

The National Measurement System



Strategy Document

2011 - 2015

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The Strategy for the National Measurement System: 2011-2015

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Foreword by David Willetts



I am very proud to be the Minister in the Coalition Government responsible for Measurement. British science and engineering has measurement at its heart. The UK can rightly be proud of the advances in measurement science made over the centuries, with inspiration from as long ago as 1215 when the Magna Carta decreed that "There shall be but one measure throughout the Realm.....". This tradition continues today in the UK's world-leading national measurement infrastructure that underpins economic growth, business enterprise, commercial transactions, consumer confidence and academic endeavour.

Despite the fact that measurement pervades almost all aspects of our daily life, or perhaps because of this, the importance of ensuring that we can measure a very wide range of parameters accurately is often overlooked. We just take it for granted. But the Measurement System is a vital foundation of a modern developed economy.

The Strategy sets out the action that Government is taking to support a National Measurement System to meet the changing needs of business and society. It will guide the Government's support for the nation's measurement infrastructure, encompassing the leadership of the National Measurement Office, the excellent research facilities at the National Physical Laboratory, LGC and NEL, and the myriad of private sector laboratories and measurement service-providers that supply the standards, knowledge and services upon which millions of users of measurement depend.

The Government's economic policy objective is to achieve strong, sustainable, balanced growth. Through the Strategy for the National Measurement System, we will support fundamental contributions in two key areas.

The first is to provide complete **Confidence** in the measurement standards at the core of the National Measurement System, on which all other measurements rely. It is vital to maintain and improve these standards to enable trust and assurance in measurements for trade, healthcare, consumer protection, law enforcement and the environment, and to grow key sectors of industry such as manufacturing and instrumentation, and enhance important consumer-facing functions such as buying and selling, dispensing medication and therapies, monitoring pollution and enforcing the law.

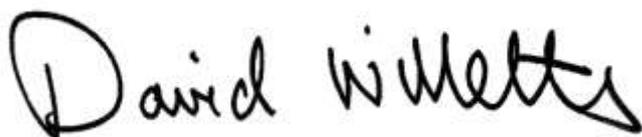
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The second is to boost **Innovation** through exploiting the link between measurement science and technological advance. The best contemporary example is the importance of the atomic clock to measuring time with utmost precision as a necessary precursor to successful global navigation satellite systems. New measurement techniques and technologies will stimulate innovation in products, processes and services, and also help to develop new skills in the workforce.

Investment in the NMS will be focused on sectors where the UK is strong or has the potential to be strong in international markets. Nanotechnologies, regenerative medicine, plastic electronics, new production technologies (such as laser based machining and industrial biotechnology), and advanced instrumentation are examples of areas where the UK is a world leader and where advances in measurement science can support that strong position.

There are massive challenges facing the UK and the world in striving for efficient energy production and use, improved health, better security, advances in digital technologies and environmental sustainability. The research programmes of the National Measurement System will support these challenges through building new strategic science capability and performing at a world-class level of excellence. A key challenge, as we move towards a low carbon economy, is to ensure that as technology advances we are confident that we can measure the carbon we trade and understand the impact of the carbon we emit or the emissions savings we make.

Through the Strategy for the National Measurement System, the national investment in measurement science will therefore be exploited to the benefit of UK business and the citizen, to generate new knowledge, promote growth and innovation, and address key societal challenges.

A handwritten signature in black ink that reads "David Willetts". The signature is written in a cursive, slightly slanted style.

David Willetts

Minister of State for Universities and Science

Part 1: Introduction

This document outlines the strategy for the UK's national measurement infrastructure from 2011 to 2015 and in particular for Government's investment of about £240m in that infrastructure. The Strategy sets out the action that Government is taking to support the infrastructure – provided by both the public and private sectors – that underpins economic growth, business enterprise, commercial transactions, consumer confidence and academic endeavour. It will form a framework for the future direction of the work of the National Measurement System (NMS) by setting out the priorities and rationale for funding and the ambitions for impact.

The Strategy describes how the National Measurement Office (NMO) and the national measurement laboratories (NPL, LGC and NEL) will deliver leadership in measurement nationally and internationally, creating the right framework for growth and innovation. It sets out how the NMS will support action to address national challenges, particularly in the fields of energy production and efficiency, environmental sustainability and improved health, through developing the UK's capability to undertake world class measurement science and research.

The Strategy sets out the scope and scale of Government's planned expenditure on the measurement infrastructure. It describes how NMO plans to achieve economic and social impact by exploiting the UK's measurement assets, working with partners and collaborators in the private sector and academia, and transferring knowledge to support measurement users and improve skills. The Strategy also outlines how NMO will assess the impact of the NMS and achieve further improvements in operational efficiency.

1.1 The importance of measurement

Measurement underpins the welfare of a modern society by supporting trade, regulation, manufacturing and consumer protection. It touches almost every part of daily life, for example by:

- Quantifying emissions of greenhouse gases to understand and mitigate climate change,
- Monitoring the quality of air and developing technologies that will reduce pollution,
- Ensuring safety and efficiency of healthcare prognosis, diagnosis and therapies,
- Supporting advanced manufacturing, enabling high-quality products to be designed and produced efficiently and effectively,
- Measuring the composition, energy value and quantity of gas piped to homes, or of fuel to vehicles,
- Ensuring a sustainable and resilient supply of affordable, safe, nutritious and wholesome food,
- Ensuring consistency of international time standards in order to communicate reliably and navigate accurately throughout the world,
- Underpinning fair trading: around £340 billion worth of goods are sold annually in the UK on the basis of the measurement of their quantity.
- Providing the foundations for science: determination of the value of fundamental constants increases our understanding of the universe.



More than 200,000 patients receive radiotherapy treatment for cancer each year, reliant upon the dose standards delivered by NPL's Clinical LINAC facility.

Part 2: The Strategy

NMO's Strategy for the NMS is focussed on:

- **Leadership in measurement** – Exercising leadership nationally and internationally, and overseeing policy and regulation as it affects the application of measurement to trade, consumer protection, healthcare, security, law enforcement, and environmental and safety legislation,
- **NMS infrastructure** – Supporting a national infrastructure of measurement standards and services provided by Government and the private sector to underpin business growth and innovation and to meet the needs of the public sector, backed by high quality science and technical expertise,
- **Responding to national challenges** – Responding to the challenges facing the UK with new enabling measurement capability, developed in partnership with business, Government departments and agencies, universities and the world measurement community.

Government, via NMO, will invest around £240m over the next four years in providing and developing the UK's scientific and legal measurement infrastructure. In addition, at least £25m will be invested over four years in the upkeep of the Government-owned facilities of NPL and the Teddington site.

2.1 Leadership in measurement

NMO sets the strategic direction of the UK's measurement infrastructure, provides world class statutory and commercial measurement services and acts as an enforcement authority.

NMO's Mission Statement

In support of the Department for Business, Innovation and Skills (BIS) vision of acting as the 'department for growth', delivering the commitment to building a new and more responsible economic model, as well as delivering fairness and the objectives of the Big Society, NMO's mission is:

"To provide policy support to Ministers on measurement issues and a measurement infrastructure which enables innovation, promotes trade and facilitates fair competition and the protection of consumers, health and the environment."

The creation of NMO brought together all aspects of measurement policy – scientific, industrial and legal – within a common leadership and delivery framework. NMO's ambition is to become a strong voice for measurement both internationally and within Government and to ensure that the NMS infrastructure supports national priorities.

NMO's international activities will be directed at ensuring satisfactory legislative outcomes for the UK by influencing the work of OIML (International Organisation of Legal Metrology), WELMEC (European Cooperation in Legal Metrology) and the International Hallmarking Convention. A priority is to avoid trade barriers by ensuring that there is proper co-ordination of international efforts to keep pace with technological developments and business needs.

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The UK's NMS laboratories will continue to lead and push forward the frontiers of measurement, enabling companies to demonstrate the performance of new products in advanced manufacturing, low-carbon technologies and nanotechnology and build confidence in new approaches and tools for healthcare practice. Government itself will benefit from advances in techniques for pollution monitoring in air, land and water, to support environmental regulations.

The UK plays a leading role in the work of the Conférence Générale des Poids et Mesures (CGPM) which defines the basis of the International System of Units (the metre, the kilogram, the second, etc.) known as the SI. The international metrology community, co-ordinated by the Bureau International des Poids et Mesures (BIPM), is working towards a "new SI" for the twenty-first century in which the base units will all be defined in terms of fundamental constants of nature. The UK is contributing to this activity through ground-breaking work on an acoustic method for measuring absolute temperatures and a quantum current standard. It is also in a leading position to contribute to a step-change improvement in the definition of the second, which will have important technological applications in the form of space-based optical clocks.

The SI (Système International d'Unités)

The SI is the global system of measurement units which was formally agreed by the 11th General Conference on Weights and Measures (CGPM) in 1960. The seven base units of the SI are: second for time, metre for length, kilogram for mass, ampere for electric current, kelvin for temperature, mole for amount of substance and candela for luminous intensity of light. The definition and realisation of the base and derived units are actively researched with more precise methods being introduced as they become available.

The UK has spearheaded an initiative to establish a European Metrology Research Programme (EMRP) funded by the European Commission. New technologies and new requirements for quality-assured data generate new demands for measurement. The scale of these requirements in areas such as fundamental standards, energy, sustainability and health requires R&D on an international scale. EMRP is co-ordinated by EURAMET, which represents the group of national measurement institutes engaged in metrology (the scientific study of measurement) within Europe. NPL will continue to exercise strong leadership for the UK within this group.

European Metrology Research Programme

The UK played a leading role in establishing the European Metrology Research Programme (EMRP). The EMRP facilitates closer integration of the nationally-funded metrology research programmes, reducing duplication between institutes and increasing impact. The €350 million seven-year main phase of the programme began in 2010 and involves 22 participating Member States. Programme Calls are planned to cover Energy, Industry, Environment, Health, the SI, New Technologies and Open Excellence. The UK has committed about €45m to the programme.

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NMO will directly, and through the NMS laboratories:

- Fully participate in the work of OIML (International Organisation of Legal Metrology), WELMEC (European Cooperation in Legal Metrology) and the International Hallmarking Convention directed in particular at promoting the principles of better regulation,
- Take a leading role in the development of the world measurement system through continued active engagement with BIPM and CGPM to ensure that UK priorities are addressed,
- Continue to lead the shaping of European priorities for metrology research and commit at least €45M in the strategy period from the NMS programme budget to co-fund collaborative projects in the seven-year European Metrology Research Programme to 2016.

2.2 The NMS infrastructure

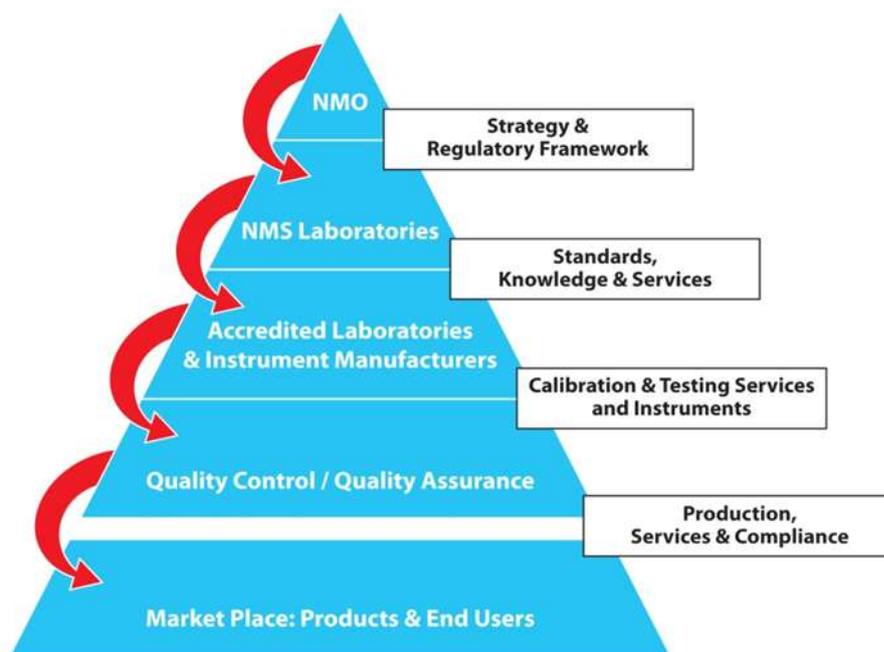
NMO will support UK business, government, public sector organisations and consumers through investment in a competitive measurement infrastructure backed by high quality science and technical expertise that is: responsive; underpins manufacturing, services and regulation; and reduces technical barriers to innovation and trade.

The National Measurement System is the collective infrastructure of national facilities, expertise, knowledge, research and legal framework for reliable, consistent and internationally recognised measurement.

The infrastructure encompasses essential elements of both the public and private sectors:

- NMO which provides the focus for the strategic development of the system and sets the regulatory framework,
- The four NMS laboratories (NPL, LGC, NEL and NMO) and their scientific staff which maintain the national standards and facilities, make them available to users through knowledge transfer and a wide range of services (mostly provided on a commercial basis), and develop new measurement techniques and services in response to requirements from business and the public sector,
- Around 1500 accredited calibration and testing laboratories (largely in the private sector, either independent or part of larger businesses, and supported by an independent self-financing accreditation agency) that use these standards to supply measurement services to characterise hundreds of thousands of instruments and components used in industry, trade, hospitals, universities, local government, forensics and defence,
- Private sector manufacturers of instrumentation and control systems (a successful high-technology exporting sector) that apply the standards and expertise of the NMS laboratories to develop innovative equipment, for example for precision engineering and delivering accurately measured quantities or doses,
- The quality control and assurance capabilities of private sector companies and public sector organisations who apply these instruments and control systems to the production of manufactured goods, operation of processes, delivery of services and regulatory compliance.

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The diagram shows the prime linkages between the four elements of the NMS infrastructure, and their interface with the market place of products and end users. NMO and the NMS laboratories are themselves part of a worldwide network of similar organisations which collectively assure the harmonisation of measurement on a global scale.

The NMS laboratories are operated in the private sector and deliver the national standards and facilities under contract to NMO. The remainder of the infrastructure does not require Government funding. Nevertheless, **the funding of around £60m per annum from Government, channelled through NMO, is fundamental to the direction and development of the infrastructure as a whole.**

In the **private sector**, the NMS infrastructure enables essential elements of business competitiveness:

- **Design.** Bringing products to market quickly requires the design to be right first time and is achieved using analytical models of the product and its subsystems, components, materials and manufacturing process. Validation of these models depends critically upon detailed *measurement*.
- **Development.** Quantitative *measurement* of the performance of a product or service plays a critical role in feeding the next development cycle.
- **Product quality.** A process that is poorly controlled leads to high levels of waste and increased costs. Controlling quality during manufacture relies fundamentally on *measurement*.
- **Customer requirements.** Customers purchase products against a specification of their requirements, which usually depends on parameters defined through *measurement*.
- **Sales and procurement.** Many customers rely on standards and certification processes to simplify and lend confidence to their procurements. These invariably rely on *measurement*.

Rolls-Royce case study

- *“Rolls-Royce is critically dependent on capable measurement. The entire life cycle of the company’s products and the services derived from them is underpinned by measurement. The support of the NMS...is central to the company’s ability to deploy best practice in measurement and to continuously improve product and business performance.”*
(Pete Loftus, Head of Measurement Engineering, Rolls-Royce).
- 200,000 items of measurement kit are used – from micrometers to engine test facilities. Substantial numbers of staff are employed in measurement – spanning design of measurement methodologies and facilities through to taking measurements in the supply chain.
- Following the life cycle of the most critical components (aero engine turbine blades, for example) has indicated that thousands of exacting measurements are made at each stage of design, manufacture, in-service maintenance and, eventually, disposal.

In the **public sector**, the NMS infrastructure supports:

- **Healthcare** (prognosis, diagnosis, manufacture and delivery of therapies)
- **Food (and feed)** (safety, authenticity and traceability)
- **Environmental protection** (air, water and soil quality, waste, industrial and landfill emissions, noise, ionising radiations)
- **Health & safety** (including product safety and performance of personal protective equipment)
- **Security and defence** (including anti-counterfeiting and maintenance of mechanical, electrical, communications and other systems)
- **Law enforcement** (forensic testing)
- **Taxation** (of trade in taxable goods such as oil, gas, alcohol)
- **Fair trading** (consumer protection and competitive markets via trading standards).

The societal benefits are wide-ranging and profound and call upon many of the same measurement capabilities that support the business community. The measurement issues frequently overlap with those in business, for example in dealing with the introduction of a new material into manufacturing which may have benefits in production and performance but also poses environmental or safety challenges.

Engagement by the government-funded NMS with the market-led drafting of documentary standards and regulations will enable the UK to shape the measurement requirements of global markets to ensure they meet the needs of UK businesses. This will include NMO’s work on legal metrology where, for example, the UK’s engagement in Europe continues to ensure that the Measuring Instruments Directive is operated in a flexible way.

2.3 Responding to National Challenges

Global trends such as climate change, demographic change and the communications revolution are affecting all nations and governments. In formulating the NMS Strategy, NMO analysed the policy objectives of Government and other major organisations, such as the Technology Strategy Board, to identify the national priorities for which there is a clear link between measurement and technological advance. Six key national challenges facing the UK were selected in the areas of Growth, Energy, Sustainability, Health, Digital, and Security. Section 3.1 sets out the priorities for measurement research in these areas. The focus has been on sectors where the UK has a capacity and capability to exploit the measurement knowledge generated through the NMS science programmes and where there are opportunities to apply the outputs commercially or for societal benefit.

Particular areas of focus will be to:

- Support the development of low-carbon and energy generation technologies and increase their speed to market,
- Bring confidence to the introduction of more sustainable products, materials and processes, including support for whole life cycle analysis,
- Enable new drugs and therapies, and diagnostic technologies, to be brought to market quickly, safely and at lower cost, and to be deployed with confidence,
- Provide the infrastructure for next generation communications systems, such as smart grids, tele-healthcare and environmental monitoring,
- Provide standards and measurement methodologies to support the security of citizens, infrastructure and utilities.

Each of the challenge areas has a strong technology dimension, in which measurement plays an essential underpinning or enabling role. NMS involvement in tackling these challenges will be most effective where it forms part of a larger enterprise, bringing measurement knowledge to broader government and industry supported projects. Collaboration through Technology Strategy Board and Research Council initiatives and European grant-funded programmes will be an important means of engaging with these projects.

An emerging priority is to work towards establishing carbon measurement standards to support carbon trading within the context of the methods for emissions measurement agreed under the Kyoto protocol and any future international climate agreements.

NMO will explore the possibility of establishing a **Centre for Carbon Measurement** which would provide a focus for the low-carbon and climate science work of the NMS programmes. It would build on existing capability in the NMS laboratories and seek collaboration with relevant capability in academia, business and other organisations across the UK.

The UK's measurement science is renowned for its quality and reputation. NMO will invest in new measurement capability to retain a leadership position in selected areas of science and to attract and retain top-class researchers. A particular focus will be the research to support the international effort to redefine selected SI units. This has potentially far-reaching applications and could contribute to developments such as more accurate global navigation satellite systems, faster internet and smaller microchips. Section 3.2 sets out the priority measurement science areas and the key scientific objectives.

Part 3: Measurement Priorities

3.1 Supporting the National Challenges

3.1.1 Growth: The Overarching Challenge

NMO will, through the NMS programmes:

- Formulate responsive research programmes that support priority sectors where the UK is strong or has the potential to be strong in international markets,
- Focus the NMS investment on measurement technologies that will assist UK business to be innovative,
- Provide measurement technology input to the priority areas identified by the Technology Strategy Board by supporting collaborative research projects,
- Support training in good measurement practice for business to develop skills and understanding of measurement science and technology.

Sustainable and balanced growth is a major priority for Government. Key to this will be manufacturing, which accounts for more than half of all exports and around 15% of GDP. The UK has competitive advantage in sectors where it is possible to build on the UK's skills and research base, both in established areas of high value manufacturing and emerging areas such as low-carbon technologies. Investment in, and support for, knowledge-intensive, high value manufacturing is vital, since reductions in transport costs, the enabling effect of communications technology, and the lowering of barriers to trade are causing more traditional areas of manufacturing to migrate to lower-cost economies.

The frontiers of measurement are forever expanding, with new science, technology and applications making fresh demands on the measurement infrastructure. At the same time, new measurement techniques and technologies stimulate and enable innovation in products, processes and services. Investment in the NMS will be focused on sectors where the UK is strong or has the potential to be strong in international markets.

To grow the high value manufacturing sector, new ideas, technologies and manufacturing processes must be introduced to maintain UK competitive advantage. Nanotechnologies, regenerative medicine, plastic electronics, new production technologies (such as laser based machining and industrial biotechnology), and advanced instrumentation are examples of areas where the UK is a world leader and where advances in measurement science can support that strong position.

Measurement, and knowledge of the uncertainty of measurement, is critical for good decision making. For example in comparing two options based on measured data, or in comparing measured data with a limit, it is essential to know how accurate (or uncertain) the data are. The concepts of accuracy, precision, uncertainty and traceability are intrinsic to measurement. The NMS will support the provision of industry-relevant training to promote good measurement practice in manufacturing and scientific and technical services.

Nanotechnology

Nanotechnology will play a significant role in future product innovation and in tackling the national challenges.

The NMS laboratories will lead the development of characterisation tools, methodologies and reference materials for nanomaterials to facilitate their application and to underpin environmental, health and safety research.

Nanotechnology devices have dimensions of billionths of a metre and cannot be measured by conventional means. The NMS has made a significant contribution to the development of scanning probe microscopy techniques which allow researchers and developers to characterise materials and determine the performance of devices.

Nanotechnology is impacting innovation in most manufacturing sectors. Industrially it offers two key advantages: the creation of innovative products, and improved competitiveness through added features or reduction in manufacturing costs. It impacts Energy through novel technologies for energy storage media (batteries, hydrogen storage) and improved energy efficiency and generation (fuel cells, photovoltaics). It offers benefits for Sustainability, through enhanced shelf-life, engineered end-of-life recycling and rapid breakdown for environmentally benign disposal. And in Health, new diagnostic systems rely on engineering and safety at the nanoscale. Novel semiconductor and optoelectronic devices will benefit Digital technologies.

3.1.2 The Energy Challenge

The UK Government has set an objective of developing a national energy infrastructure that provides increased security of supply through the development of next-generation technologies. These will be either intrinsically low-carbon, or provide the means of reducing or avoiding carbon emissions into the atmosphere, and will maximise the recovery and use of UK natural fuel resources. More efficient means for the provision of energy to the end user must be introduced and it should be consumed at higher levels of efficiency in order that energy can be conserved and provided at affordable levels. Smart grids and smart metering will play a role in saving energy and controlling energy demand.

An urgent challenge is to reduce the generation and release of carbon dioxide to limit the effects of climate change. The UK has adopted legally binding reduction targets for 2020 and 2050. Achievement of these objectives will depend on the development of a validated energy accounting framework and standards, to enable businesses and Government to understand their contribution to carbon dioxide generation and to underpin carbon trading, taxation and regulatory instruments.

Expert opinion on the evolution of the energy mix within the UK indicates that fossil fuels will remain the primary source of energy for the next 25 years. It is therefore important to continue to underpin the measurement challenges with regard to such fuels, while at the same time also providing the measurement standards and framework to support the introduction of low-carbon energy generation technologies such as wind, tidal, photovoltaic and biomass and a new generation of nuclear plant.

With respect to energy from fossil fuels, the priorities will be to provide a measurement infrastructure that allows fair trading, taxation and regulation of carbon and supports the development of technologies and processes for the capture and storage of carbon emissions. There are also challenges around the production and transportation of high viscosity fuels and improvement of the efficiency and extension of the operational lifetime of fossil fuel plant.

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In terms of the low-carbon sector, over the next five years, the deployment of wind power will continue and tidal and wave power may become economically feasible. Investment in the national power grid will be necessary so that these low-carbon energy sources can connect to it. Means of transportation will move progressively towards low-carbon solutions, with the development of both hybrid and electric vehicles and the introduction of alternative fuels. The provision of heat and lighting to homes, communities and industrial units will become more localised; and in the longer term large power generation capability will turn increasingly towards nuclear as a low-carbon solution.

The technologies and processes used in the energy sector are underpinned by measurement standards and capabilities addressing the energy content, purity and origin of fuels (including bio-fuels), flow measurements, materials and fluid properties in harsh environments and measurement of the operational environment of energy systems and components. The NMS laboratories are expected to continue to form strategic relationships with the R&D departments of major fuel producers, energy generators and distribution companies in order that NMS capabilities can be applied with major impact. The NMS programmes need to respond to and anticipate future requirements in this rapidly evolving sector and apply expertise to help increase the speed to market of low-carbon technologies.

NMO will, through the NMS programmes:

- Support the achievement of carbon reduction targets to address climate change, by providing the underpinning measurement infrastructure needed to verify reductions in energy consumption and improvements in energy efficiency,
- Facilitate market acceptance of low-carbon energy generation technologies through the development of standard methods of assessing and proving technical performance,
- Provide measurement and characterisation methods to support the development of carbon capture & storage, bio-fuels, wind and marine energy, photovoltaics, fuel cells, hydrogen energy, and the connection of low-carbon energy to the national grid,
- Provide performance data for materials and develop in situ monitoring techniques to improve the efficiency and extend the operational lifetime of fossil fuel plant and support existing and next generation nuclear plant,
- Assist the drive towards greater energy efficiency through measurement research to improve energy management, including the use of novel technologies for energy storage,
- Provide standards for purity and stability of fuels, and their safe transportation and metering (to include liquefied natural gas, synthetic fuels and hydrogen).

Measurement for low-carbon technologies and climate science – Supporting Energy and Sustainability

Responding to the threat of global climate change is a national and international priority and one in which the UK has taken a lead. Work to achieve international agreements on climate change mitigation has been backed by national policies that seek to: reduce greenhouse gas emissions from energy generation, improve energy efficiency, support the development and deployment of low-carbon technology, encourage changes to individual behaviour and build world class capability in climate science.

NMO will explore the possibility of establishing a **Centre for Carbon Measurement** which would provide a focus for the low-carbon and climate science work of the NMS programmes. It would build on existing capability in the NMS laboratories and seek collaboration with relevant capability in academia, business and other organisations across the UK.

NMO will, through the NMS programmes:

- Support national and international efforts to understand and mitigate climate change by providing confidence and reducing uncertainties in climate data used to monitor and model climate change,
- Assess the performance and facilitate market acceptance of low-carbon technologies in order to accelerate the development of the UK low-carbon technology sector,
- Seek to establish carbon measurement standards to support carbon trading within the context of the methods for emissions measurement agreed under the Kyoto protocol and any future international climate agreements,
- Ensure strong representation of UK interests in international discussions around measurement science, technology and standards related to climate change and low-carbon technology.

3.1.3 The Sustainability Challenge

National attention on the sustainability of our present consumption of resources has been brought into sharp focus by: long-term increases in the cost and availability of feedstock materials and energy (driven by increasing global demand especially in the emerging economies); concerns about the poor efficiency of material, water and energy usage in the built environment, manufacturing industry and transport; issues surrounding biodiversity; and the need to recycle/re-use to avoid expensive disposal of waste via landfill.

Tackling these issues will require the reduction of our dependency on production from carbon (petroleum) based products and will involve the design, production and transformation of basic materials into other more complex products. Sustainability of resources will also involve the use of new materials (less resource/energy intensive, lightweight, improved thermal/acoustic properties, low maintenance, corrosion resistant, suitable for retro-fit, and recyclable/re-usable) and a transition to a new generation of functional materials (chemical, biotechnological etc), intelligent buildings, structures and transport systems using sensors for efficient energy and process management.

At the same time there is a continuing need to measure pollutants in air, soil and water to protect life, underpin remediation and ensure the safe disposal of hazardous materials.

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Understanding and modelling global climate change is critical for shaping policies for adaptation and mitigation, and for monitoring their impact. This requires measured data of known and high quality, including from earth observation satellites. Long time-series must be constructed from small signals against a noisy background using instruments across the globe, and there is a need to work with the climate science community to put in place a more secure measurement infrastructure for this data. Earth observation data are also now becoming a commercial product with the potential to provide real economic benefit to the UK.

NMO will, through the NMS programmes:

- Bring confidence to the introduction of more sustainable products, materials and processes, by providing objective methods of process control and performance evaluation, including support for whole life cycle analysis,
- Enable characterisation of wastes, to allow safe and secure disposal within legal limits,
- Provide standards and techniques for measurement of emissions of greenhouse gases,
- Underpin the development and evaluation of novel alternative materials to replace those with limited reserves,
- Establish increased confidence in Earth Observation data on climate change by developing instrumentation and techniques for data validation and by leading the introduction internationally of long-term reference methods.

Measurement for food science and technology – Supporting Sustainability and Health

Poor diet is estimated to account for a third of all cases of cancer and a further third of cases of cardiovascular disease. Obesity increases the risk of certain diseases. The health benefits of safe, nutritious and wholesome food – supplied sustainably and resiliently – are clear both socially and financially.

NMO will, through the NMS programmes:

- Provide enhanced methods for determining traceability and authenticity of food and feed, assuring confidence in functional foods, and assessing benefits and risks of novel food processes including use of nanotechnology and testing for food spoilage,
- Develop methods and standards to enable rapid, on-farm diagnosis of plant and animal diseases and to protect wildlife and biodiversity of the farmed environment,
- Support crop and livestock improvement through advanced identification of genetic markers linked to observable traits.

3.1.4 The Health Challenge

Health priorities will be driven by predicted changes in population demographics and the increasing prevalence of age-related health issues such as cancer and dementia. Acute and chronic illnesses related to alcohol misuse, obesity and other lifestyle causes place additional burdens on healthcare provision. Globalisation means diseases are not constrained by borders and pandemic outbreaks can no longer be tackled by single governments. These drivers are causing a re-evaluation of priorities in the NHS.

There is a need to introduce more efficient clinical practices, and (early) prognostic and diagnostic techniques, therapies and assistive technologies for deployment in the hospital, surgery and home environment, both to meet patient needs and to improve value for money. These new practices and technologies must be validated as safe and effective.

The UK has a highly successful pharmaceutical industry, delivering a significant trade surplus, but which is undergoing strategic consolidation and rationalisation. It has a burgeoning biopharmaceutical industry and an emerging regenerative medicine industry. It is important that these industries are able to translate capability into new drugs and medical products and get them to market quickly and safely, compliant with the associated regulatory framework and assuring public confidence.

Measurement can support the needs of medical researchers and companies through its application earlier in the development pipeline, to improve effectiveness and safety. It can improve the speed, reliability and cost of diagnostics to underpin accurate and reliable clinical decisions and treatment regimes. It can remove technical barriers and mitigate regulatory barriers to the exploitation of novel interventions.

The benefits to society are an improved quality of life with increased life expectancy. There will also be a greater preparedness for future health demands and new disease threats.

NMO will, through the NMS programmes:

- Enable new drugs and therapies, and prognostic, diagnostic and assistive technologies to be brought to the market quicker and at lower cost, consistent with regulation,
- Support the optimisation of these technologies in clinical practice,
- Support the reduction in animal testing through the validation of new types of testing protocols, to the satisfaction of the regulators,
- Develop measurement protocols and standards to enable infectious disease detection technologies to be deployed and utilised with confidence,
- Contribute to the development of performance testing standards designed to keep less able people safe and secure in their own homes.

3.1.5 The Digital Challenge

Digital and broadband technologies are reshaping communications, business models and the delivery of public services worldwide. Consequently if the UK is to remain internationally competitive it must, over the next five years, upgrade its wired and wireless communications and broadcasting networks to provide the capacity to meet the growing demand for high bandwidth services. This investment will provide opportunities for UK instrumentation and communication system suppliers. It will also bring new measurement challenges to the industry requiring higher speed instrumentation, higher performance antennas, higher speed synchronisation, tighter control of the electromagnetic spectrum, and more resilient systems and data authentication.

These developments will enable the introduction of 'smart infrastructures' servicing energy use and supply (smart grids), tele-healthcare, environmental monitoring and communications across the transport infrastructure. This will require in-situ measurements of systems and components in real operating conditions, models of system behaviour to enable cost effective evaluation of modifications, and test beds to simulate real systems under severe conditions.

NMO will, through the NMS programmes:

- Develop measurement methods to underpin the specification and reliability of the technology for next generation communication systems,
- Enable systems evaluation and modelling to support the development of smart infrastructures.

3.1.6 The Security Challenge

One of Government's primary responsibilities is to ensure the safety and security of its citizens and national assets. The UK faces a continuing threat from extremists who believe they can advance their aims by committing acts of terrorism against citizens in the UK and against UK interests abroad. Similarly, organised and serious crime leads to threats to individual security, through violent crime, human trafficking, antisocial behaviour and increased drug abuse. The growing likelihood of epidemics, whether caused by natural effects or deliberate malicious intervention threatens whole sections of society, either geographically, or based on demographics. Finally, security of food supplies against contamination or other disruption is vital to the welfare of the population.

NMO will, through the NMS programmes:

- Provide standards and measurement methodologies to support the security of citizens, infrastructure and utilities, intelligent surveillance and border and data security, and the maintenance and development of defence capabilities.

The gathering, processing and fusion of measurement data, and the quantification of the uncertainties in the data, are critical to success in combating these threats. Security risks must be managed effectively, collectively and proportionately, to achieve a secure and confident working environment. The NMS provides the measurement infrastructure for the new technologies and solutions deployed to provide the Government with assurance of this security.

3.2 Investing in excellent science

The quality and reputation of the UK's measurement science is paramount – it is what enables it to add value to the development and introduction of new technologies. Measurement needs are ever changing and measurement scientists must stay at the forefront of the developing technologies that will drive future growth such as low-carbon, nano, bio and quantum technologies.

NMO will support the NMS laboratories to retain a leadership position in selected areas of science important for the future UK economy. These will be chosen to build on existing core scientific strengths, in areas where there is the potential for the UK to achieve and sustain a lead over competing research teams.

The NMS laboratories will be supported in the priority science areas of:

- Next-generation metrology and its application (including the SI units and their extension),
- Measurement across the scale – from atoms & cells to whole systems,
- Quantitative environmental monitoring (including remote sensing),
- Validation of low-carbon and sustainable technologies,
- Statistical modelling of heterogeneous data.

It is essential that NMO invests in new measurement capability to underpin the science necessary for the NMS to be internationally competitive and enable the NMS to attract and retain top-class researchers. It is also vital that the NMS programmes support UK growth and innovation, and respond to the developing technology priorities of Government and its prime innovation agency – the Technology Strategy Board. The NMS laboratories will be expected to work in partnership with innovative UK companies and the academic community, making maximum use of combined resources and facilities and bringing co-funding to the delivery of NMS programmes.

NMO will encourage the NMS laboratories to:

- Strengthen links with the academic community,
- Strengthen links with companies working on the commercialisation of new technologies.

Key scientific objectives include:

- Making a significant contribution to the evidence base for the redefinition of selected SI units by the CGPM. To maximise impact, the programmes will concentrate on the redefinition of the ampere, kelvin, mole and second and extension of SI units to biomeasurements,
- Supporting leadership and participation by the NMS laboratories in collaborative projects with European national measurement institutes in the European Metrology Research Programme. NMO will encourage the development of projects in areas of national priority where the NMS will gain from the international pooling of collaborative research.

Quantum Technology including optical clocks

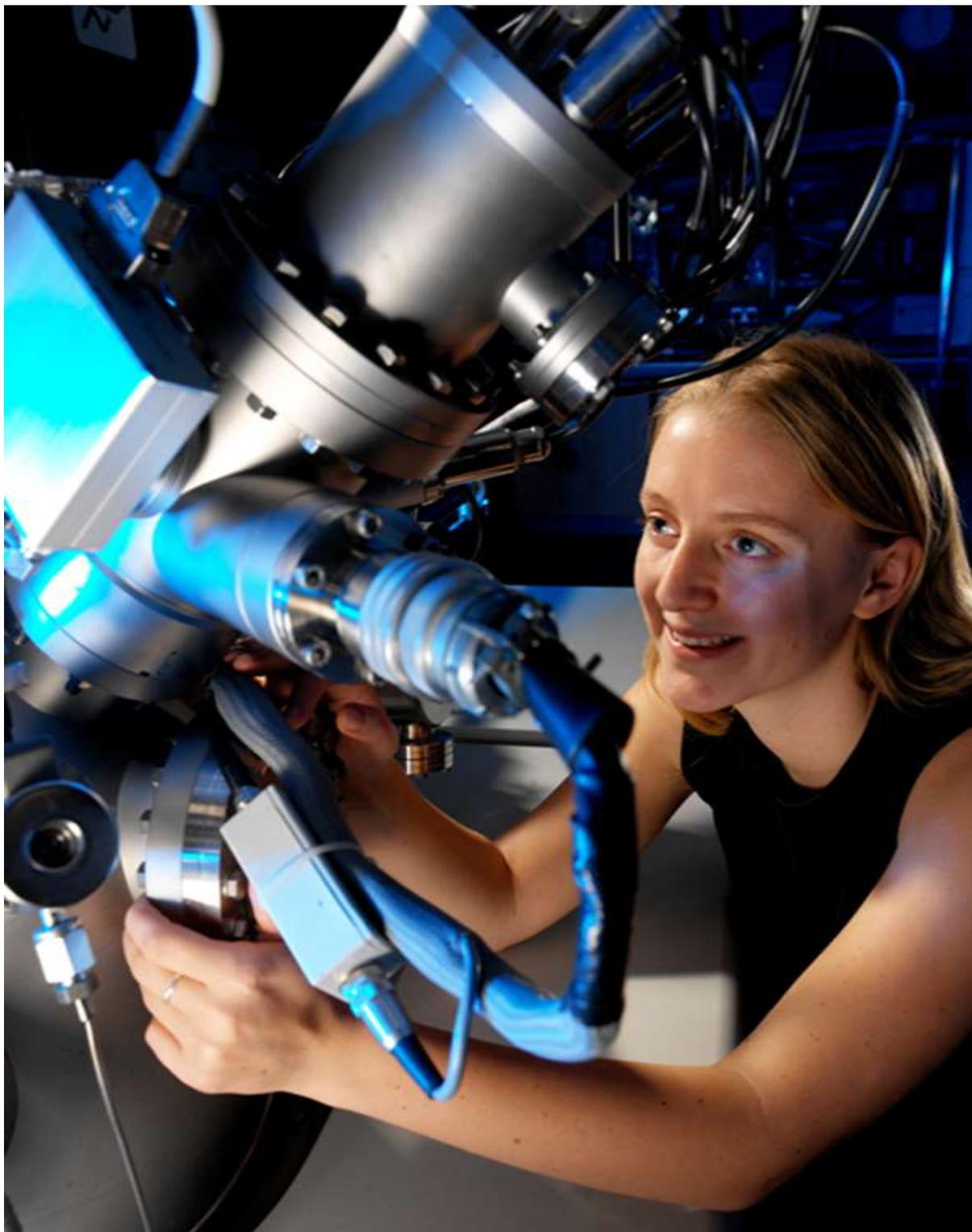
NPL is developing a range of new measurement methods and sensors based on physics at the quantum level. This includes applications of quantum technology for computing and fundamental electrical and time measurement. Current atomic clocks use microwave technology and can achieve uncertainties close to 1 part in 10^{15} in a day. NPL is playing a prominent role in an international effort to develop optical clocks which should be accurate to better than 1 part in 10^{17} . The success of this work will lead to a redefinition of the second and significant improvement in the performance and resilience of satellite navigation systems.

The NMS programmes are subject to systematic review to ensure that they deliver economic and social benefits both in the short and long-term. The research is often delivered in partnership with leading academic teams and innovative companies. Review against international benchmarks is through a number of routes:

- The programmes are overseen by independent Advisory Groups, comprising industrial, academic and Government specialists, and international metrologists,
- An independent body of eminent scientists from the Royal Society and Royal Academy of Engineering regularly reviews the scientific work of NPL,
- Statistics are collected on published papers reporting the work of NMS scientists. Targets will be set for publication in high-impact scientific and technical journals of a quantity of papers by the NMS laboratories that are commended and cited internationally. Other measures include the number and status of metrology committees chaired, secondments to/from international institutions and patents and licences generated.

Research publications

The NMS laboratories produce high quality and widely cited research. They publish around 200 papers per annum in leading peer-reviewed scientific journals across many disciplines and the citation record (a widely used quality indicator) bears comparison with university research. They also publish in specialised technical journals and produce many papers for conferences, thus making metrology knowledge available to industry and the research base.



G-SIMS, a technique invented by NPL scientists to gain chemical information about molecules attached to surfaces.

Part 4: Achieving Impact

4.1 Understanding the measurement needs

If the NMS is to make a major contribution to economic growth, it must do so in partnership with Government, industry (from multi-nationals to SMEs) and academia in order to identify the priority measurement needs and supply the best solutions, for example new measurement standards and techniques or new services. Working with other stakeholders ensures that projects remain focused on desired outcomes and the delivery of impact. Working with appropriate academic teams ensures the application and exploitation of the most recent academic thinking that is relevant to the work. NMO consults with a large number of stakeholders (200+) who advise on and support the NMS programmes.

4.2 The UK Innovation Infrastructure

Government plays a role in supporting and underpinning innovation through a range of organisations sometimes referred to as the UK innovation infrastructure or ecosystem. As well as the measurement infrastructure, the wider infrastructure includes direct support to business (through the Technology Strategy Board), intellectual property protection (Intellectual Property Office), standards (BSI British Standards), accreditation (United Kingdom Accreditation Service), design (Design Council) and innovation research (NESTA).

NMO will continue to work with the innovation infrastructure organisations to increase innovation in businesses and the public sector by:

- Sharing information, including impact assessment and horizon scanning, in order to develop sound complementary business-facing policies and activities,
- Joining up relevant activities, initiatives and services,
- Optimising access by businesses to information and advice by signposting between the organisations.

4.3 Working with partners

4.3.1 Technology Strategy Board

NMO will, through the NMS programmes:

- Engage actively in Technology Strategy Board programmes where measurement has the potential to generate growth and address key societal challenges,
- Work with the Knowledge Transfer Networks (KTNs), including using the **_connect** platform, to provide a conduit for business into the NMS capability and to give businesses insight into advances in measurement techniques that can be exploited by members,
- Use feedback from the KTNs and business to help shape future investment in the NMS,
- Support the newly-established Technology and Innovation Centres, partnering with them where appropriate, to develop new measurement techniques and standards to underpin new technologies.

The Technology Strategy Board's task is to ensure that the UK is in the forefront of technology-based innovation. Measurement technology is an enabler of innovation and NMO will work with the Technology Strategy Board to ensure that the national investment in metrology is exploited to the benefit of UK business, to generate growth and address key societal challenges.

4.3.2 Research Councils and universities

NMO will, through the NMS programmes:

- Seek opportunities to exploit collaborative access by NMS and Research Council funded researchers to NMS laboratories, university and Research Council facilities, and for new investments to be shared,
- Share expertise in understanding and assessing the economic and social impact of NMO and Research Council funded research,
- Support strategic partnering by the NMS laboratories with universities to develop and deliver new measurement techniques and technologies.

The work of the NMS sits at the interface of business, academia and Government, and the NMS laboratories carry out a significant fraction of their research and development work in partnership with universities. As a consequence there is scope for programme alignment, co-funding, and sharing of access to high-cost facilities by Research Councils and NMO.

4.3.3 Standards organisations

Standardisation is a vital component of business innovation, enabling the pull-through of products, services and processes into the market. Many organisations' first interaction with measurement is through the route of compliance to a documentary standard. It is vital that the measurement requirements specified within standards are appropriate and there is an infrastructure in place to enable organisations to demonstrate compliance.

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NMS scientists are expected to work closely with the standards-making community, most notably BSI British Standards. The NMS will also link with the work of standards providers such as the National Institute of Biological Standards and Control (NIBSC), a centre of the Health Protection Agency dedicated to ensuring the quality of biological medicines used in the treatment and prevention of disease.

NMO will, through the NMS programmes, or directly:

- Work with the standards-making community to identify emerging fields for standardisation and develop measurement methods and reference materials to support them,
- Provide advice into standards committees as appropriate on measurement-related issues,
- Ensure that international documentary standards are based on robust science and address UK priorities,
- Support UK standards organisations, such as NIBSC, by providing accurate and traceable measurements which underpin and ensure recognition of the standards they produce.

4.3.4 United Kingdom Accreditation Service (UKAS)

UKAS is the Government appointed National Accreditation Body for the UK and, as such, accredits calibration and testing laboratories, inspection and certification bodies against international standards for competence, impartiality and consistency. UKAS plays a vital role in the National Measurement System by accrediting the many laboratories that provide calibration and testing services as part of the NMS.

NMO will, through the NMS programmes, or directly:

- Ensure calibration and testing laboratories are adequately supported by the NMS infrastructure through the provision of traceable measurement standards,
- Work with UKAS to ensure that calibration and testing laboratories are fully aware of the benefits of being accredited,
- Provide advice to ensure that the accreditation process delivers the required level of confidence in the organisations accredited,
- Influence the European and world measurement and accreditation communities to work more closely together to achieve the above objectives on a European and global level,
- Work with UKAS to ensure that UK measurement standards and accredited services are recognised by our international trading partners.

4.4 Knowledge Transfer

A goal of the NMS is to translate advances in measurement science into knowledge that can be exploited to fuel economic growth from business-led technology innovation. Analysis published by BIS economists concludes that the economic impact of the NMS is predicated on the effective dissemination of research outputs and measurement knowledge. If these activities do not take place effectively, the Government would fail to gain economic value from exploiting the investment in the measurement infrastructure.

Increased impact will be achieved when users understand the benefits of good measurement practice and make improvements to working practices and tools. Technology-based companies, ranging from multi-national to micro, collaborate directly in NMS research and development or use NMS calibration, testing, training and consultancy services. Others utilise the scientific outputs from the NMS that are embodied in publications, documentary standards and recommended practices. The early adopters of the outputs of the NMS tell us that they gain competitive advantage and increase profits. However, there are others, particularly small and medium sized manufacturing companies, who are unaware of the benefits.

NMO will, through the NMS Programmes:

- Focus on further penetrating sectors that already interact with the NMS (for example instrumentation, utilities, nuclear, aerospace, healthcare, defence, manufacturing and processing) and also reaching out to sectors that have limited exposure to the NMS but are Government priorities (for example high value services).

The benefits to the public sector (health service, environmental protection, health and safety, security and defence, law enforcement, consumer protection) are similar, with gains in confidence, efficiency and effectiveness to be secured through the adoption of new measurement technology, standards and methodologies.

NMO will, through the NMS Programmes, and in compliance with the Government's controls on marketing expenditure, undertake the best value, effective, essential knowledge transfer which will:

- Connect technology-driven businesses (from multi-national to micro), and technically-based public sector organisations, to measurement expertise,
- Support the application of measurement best practice,
- Adapt to satisfy the changing needs for guidance and support,
- Extend awareness of measurement knowledge and make it accessible to broader market-based audiences,
- Translate the knowledge into more accessible forms,
- Deliver the knowledge through channels with which users can readily engage,
- Involve intermediaries (professional, trade, sector-based, regional) in reaching a broader audience.

The Strategy for the National Measurement System: 2011-2015

To raise awareness and to prompt action, NMO's knowledge transfer programmes will use the best value communication methods, including targeted workshops, trade or technology-focussed meetings, scientific publications, reference guides, website and related e-communications. Much will be undertaken in partnership with intermediary organisations that can help to reduce or eliminate costs and tailor the messages to audiences by sector, region, application or technical need as appropriate and practical. NMO will continue to develop a Measurement Network, based on the successful Knowledge Transfer Network model promoted by the Technology Strategy Board.

The Measurement Network

In 2010, on behalf of the NMS, NPL launched a Measurement Network to provide comprehensive access to the latest measurement science for UK industry and academia.

The Network enables the dissemination of NMS knowledge more efficiently and effectively using a sector focus, as well as continuing to operate through *application-* and *technology-*aligned channels. It links Network members with NMS experts by providing a forum for the exchange of information and advice. Members have the opportunity to attend specialised events and to influence the research that the NMS undertakes.

The Measurement Network will gain advantage from joining the Technology Strategy Board's online platform (**_connect**) for the Knowledge Transfer Networks. This will enable members of all the networks to share knowledge, find opportunities and gain common access to information on measurement technology and methods from all the NMS laboratories.

Membership of the Measurement Network has grown to nearly 2,000 scientists, engineers, academics and managers from the business, public and education sectors.

4.5 Skills

There is evidence that measurement skills have declined in the UK workforce. Surveys of companies have highlighted the lack of formal measurement training included in current academic and vocational qualifications. Measurement tools and techniques have become increasingly sophisticated, combining science and technology at the interfaces between physics, chemistry, biology and engineering. Part of the sophistication is automation, which on the one hand makes measurement easier for the user but on the other obscures the measurement process and generates results that are easily misinterpreted. The advance of automated technologies has been accompanied by a decline in understanding of the basic concepts of measurement accuracy and uncertainty. The loss of measurement skills from the manufacturing workforce has also adversely affected the ability of companies to apply measurement for design, development and control.

NMO will, through the NMS programmes, or directly:

- Promote the development of an understanding of measurement principles and the benefits of applying good measurement practice in manufacturing and scientific and technical services,
- Respond directly to the skills agenda by pump-priming industry-relevant measurement training.

Skills and education

NPL supports nationally recognised qualifications in metrology, validated by the National Skills Academy for Manufacturing. It has developed a Training Framework with support from stakeholders such as Rolls-Royce, BAE Systems, Airbus and instrumentation Original Equipment Manufacturers.

The NPL Training Framework is supporting the revitalisation of the UK's manufacturing economy. To date, more than 1,250 delegates have been trained. It forms part of Coventry University's Foundation Degree in Metrology and is to be introduced to a number of company-specific apprentice programmes.

4.6 Regulation

Effective and well focused regulation plays a vital role in correcting market failures, promoting fairness and increasing competition. Each year in the UK, around £340 billion worth of goods are sold on the basis of the measurement of their quantity (around £210 billion of this is controlled by weights & measures legislation and £130 billion by gas & electricity legislation), equating to over £6 billion a week. In addition to this, goods worth around £280 billion per annum are weighed/measured at the industrial/business-to-business level.

NMO is committed to seeking a proper balance between effective protections and appropriate levels of compliance costs. On the one hand it is entirely right that we have controls in place to protect consumers (including businesses as consumers) when they are making purchases. On the other hand, businesses expect a regime to be in place that they can understand easily and which is not unduly costly. They also demand an enforcement regime that is consistent and proportionate and does not give rise to undue compliance costs. It is also vital that consumers have access to sufficient information for them to make informed choices and comparisons. For most purchases e.g. gas, electricity, petrol, it is virtually impossible for the consumer to check the quantity they are paying for, so it is important for there to be controls in place to protect them.

NMO maintains a legislative infrastructure that covers units of measure, measuring instruments, pre-packages, transactions of goods, and hallmarking. Statutory and commercial product and process assessment services are also provided which assist UK manufacturers, particularly SMEs, to compete in an international market for the sale of their products. NMO will continue to look for imaginative ways of working with colleagues in the Trading Standards community responsible for enforcing weights and measures legislation, and elsewhere in Government.

4.7 Evidence of impact

Good measurement practice makes a fundamental contribution to the UK economy in two key areas:

Confidence. The primary and national measurement standards, forming the core of the NMS, underpin the system of traceable measurement in the UK, on which measurements rely. Traceable measurement supports legislation, regulation, standardisation, calibration and testing. It plays an essential part in demonstrating compliance and meeting specifications in the advanced manufacturing and instrumentation sectors which will contribute to future growth. A regulatory framework, based upon measurement confidence, ensures global markets are fair and open by eliminating unnecessary barriers to trade. To trade successfully, consumers and businesses need to have confidence that measurements of goods sold by weight, volume, etc, are consistent, accurate, fair and legal.

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Innovation. Increasingly accurate measurement standards and techniques enable advances in science and technology, so facilitating innovation and economic growth. Such improvements can lead directly to new products, processes and services through better measurement of quantity, quality and performance.

NMO has evaluated the impact of the NMS and in particular the effectiveness of public funding using four approaches:

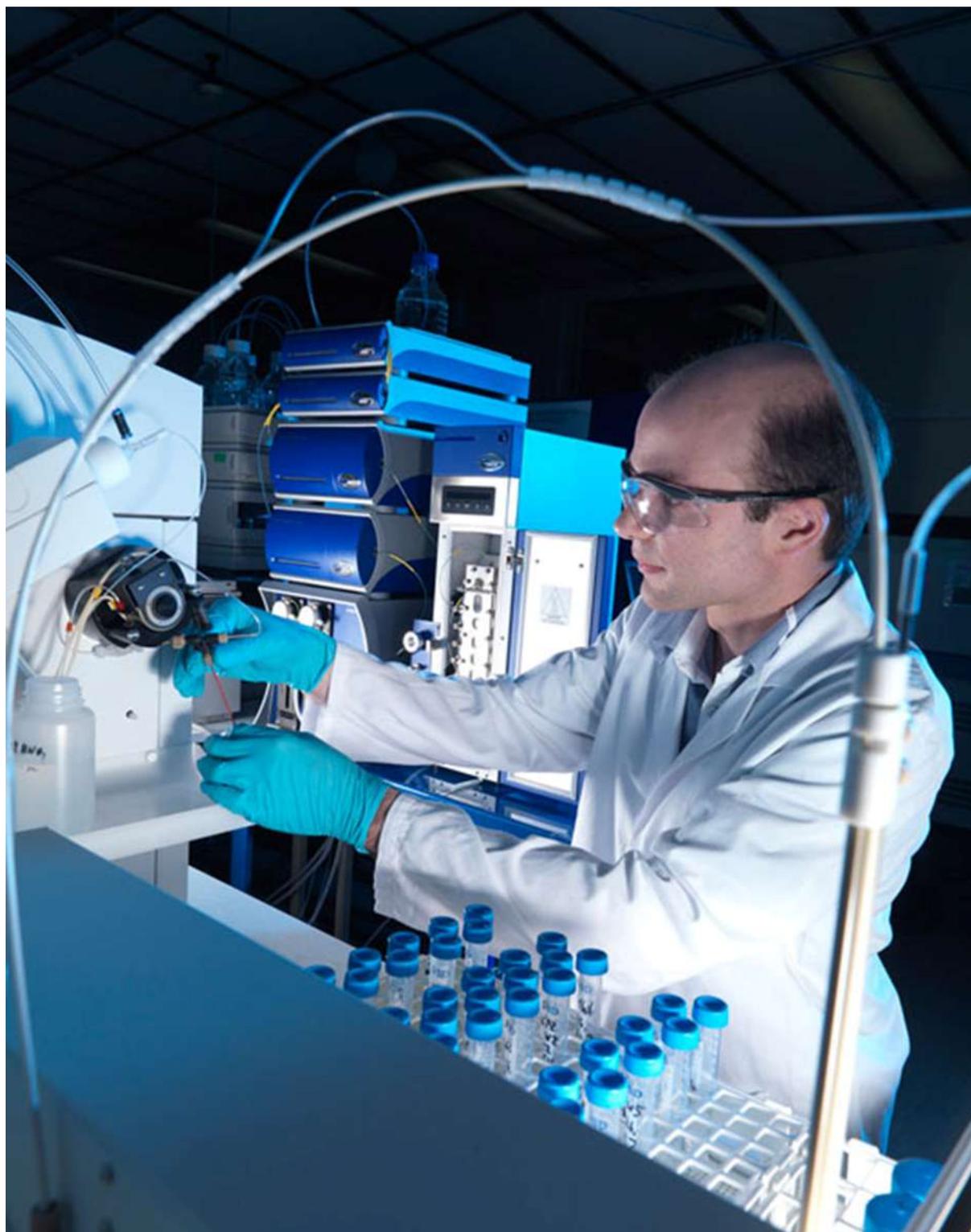
- **Economic modelling.** Studies by BIS and academic economists indicate that there is good evidence of substantial economic impact – on innovation, productivity and public services – from public investment in measurement.
- **Customer surveys.** An independent survey of businesses found that in a single year the NMS infrastructure and programmes helped businesses introduce new products and processes that increased profitability by more than £700m.
- **Case studies.** Case studies carried out to quantify the impact of specific projects from NMS programmes typically show a return on investment of between 10 and 30 times.
- **Output metrics.** The outputs of the NMS research programmes are continuously monitored, for example the number of scientific publications and citations, the number of downloads of measurement guides, and the satisfaction of customers of measurement services.

Base station antenna testing for 3G mobile phone networks

An important feature of the networks is the use of a type of variable tilt antenna. The antenna range at NPL delivered better information about how the antennas would behave. Evaluations have shown that the calibration data improvements supplied by NPL's measurements could have equated to a 1% one-off saving in network capital costs, or around £50 million. Even if the antenna range were used for nothing else (which is not the case) this indicates a benefit/cost ratio (in terms of additional economic surplus) of 25:1.

NMO will:

- Continue to develop an evidence base of impact, including economic modelling, cost-benefit analyses, case studies and surveys,
- Develop a scorecard for NMS research and development programmes to record the outputs and the evidence of impact in the form of outcomes, as assessed through evaluations and surveys. In this way, it will be possible to scale up the data to form an assessment of some of the outcomes and impact of the totality of Government investment in measurement science.



LGC innovatively couples field flow fractionation to inductively coupled mass spectrometry to improve the detection and characterisation of nanoparticles in complex matrices such as food.

Part 5: Resources

5.1 Why does Government provide funding?

A major part of the NMS, and the services that support it, is supplied and used by the private sector market place. Government provides the underpinning measurement infrastructure that the open market would not otherwise supply.

Government provides funding in order to:

- **Enable correct and traceable measurement.** The reliability of the measurements carried out by private sector producers and suppliers is underpinned by the traceability of the measurements to the standards maintained on behalf of Government by the NMS laboratories.
- **Underpin regulation and healthcare.** Accurate measurement is essential for assuring consumer protection, security, law enforcement, environmental and safety legislation and the quality of healthcare. For example, reliable measurements are essential to underpin effective standards and regulations to drive lower emissions and to support a greener economy.
- **Apply new knowledge to innovation in goods and services.** The research performed by the NMS, as part of the broader national science investment in universities and through the private sector, is a key enabler of innovation by providing new and improved measurement references and techniques. Through Government support, new measurement techniques are available to all potential producers, enabling uptake and application, so spreading the benefits widely to users.
- **Achieve economies of scale and scope in research.** Government-funded measurement research is carried out jointly with universities as well as with business so ensuring synergy, value for money and impact.

A single comparable system of measurement standards is necessary for the proper functioning of the economy. Measurement standards and research are convincingly seen as **public goods**, whose use by one business does not preclude their use by others. Government investment ensures that the infrastructure and new measurement science is independent, visionary and accessible by all.

Government also has a responsibility for ensuring that the UK's measurement infrastructure is **integrated into a consistent global system** of measurement that enables UK-based companies to trade worldwide in goods and services with confidence. Government engagement with the measurement system also provides **UK influence**, based on extensive expertise and leading edge research, on the development and setting of international standards and measurement frameworks by which the UK public and private sectors will be bound.

In formulating the Strategy, NMO considered the respective involvements of the public and private sectors in the provision of the NMS infrastructure, in which both play key roles. Government's provision of measurement standards and research is essential but the private sector, as the prime beneficiary of accurate measurement and advances in technology, provides the vast majority of the supporting infrastructure of accreditation, testing and measurement services.

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NMO regards this model of provision as the most efficient and effective in focussing public sector investment on essential functions in the national interest and in maximising the opportunities for the private sector to provide and benefit from measurement services and solutions. In determining the allocation of Government funding, the following considerations will be applied:

- The balance between the need to maintain the existing measurement capability in the NMS laboratories and the requirement to invest in new capability at the leading edge in response to evolving and expanding demands,
- The readiness and competence of the private sector, or overseas national measurement laboratories, to take over the economic and responsive provision of certain measurement standards and services, accepting that transitional arrangements may need to be put in place to ensure continuity of supply,
- Appraisal of the impact of the NMS laboratories withdrawing support to established non-strategic measurement standards recognising that standards and measurement services are now traded in an international market.

As previously, for example in respect of high voltage electricity and vacuum standards, NMO and the NMS laboratories will look for opportunities to withdraw from supporting established areas of measurement where provision is reliably available from other sources or can be provided adequately without government intervention.

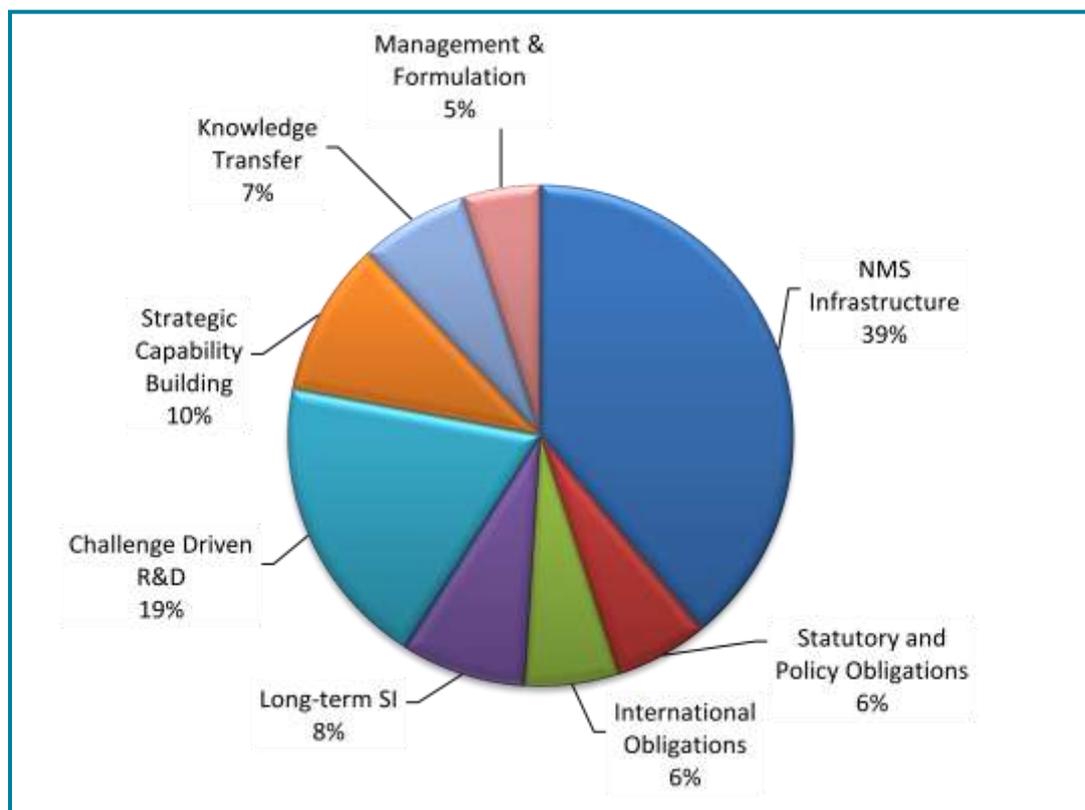
5.2 Government investment

Following the Spending Review settlement announced in October 2010, Government, via NMO, will invest around £240m over the next four years in providing and developing the UK's scientific and legal measurement infrastructure. This represents level funding compared with previous years' funding. In addition, at least £25m will be invested over four years in the upkeep of the Government-owned facilities of NPL and the Teddington site.

The introduction of the distinction between Programme expenditure and Administration expenditure into Non Departmental Public Bodies and Executive Agencies poses a particular challenge. Much of what was formerly the Legal Metrology Programme has been reclassified as Administration expenditure. In common with other Government Departments and agencies, NMO's budget for "Admin" will decline over the four year period determined by the Spending Review. This means keeping tight control of the cost of the work on managing the NMS Programmes, oversight of the management of the Teddington estate, developing Regulatory Policy and providing Corporate Services for the Agency.

To make optimum use of the resources available, NMO has to make difficult choices about the balance, scope and priorities of the NMS programmes, which will be reflected in the allocation of funds over the period 2011-2015. The following pie chart (Figure 1) shows the present balance of activities represented by indicative percentages of funding, noting that funding often supports more than one activity.

Figure 1: NMS Portfolio by Activity



5.2.1 Core functions of NMS infrastructure, Long-term SI, Statutory & policy obligations and International obligations

Around 39% of NMS effort is focussed on the core function of maintaining and extending the capability of the measurement infrastructure and the provision of top-level standards and certified reference materials. For many industrial activities, the availability of responsive, internationally leading measurement capabilities in the UK is crucial to minimising costs and driving competitiveness. The core functions of the NMS also include putting in place long-term developments in the SI (8%), for example fundamental re-definitions of the base units of measurement.

It further includes statutory obligations laid down in legislation (6%), for example the Weights & Measures Act and the Food Safety Act, and international activities (6%) including promoting the UK as a leading player in OIML (International Organisation of Legal Metrology) and EURAMET (the group of European national measurement institutes engaged in scientific metrology) and facilitating the UK's participation in the CIPM MRA (International Committee for Weights & Measures Mutual Recognition Arrangement) for national measurement standards.

NMO will protect the priority areas of the NMS infrastructure but will look for opportunities to withdraw from supporting established areas of measurement where provision is reliably available from other sources or can be provided adequately without government intervention. NMO will put in place transitional arrangements if standards or services are to be withdrawn. Therefore, overall NMS resources will decline over the four-year planning period.

5.2.2 Challenge-driven R&D

Around 19% of effort is directed at R&D focused on the challenges highlighted in section 3.1. Work in this category will typically be carried out in collaboration with business, academic and government partners or other European national measurement institutes and is likely to be co-funded from non-NMS sources including the European Metrology Research Programme, Technology Strategy Board, EU Framework Programme and business. It delivers highly relevant research results of value to commercial exploitation and to the solution of societal problems.

Overall NMS effort on challenge-driven R&D will be at least maintained over the four-year planning period.

5.2.3 Strategic capability building

Around 10% of the NMS budget is committed to building new strategic capability – anticipating significant trends in technology, underpinning the science necessary for the NMS to be internationally competitive to support UK growth and innovation, and enabling the NMS to attract and retain top-class researchers.

NMO views the maintenance and growth of new scientific capability in the NMS as a priority. The investment in this activity will therefore increase over the four-year planning period, particularly in order to enable NPL to focus on significant packages of more ambitious work.

5.2.4 Knowledge transfer

Around 7% of the NMS budget is committed to knowledge transfer aimed at connecting businesses and public sector organisations to measurement knowledge and facilitating the translation of that knowledge into application for economic and social impact. The value and effectiveness of the investment will be enhanced by working with intermediary organisations to extend outreach.

Overall NMS effort on knowledge transfer activities is planned to remain at 7% of the NMS budget over the four-year planning period but will be regularly reviewed in order to comply with the Government's spending controls on paid-for marketing and advertising.

5.2.5 Programme management and formulation

At 5% of the NMS budget, this includes the work necessary to properly manage and report on the progress of projects, and formulate new work in accordance with stakeholder needs.

5.2.6 Activity summary

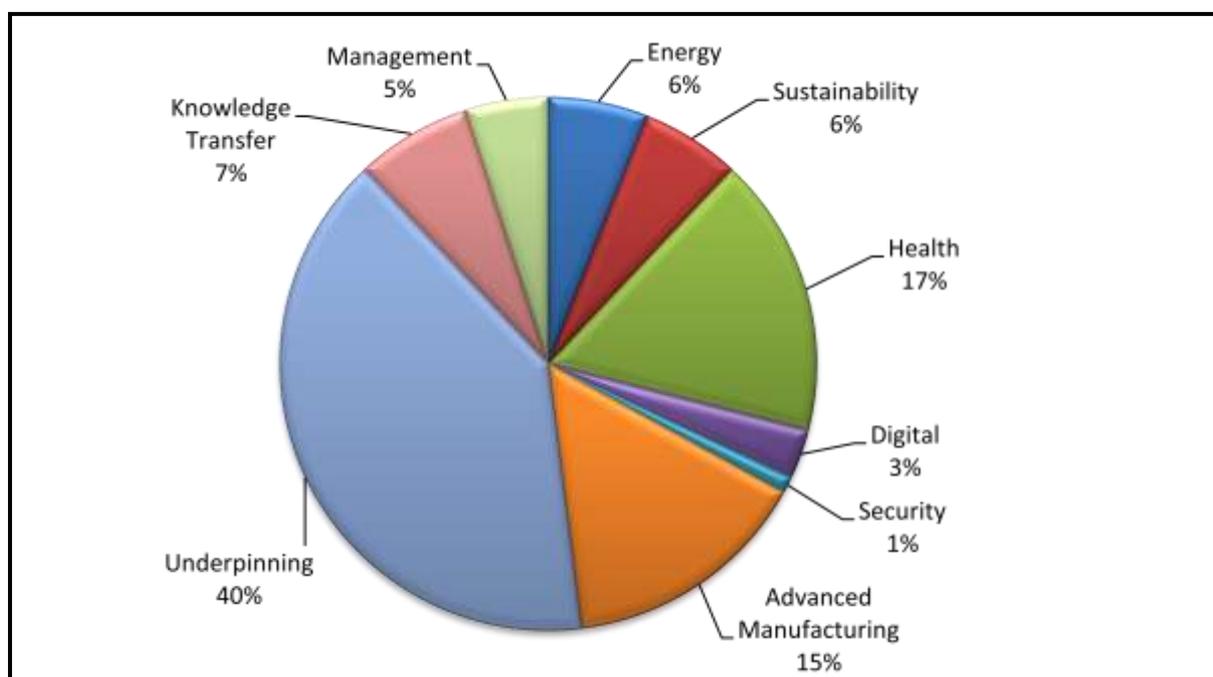
NMO will:

- Maintain a balanced portfolio of activities,
- Protect the priority areas of the core infrastructure but look for opportunities to withdraw from supporting established areas of measurement where provision is reliably available from other sources or can be provided adequately without government intervention,
- At least maintain NMS effort on challenge-driven R&D over the four-year planning period,
- Sustain the international competitiveness of the NMS by building new scientific capability, in particular at NPL where investment will be in significant packages of more ambitious work which have the potential to be world class,
- Commit around 8% of the NMS budget to research with long term impact on the world measurement system,
- Commit around 7% of the NMS budget to knowledge transfer activities, to deliver maximum economic and social benefit from the investment in science (whilst operating within the Government's spending controls on paid-for marketing and advertising).

5.2.7 The sectoral priorities

NMO has considered the market sectors that underpin the challenge areas addressed in section 3.1 of this Strategy. The following pie chart (Figure 2) shows the relative proportions of NMS expenditure in each area. The percentages shown are indicative and there is inevitably cross-over in the measurement research that is allocated to supporting the various sectors. The largest element is characterised as Underpinning as it is of such basic utility to the NMS that it cannot be ascribed to a sector. NMO plans to review the methodology for assessing the relative proportions of NMS expenditure in market sectors so that it can gain a fuller picture as it implements the NMS Strategy.

Figure 2: NMS Portfolio by Sector



The Strategy for the National Measurement System: 2011-2015

NMO has taken the following decisions about the balance of investment in the challenge sectors:

- Energy and Sustainability, at 6% each currently, will grow, responding to Government priorities around climate change and carbon emission targets,
- Health, at around 17%, will be static,
- Digital, currently at 3%, will be sustained but directed towards new developments, e.g. in smart infrastructures,
- Security is very small, but important and the NMS will maintain a capability in this area,
- Advanced manufacturing represents the NMS investment in high value manufacturing, advanced instrumentation and sensors. Investment will be sustained at 15%,
- 'Underpinning' represents the non sector specific investment that supports the very basis of the measurement infrastructure. This will be preserved but reviewed with the aim of securing savings by discontinuing mature capability that is reliably available from other sources or could continue to be provided adequately without government intervention.

NMO has taken the following decisions about the work of the NMS laboratories:

- We see NPL, the prime National Measurement Institute, as the main national asset in measurement science, so intend to increase the proportion of the NMS budget it receives in order to maintain the excellence of science and invest in new capability for the future,
- LGC carries out both the statutory Government Chemist role and is the Designated Institute for Chemical and Bioanalytical metrology. This is recognised as an increasingly important area of scientific metrology globally. Our view is that investment should be retained in cash terms with the aim of ensuring the maintenance of the chemical and biological capability at LGC,
- The third major contractor to the NMS is NEL, which is the Designated Institute for Liquid and Gas Flow metrology but also has interests in other energy related work. There will be a necessary reduction in funding of NEL's lesser priority work in order to rebalance the NMS portfolio. NMO will work with NEL to support co-funded developments in the aspects of energy and sustainability that are related to flow metrology,
- The non-statutory elements of NMO's Legal Metrology Programme will reduce.

5.3 Measurement assets

5.3.1 People

The most important resource of the national measurement infrastructure is a high quality workforce comprising multi-disciplinary teams of skilled scientists, engineers and support staff.

The NMS laboratories will develop a strong pool of scientific talent through:

- Targeted recruitment of talented scientists, by developing improved mechanisms to attract researchers with an established track record and engaging post-doctoral staff and graduates through Research Council programmes and Engineering Doctorates,
- Encouraging knowledge transfer, through hosting high quality visiting researchers on secondments, fellowships, etc., working alongside existing NMS staff,
- Benchmarking the scientific work and impact achieved by senior scientists, with particular regard to achieving internationally competitive positions in chosen fields.

5.3.2 Facilities

NMO invests in specialist measurement facilities at NPL, LGC and NEL through the NMS programmes. NMO also oversees the management of the Government-owned assets on the Teddington site, which have undergone a complete transformation over the past 10 years. A new single laboratory for NPL has been built removing costly old infrastructure and utilising remaining buildings for scientific and support activities as appropriate.

NMO will, directly and through the NMS programmes:

- Continue to exploit the Teddington site to ensure that it sustains a world-class reputation for both measurement science and business support,
- Promote and facilitate the use of measurement facilities at Teddington by other researchers e.g. by universities for the delivery of Research Council grant-funded research.

NMO recognises that the commercialisation of quantum technologies is a major opportunity for the UK through capitalising on its strong science base. Quantum metrology will be an important enabler and NPL has a recognised world-class capability. Current laboratory facilities at NPL may not be adequate to support the demanding environmental requirements for quantum metrology research, in particular the need for low seismic vibration, tight temperature control, low acoustic noise and control of electric and magnetic fields.

NMO will endeavour to enable NPL's quantum metrology research to continue by improvements to the facilities at Teddington or by seeking partnerships with others to make facilities available.

The Strategy for the National Measurement System: 2011-2015

5.3.3 NPL

NPL is the UK National Measurement Institute and a major Government-owned science asset. It has been at the forefront of innovation in measurement for more than a century, for example pioneering the introduction of atomic timekeeping that now underpins the operation of satellite navigation systems. NPL is a world-renowned leader in measurement science that combines creative blue-sky research with hard-edged applied measurement support to business and government.

NMO will, through the NMS programmes, support NPL to fulfil its role as the UK's prime national measurement laboratory, specifically to:

- Maintain its leading international status in measurement to keep the UK competitive with the best National Measurement Institutes elsewhere in the world,
- Enhance its capability to support the requirements of advanced manufacturing and associated services and a low-carbon future,
- Sustain it as a world-leading laboratory by enabling it to introduce new scientific capability and maintain critical mass,
- Exploit it as a national resource, undertaking work in the national interest to deliver social and economic impact through world-class measurement science, innovative applied research and knowledge services.

5.3.4 LGC

LGC is an international science-based enterprise, operating in socially responsible fields underpinning the health, safety and security of the public. Its products and services enable customers to have a sound measurement basis on which to take scientific and commercial decisions and assure conformity to international statutory and regulatory standards.

LGC delivers a range of formal roles and functions on behalf of Government, including the Designated Institute for chemical and bioanalytical measurement and the statutory Government Chemist function.

NMO will, through the NMS programmes, support LGC to fulfil its role to:

- Provide leadership in the development of the UK's chemical and bio-measurement system in harmony with those of other countries,
- Strengthen measurement science supporting technological innovation in healthcare and food security,
- Maintain and develop measurement standards and reference materials that underpin UK competitiveness and quality of life.

5.3.5 NEL

NEL is an international technology services organisation which delivers innovative solutions to technology and engineering challenges. It provides services to the energy, environmental and manufacturing sectors and supports industry in the research, development, evaluation, modelling, testing and calibration of technologies.

NEL is the UK's Designated Institute for liquid and gas flow measurement technologies and provides the UK's national flow measurement facilities.

NMO will, through the NMS programmes, support NEL to fulfil its role to:

- Maintain world-class research, development, modelling, calibration, measurement and testing facilities relating to flow and fluids measurement to serve the energy, environmental, manufacturing and government sectors,
- Develop standards and disseminate knowledge relating to flow and fluids measurement,
- Support the development of low carbon technologies through new measurement methods to evaluate performance.



The National Wind Energy Centre at NEL supports the growth of the UK's wind energy industry by providing a resource for research, development, measurement and testing of wind turbines.

5.4 Operating efficiently

NMO will:

- Constantly review the efficiency and effectiveness of its own processes for commissioning and supervising measurement research work,
- Complete the introduction of a rolling programme formulation process to bring greater flexibility and responsiveness to the NMS programmes and to review the progress and impact of existing work and its relevance to national challenges,
- Review and update each programme roadmap on a rolling cycle, and invite input from users and beneficiaries of measurement research,
- Employ a number of impact assessment models and techniques to monitor impact and ensure that the measurement research is achieving value-for-money – results will be published on NMO's website,
- Look for ways to exploit more effectively the land, buildings, scientific assets and capability based on the Teddington site.

NMS programmes are largely delivered through four organisations: NPL, LGC, NEL and the NMO's own operations. Each organisation, to a greater or lesser extent, supplements Government funding with commercial income, either from business or public sector customers. By doing so, each can help optimise the utilisation of expensive equipment and staff to maximise value for money for Government investment.

NMO and the NMS laboratories consult private sector businesses and public sector organisations in order to focus and guide the government's investment in the NMS infrastructure. NMO will continue to evolve the sector-based and technology-based roadmaps used to address the nature of the NMS intervention needed to support measurement users – be it a measurement standard, technique, reference material, guidance, training, documentary standard or change in regulation. The roadmaps are published on NMO's website.

In implementing the Strategy, choices will have to be made. NMO will target the investment in the NMS research programmes through a process of continuous engagement with business and public sector users. Representatives from business, government, regulatory bodies, the universities and the international metrology community will be directly involved in advising NMO on the priorities for the research content of the NMS programmes.

NMO has established a Measurement Board to steer the strategic priorities of the NMS portfolio. A set of Advisory Groups operate for each NMS programme. NMO regularly reviews the membership of these Groups to ensure they are representative of the areas of focus, with a sufficiently strategic perspective.

The Strategy for the National Measurement System: 2011-2015

The Measurement Board offers strategic advice to NMO and the Department for Business Innovation and Skills (BIS) on:

- The broad objectives and strategy for the Government's investment in the UK's measurement infrastructure, services and science programmes, taking into account the international context,
- The priorities and balance that Government should assign to programmes of work undertaken to meet the measurement needs of the UK,
- The effectiveness and impact of the NMS in promoting innovation, competitiveness and growth in UK businesses and in bringing economic, social, quality of life and environmental benefits to UK citizens,

It aims to be fully representative, at a high level, of the community of NMS stakeholders, including those from relevant scientific, innovation and research organisations, standards bodies, Government Departments and agencies as well as users and collaborators in industry and academia.

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National Measurement System



The National Measurement System delivers world-class measurement for science and technology through these organisations

