiscal environment which would enable CCS to be economically attractive.

CST agreed that it would look again at its conclusions in the light of developments following the Energy White Paper. It would also be useful for CST to explore how the Energy Technologies Institute and DBERR Energy Group could be involved in taking this work forward. CST will be arranging meetings.

There was a question of whether CST was considering small-scale CCS (e.g. for vehicles) or if its data was confined to large scale CCS in power generation. CST agreed to make this point more transparent when making its final recommendations.

Disaster Mitigation Technology

There was a question of whether this technology included man-made disasters as well as natural disasters – given that the UK has very high capability in modelling systems, habitats and in insurance/risk/financial services/consultancy, all of which have applicability to manmade disasters.

It was suggested that there may be useful points that CST could include in the report on environmental mitigation. CST will consider.

Low Carbon Distribution Networks for Electricity Generation

CST agreed that it would look again at its conclusions in the light of developments following the Energy White Paper, and in the light of the Renewables Obligation. It was also suggested that the description of the technology should be rewritten to specifically include software.

Participants agreed that this technology was very important in enabling the use of microgeneration. Government interventions suggested by participants included regulatory interventions, encouraging the development of standards, R&D and the provision of large-scale demonstrations using parts of the Government estate.

A further implication of developing low carbon distribution networks was that it would turn energy consumers into producers. This could potentially cause a significant behavioural change, the implications of which were not yet fully understood.

Medical Devices

Participants considered a bald statement such as: “the NHS is a unique selling point” could lead to oversimplification of the issues. Although intelligent NHS procurement could lead to large economies of scale and a stimulation of innovation, small companies currently faced difficulties in entering the NHS market. Participants agreed that encouraging NHS procurement to stimulate innovation should be a major part of Government intervention.

It was also suggested that Government intervention could play a valuable role in improving connectivity throughout the sector. This could include improving the linkages between academia in industry, as well as improving linkages between companies – many of which are SMEs – and the market.

E-Health

Participants considered it was important to emphasise that the value of E-Health lay not only in the size of the market but in its enabling capacity for research and the pharmaceutical industry. Successful implementation of E-Health could contribute strongly to making the UK a more attractive place for the pharmaceutical industry, which was of vital importance to the UK economy. The societal benefits by improving medical care and public health were also very large.

Other countries were envious of the UK because of the advantage that having an NHS gave in implementing E-Health – the fact that a single organisation held an entire nation’s medical records. Participants were sceptical that the differences between the UK and other countries’ health systems would form a sizeable barrier to exporting E-Health technology: the system and software, once developed and implemented, could likely be adapted for use elsewhere with relative ease.

Government was already investing significantly in this technology via Connecting for Health. Other funders plan further, complementary, investments.

Plastic Electronics

Participants agreed that this was a very promising set of technologies but concerns were raised over the extent to which there were large companies in the UK able to exploit it, and whether the skills base existed.

CST acknowledged these concerns – that was why CST had classified plastic electronics as high-risk/high-return. Some participants felt that these risks increased the case for Government intervention, which could help to ensure that key parts of the value chain remained in the UK. The point was also emphasised that plastic electronics is a disruptive technology and that focusing upon it could stimulate many other technologies, including fuel cells and RFID.

CST noted that it was carrying out more in-depth work on plastic electronics to demonstrate more clearly the most appropriate interventions needed.

“Good News” stories and Platform/Enabling Technologies

A number of participants questioned the differentiation between ‘Good News’ and ‘Platform/Enabling Technologies’. It was also proposed that Bandwidth Telecommunications and Pervasive Systems were strongly linked, the latter relying on the former for implementation. Both were therefore better characterised as platform/enabling technologies.

Similar questions had been raised by Graham Spittle at a meeting earlier that morning. CST agreed to consider merging Bandwidth Telecommunications and Pervasive Systems under one heading and would, regardless of whether or not they were merged, move them into the Platform/Enabling Technologies grouping.

Participants therefore supported the classification of Bandwidth Telecommunications and Pervasive Systems, Cell and Tissue Therapies and Simulation and Modelling as platform/enabling technologies. They emphasised the UK strength in these areas, the need to continue existing support and their importance to the UK economy in supporting a broad range of technologies.

3. Taking the Work Forward

Participants strongly supported CST’s proposal that the next step before any Government intervention should be a more in-depth study of the selected technologies, including a value chain analyses. There was agreement that organisations such as TSB may be best-placed to do so.

Before submitting advice to Government, CST agreed it would incorporate the suggestions made by participants into the final document. This would include a modification of how the framework was presented, recognition of some additional ways in which it could be improved and specific points to incorporate on each of the selected technologies.

CST will also be having conversations with other stakeholders who were not at the Road-testing workshop, to gain broad agreement for the process and invite suggestions on how the work could be taken forward. CST will be meeting Sir Keith O’Nions and will be looking to arrange meetings with DBERR Energy Group and the Energy Technologies Institute.

Participants

Adrian Alsop (Direct Research, Training and Development, ESRC)

Colin Blakemore (Chief Executive, MRC)

Tim Bradshaw (Head of Innovation, Science and Technology, CBI)

Colin Brown (Engineering Director, IMechE)

John Burland (Chair of Royal Society Innovation Panel)

Peter Davies (CST Member)

Janet Finch (CST co-chair)

David Golding (Secretary, Technology Strategy Board)

Andrew Haslett (RAEng representative; Business Technology Consultant, ICI)

Bill Maton-Howarth (Chief Research Officer for Public Health, DH)

Vicky Pryce (Chief Economist, DTI)

Raj Rajagopal (CST Member)

Lesley Thompson (Director Research and Innovation, EPSRC)

Mark Walport (CST Member)

CST Secretariat

June 2007

Annex E: Plastic Electronics – developing a new industry in the UK

Plastic electronics has the potential to be an area of great strategic importance to UK industry – it is an emerging technology based on science pioneered in this country, which is predicted to have a huge market. Elements of a supply chain exist in the UK which, if developed, could make it a world leader. However, plastic electronics is a nascent industry; we are concerned that the supply chain is fragmented and somewhat disconnected from the science base. In a fast-moving field there is a risk that other countries will capitalise on the opportunities before the UK. This short report surveys Government activity so far, and makes recommendations for next steps to take.

A comprehensive value chain analysis of the sector will identify where the potential value will lie, and what the key elements of the supply chain are. Such an analysis will allow Government to take a strategic view of where and how to focus its intervention, such that the UK captures as much value as possible. We consider that organisations such as the Technology Strategy Board may be well-placed to carry out this work.

Given the outcome of a value chain analysis, the Government should consider how they can bring the key players together most effectively: whether existing systems are sufficient, or a new mechanism, such as appointing an individual from the private sector to oversee and advise on a national strategy, is required.

Background

Government asked the Council for Science and Technology (CST) to advise on what would be the best areas to really focus resources for science, technology and innovation which could lead to applications in around five years time. CST responded by developing a process which identified a set of six technology areas. One of these was 'Plastic Electronics', though it was noted to be an area which carried greater uncertainty on whether the high rewards could be delivered.

As a case study, CST has looked at the current state-of-play in the Plastic Electronics (PE) industry, in particular how Government has supported the development of the technology in the UK. There has been a high level of interest in PE within Government already: the Office of Science and Innovation (as was) prepared a business case to support the commercialisation of Plastic Electronics which led to funding from the Technology Strategy Board (TSB), there have been initiatives from EPSRC and a prototyping plant is being established in Sedgefield, County Durham.

This is a fast-moving technology area, nearing commercialisation: Plastic Logic – a University of Cambridge spin-out – has announced that it is setting up the world's first commercial-scale manufacturing plant in Dresden, Germany, with production of flexible displays beginning in 2008; and Innos, a spin-out from the University of Southampton, has won a contract to manufacture rollable displays for mobile phones expected to be commercially available by Christmas 2007. It was in this context that a subgroup of CST met with

academics, business people, venture capitalists and Government officials to assess the effect of activities that are underway, and what further steps may be required for the UK to benefit from its strength in the science base.⁵⁶

Further to the information gathered to support CST's work for the main report, in spring/summer 2007, members met with

- Amadeus Capital Partners, London (investors in Plastic Logic)
- the Plastic Electronics Technology Centre (PETeC), Sedgefield, Co. Durham
- Innos, Southampton
- the Integrated Knowledge Centre in Advanced Manufacturing Technologies for Photonics and Electronics, University of Cambridge
- Aimin Song, Professor of Nanoelectronics, University of Manchester

Notes of these meetings are available on the CST website at www.cst.gov.uk. We are very grateful to those who gave up their time, providing us with information and their perspectives which we draw on in this report.

State-of-play in UK Plastic Electronics

Plastic Electronics is the general term used to describe electronics based on semiconducting organic materials, as opposed to silicon semiconductors. It is a disruptive technology (i.e. one that could overturn the existing dominant technology), and the use of plastic materials in conjunction with high-volume, low-cost production techniques offers the prospect of electronic circuits with radically different price, performance and functionality on large-area, flexible substrates. The worldwide market for plastic electronics products has been estimated to be worth up to £15 billion by 2015 and the opportunity for new markets could be worth up to £125 billion by 2025.⁵⁷ We heard the view that the development of PE is happening at ten times the speed of silicon technology.

Applications from plastic electronics will bring benefits across the economy, with impacts for wider society in areas such as in health care. Potential applications include point-of-care medical diagnostic devices, novel drug delivery devices, smart packaging, real-time newspapers, intelligent signage, smart sportswear, fashion clothes and accessories, printed electronics for consumer products, flexible solar cells and solid state lighting. Future applications for PE are likely to be split between high-resolution/small area and low-resolution/large area devices. The former will be developed for electronics and sensors, the latter for displays and photovoltaic panels (as examples).

The UK has strengths in the academic and business spheres which PE depends on, covering thin films, organic chemistry, printing, and circuit design. We have visited universities centres at Cambridge, Southampton and Manchester, and there are about a dozen other research groups active in the field across the UK. On the business side, 42 UK companies have been identified with competence relevant to PE, including 14 materials suppliers, 15 equipment suppliers, nine processing companies and three commercial research organisations.⁵⁸

⁵⁶ Three CST members have declared interests in the technology: Hermann Hauser (non-executive director of Plastic Logic and co-founder of Amadeus Capital Partners), Alan Hughes (an investigator at the Integrated Knowledge Centre in Advanced Manufacturing Technologies for Photonics and Electronics, University of Cambridge), and Wendy Hall (director of Innos until July 2007). These members did not take part in discussions where there would have been a conflict of interest.

⁵⁷ Forecast from IDTechEx, <http://www.idtechex.com/>.

⁵⁸ Data from PETeC.

Two recent start-ups show the diversity in how PE is being adopted for products. Plastic Logic is developing an entirely new process to manufacture flexible displays. Though there are inherent risks in this approach, it has prospects of high volume and low unit cost production. In contrast, Innos described their process as adapting existing silicon fabrication technology to reduce the time to market, but with some limitations to the product and the relatively higher costs associated with silicon.

Public money has been used to set up two significant initiatives in PE: the UK Plastic Electronics Technology Centre (PETeC) which has received £10 millions of funding from sources including the RDA, central Government, and the European Union; and an Integrated Knowledge Centre (IKC) in Advanced Manufacturing Technologies for Photonics and Electronics at the University of Cambridge, which has received a £6.9 millions grant from EPSRC. PETeC is located at NETPark in Sedgefield Co. Durham, with a 1000 sq m clean room. It will give companies access to prototyping and development facilities, with opportunities for demonstration and to scale-up processes for low-volume device manufacturing. It is expected to be built and commissioned by April 2008.

IKCs were established as part of the response to the Warry report *Increasing the economic impact of Research Councils*.⁵⁹ The components of the Cambridge IKC will allow for the development of advanced manufacturing technologies using new macromolecular material systems and valid exploitation models. At the same time the IKC will create a range of innovative knowledge transfer activities spanning business research, training and specific product exploitation.

Key themes

From the reports we have seen, and discussions we have had, some key themes have emerged:

1. **The value chain** – requirements for an in-depth analysis of where the value lies so that Government can then take a strategic view of where and how to focus its intervention.
2. **Manufacturing in the UK** – the importance of this part of the value chain to the economy.
3. **Skills** – whether the availability of a skilled workforce will be a determining factor to the UK's ability to capture the value.
4. **Cash flow for SMEs** – spin-outs and start-up companies are an important force in the emerging PE sector and particular attention needs to be paid to how they are supported.
5. **Government support** – the role for Government in developing the industry.

These are treated in turn below:

1. The value chain

An in-depth value chain analysis of the PE field should be commissioned as a priority. The value chain is complex, and any analysis should be made at a granular level to pinpoint where the UK can appropriate value and where it requires collaborations with players who have key complementary assets (whether technological or product development/market access related) This will indicate what kind of business model is most appropriate, where the value to the UK lies, and how it can be captured.

⁵⁹ <http://www.dti.gov.uk/science/page32834.html>

From our meetings, we have heard how the UK has a number of elements of a potential PE supply chain. Some existing industries have expertise in 'conventional' processes, such as thin films, printing and chip design, which could adapt to PE. There is concern that these businesses will be at risk if similar companies elsewhere move into the PE market first.

However, the supply chain is felt to be fragmented in the UK, with small companies unable to assemble overseas supply chains effectively. This may be because the UK is missing an indigenous vertically integrated company to act as a 'parent' in the sector, and pull-through applications to the market.

A comprehensive value chain analysis of the sector will identify where the potential value will lie, and what the key elements of the supply chain are. Such an analysis will allow Government to take a strategic view of where and how to focus its intervention, such that the UK captures as much value as possible. We consider that organisations such as the Technology Strategy Board may be well-placed to carry out this work.

Given the outcome of a value chain analysis, the Government should consider how they can bring the key players together most effectively: whether existing systems are sufficient, or a new mechanism, such as appointing an individual from the private sector to oversee and advise on a national strategy, is required.

2. Manufacturing in the UK

Manufacturing is an important component of the supply chain, and would provide jobs and investment to the UK. From our meetings we conclude that there is a real prospect of at least some aspects of a PE industry manufacturing in the UK – the high capital expenditure required on equipment makes labour costs less important, so the competitive advantage of the Far East is diminished. Also, as we have seen with the process that Innos is promoting, fabrication plants (fabs) used for conventional silicon processes in the UK can be adapted. These fabs are fully depreciated and the costs of converting them are relatively low, requiring the addition of just a few pieces of equipment.

However, the location of Plastic Logic's (PL's) manufacturing plant in Dresden raises a number of critical issues that need to be addressed, including the reasons behind PL's decision, and what value PE manufacturing would bring to the UK.

According to PL, the main plus point for the economic development promoters in Dresden was their promise to construct the factory within a very short time.⁶⁰ This, they have said, gave them a huge lead over the competition. There are other possible reasons that could have influenced PL, including the form and level of subsidy received (from the German or Lander governments), a readily available skilled workforce, and existing infrastructure that could take a major new plant.

Though manufacturing may be a relatively small part of the full value chain, we do see it as being potentially critical when a new technology is emerging. There is a risk that when a spin-out attracts overseas investment (BASF and Siemens are big investors in PL) and the manufacturing is established outside the UK, further development of the sector, including jobs, will take place elsewhere. On the other hand, a 'fab-less' industry can be sizeable, with

⁶⁰ Plastic Logic press release (23 May 2007) available at <http://www.plasticlogic.com/news-detail.php?id=320>.

the fab-less semiconductor industry worth 20 % of the worldwide integrated-chip market in 2006.⁶¹ A UK company which develops a technology, with prototypes and demonstrator production lines taking place somewhere such as PETeC, but goes on to source large-scale manufacturing in the Far East, could still return significant revenue to the UK.

On the basis of a value chain analysis, Government should decide whether there is a case to take strategic investment decisions to maximise the opportunities for the UK to benefit from the exploitation of technologies developed in our research labs. Support for underpinning technologies should be accompanied by appropriate incentives to keep businesses/structures anchored here. We discuss how the Government can support business in the following sections.

3. Skills

We have heard conflicting views as to whether a new industry, such as in PE, is being, or would be, hindered by any lack of skills in the workforce. One of several reasons put forward for Plastic Logic locating its plant in Germany, rather than the UK, was availability of a skilled workforce (Dresden, in so-called 'Silicon Saxony', is home to several semiconductor manufacturers, such as AMD).

The location of a demonstrator plant in Co Durham, when the research has been focused in Cambridge, has provoked some questions. Those we met at PETeC were confident that getting the right people would not be a problem, with the Universities of Durham and Newcastle close-by, and a well established and interested chemicals processing industry in the area at Wilton.

A comment we heard from Innos was how the entrepreneurial spirit was lacking, rather than hard skills. Employees were more concerned with negotiating a favourable contract rather than being part of an exciting new industry. There are signs that this is changing. In regions where new companies are starting-up on a regular basis, people are more accepting of a risk of the company failing as further opportunities will arise. This has been the case in Silicon Valley, and is beginning to be evident in places such as Cambridge.

A growing industry will create a demand for skilled workers. We believe the UK can meet this, but on the basis of a value chain analysis, the Government must consider if there are any gaps in training that industry or intermediaries could meet.

4. Cash flow for SMEs

For a small but growing company, cash flow is critical. Government has a tradition of helping through the provision of grants, though here we recommend public procurement be used as a tool to a greater extent.

Venture capital (VC) can also provide support in the early stages of a company's growth, though amounts available in Europe are much smaller than in the US. The Government formed Partnerships UK in 2000 with a VC arm, PUK Ventures, to invest capital in ventures with a public/private profile (such as a company originating from a university lab) and a strong commercial potential.⁶² Though its website states that it is "not constrained by the concerns that guide typical VC investment funds", Innos told us the majority private money in the fund meant they had found the scheme to be too similar to conventional VC.

⁶¹ Research for 'IC Insights', details at <http://www.icinsights.com/news/bulletins/bulletins2007/bulletin20070117.html>.

⁶² <http://www.partnershipsuk.org.uk/BusinessSectors/equity-sector.asp>

From our meetings we have heard how grants offered by the Technology Strategy Board are paid quarterly in arrears. For an SME in the early stages of growth, cash is needed up-front. We recognise the need for accountability of public expenditure, there needs to be accountability for funds, and safeguards in place to ensure it is not misused. However, we believe there should be some flexibility that would allow access to funds when they are needed. For example, an arrangement to secure funds against equipment.

We recommend that the Technology Strategy Board review their policy to pay grants from the Technology Programme quarterly in arrears.

Public procurement has emerged as a key enabler for innovation from several areas of CST's activities. Many groups have identified this component as a means to embed and encourage promulgation of their objectives. Winning an order for a new product or service is much more effective than the provision of a grant to support the activity!

The recommendations we have made previously on procurement, and reiterate here, have two specific objectives: first, to enable Government to better meet its own objectives through procuring innovative solutions, and second, to stimulate innovation in businesses, particularly in smaller businesses.⁶³

We recommend that:

- **there needs to be a strong drive right at the centre of Government to put innovative and SET-based solutions at the heart of procurement policies.**
- **procurement policies need to be less risk-averse, and Government officials need to have the skills and incentives to be able to procure with confidence future capability through innovative solutions.**

5. Government support

A key role for Government is to provide mechanisms which bring the right people together, from existing industries, new start-ups, and academia. This would start with a coordinated road-mapping among key players led by an individual or a group looking at the development of the sector as a whole. There are several Knowledge Transfer Networks and industry groups which could form the basis along with emerging groupings such as the IKC.

Plastic electronics, if it is to succeed, needs focused investment to build up places like PETeC quickly and get industry support via IKC-like structures. PETeC is only now being constructed, after prolonged discussions. Facilities such as these have an important role to play, allowing industry to test new processes, assess feasibility and the likely costs – essentially 'de-risking' a company's involvement, and encouraging it to innovate.

There is publicly funded support for the development of PE from Research Councils, the Technology Strategy Board, and RDAs. A number of private companies are showing strong interest in potential applications. At the same time, elements of a future plastic electronics supply chain exist in the UK, from chip design to thin film processes, which are currently fragmented.

⁶³ CST's report available at <http://www.cst.gov.uk/cst/reports/>.

Government needs to play a key strategic role in facilitating interaction between the users of technology and the science base. PETeC and the Cambridge IKC are good examples of how this can be done. They must be allowed to carry out their mandate, and be further supported as they meet their objectives. Rapidly scaling-up their facilities, or the setting-up of similar facilities in other locations, if they are seen to be working, should be an option.

