**COUNCIL OF
THE EUROPEAN UNION**

**Brussels, 15 July 2013
(OR. en)**

**12372/13
ADD 1**

**RECH 358
COMPET 576**

COVER NOTE

From:	Secretary-General of the European Commission, signed by Mr Jordi AYET PUIGARNAU, Director
date of receipt:	12 July 2013
To:	Mr Uwe CORSEPIUS, Secretary-General of the Council of the European Union
No. Cion doc.:	SWD(2013) 249 final
Subject:	COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document Proposal for a DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the participation of the Union in a European Metrology Programme for Innovation and Research jointly undertaken by several Member States

Delegations will find attached document SWD(2013) 249 final.

Encl.: SWD(2013) 249 final

EUROPEAN
COMMISSION

Brussels, 10.7.2013
SWD(2013) 249 final

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a
DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on the participation of the Union in a European Metrology Programme for Innovation and Research jointly undertaken by several Member States

{COM(2013) 497 final}
{SWD(2013) 250 final}

Table of Contents

Introduction 1

1. Procedural Issues and Consultation of Interested Parties 3

1.1. Organisation and Timing 3

1.2. Consultation of the IA Board 3

1.3. Inter-service Impact Assessment Steering Group (IASG) 3

1.4. Consultation and Expertise 3

1.4.1. Interim evaluation of EMRP 4

1.4.2. Public online consultation 5

1.4.3. Public consultation: stakeholder meeting 6

1.4.4. Expert Group 6

2. Problem definition 7

2.1. Responding to the metrology research & innovation challenge 7

2.1.1. Metrology research for innovation and industrial competitiveness 7

2.1.2. Metrology research for major societal challenges 9

2.1.3. Call for coordinated action at EU level 9

2.2. Key problems and their drivers 10

2.2.1. Underexploited potential to have a greater impact on growth and socio-economic challenges 12

2.2.2. Fragmentation and structural weaknesses of the European metrology research and innovation system 13

2.3. EMRP: Key achievements and lessons learned 15

2.4. Baseline scenario 17

2.5. The EU's right to act and the application of the subsidiarity principle 17

3. Objectives 18

3.1. General Objectives 18

3.2. Specific objectives 18

3.3. Operational Objectives 18

4. Policy Options 20

4.1. Options 20

4.1.1. Policy Option 1: "No dedicated EU action" 20

4.1.2. Policy Option 2: "Business-as-usual – EMRP2" ... 20
4.1.3. Policy Option 3: "Improved Article 185 initiative – EMPIR" ... 20
4.2. Discarded Options ... 21
5. Analysis of the Impacts of the Options ... 22
5.1. Impact on achieving the operational objectives ... 22
5.2. Economic, social, environmental and other impacts ... 24
5.2.1. The economic impacts ... 24
5.2.2. The social impacts ... 26
5.2.3. The environmental impacts ... 26
5.2.4. Impacts on European Research and Innovation Policy ... 27
5.2.5. Efficiency and administrative burden ... 28
6. Comparison of Options ... 28
6.1. Comparing the options on contribution to objectives ... 29
6.2. Comparing the options on impacts ... 29
6.3. Preferred Option ... 30
6.4. Risk register for the preferred option ... 30
7. Monitoring and Evaluation ... 31
8. Annexes ... 33
Annex I: List of acronyms and abbreviations ... 34
Annex II: National commitments to EMPIR (December 2012) ... 35
Annex III: Measurement and economic returns ... 36
Annex IV: Public online consultation: analysis of the responses ... 37
Annex V: Examples of EMRP projects and expected results ... 44
Annex VI: Metrology landscape in Europe ... 49

INTRODUCTION

The central nerve in the spine of our high-tech world is metrology[1], the science of measurement. Every aspect of our daily lives is affected by metrology and ever more precise and reliable measurements are essential to drive innovation and economic growth within our knowledge based economy. ***What we cannot measure, we do not understand properly, and cannot control nor manufacture or process reliably***. Thus, advances in metrology have a profound impact on our understanding of, and ability to shape, the world around us.

Metrology sets the basis for European and worldwide standards increasing the competitiveness of European businesses in the global market, supporting trade and allowing them to access foreign markets with business partnerships around the globe. European standards and standardisation are very effective policy tools for the EU to ensure, inter alia, the interoperability of networks and systems, a proper functioning of the Single Market, a high level of consumer and environmental protection.

Metrology is a particularly important driver of innovation to improve European industrial competitiveness. New scientific breakthroughs can be exploited through new metrological techniques to bring improvements in manufacturing through better measurement instruments and techniques. These advances spin off into industry resulting in new and improved products, processes and services across the breadth of the economy. Countries advanced in industrial economy invest between 3 to 6% of GDP for measurement and measurement-related operations[2].

In the health sector, accurate and reliable measurements are a necessary prerequisite to decide on the correct diagnosis and therapy. Road and workplace safety as well as safety in many other areas call for unambiguous regulations that can be verified by means of reliable measurements. A prerequisite for environmental protection measures is that pollutants in soil, air, and water can be accurately determined. Supervising both measuring equipment and their use ensures global trade of goods.

Metrology is a key enabling tool for advancement of fundamental research, often supporting progress into new, hitherto unknown dimensions. In a mutually beneficial relationship, the improved ability to measure facilitates scientific progress, whilst science opens up new and improved measurement capability. The Nobel Prize in Physics 2012 was awarded jointly to Serge Haroche and David J. Wineland *"for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems"*.

In summary, reliable and traceable measurement underpins our modern society and plays a critical role in supporting economic competitiveness, manufacturing and trade as well as quality of life. In this modern world, a well-developed measurement infrastructure provides confidence in many aspects of our daily life by enabling the development and manufacturing of reliable, high quality and innovative products, supporting industry to be competitive and sustainable in its production, facilitating the removal of technical barriers to trade, ensuring safety and efficacy of healthcare, as well as addressing the measurement-related needs for energy and the environment.

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1 Metrology is defined by the International Bureau of Weights and Measures (BIPM) as "the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology".

2 Comptes Rendus Physique, Vol 5 - N°8 - October 2004 (p. 791 – 797): Measurement and society; Terence J. Quinn, Jean Kovalevsky

National Metrology Institutes as the metrology infrastructures in Europe

National Metrology Institutes (NMIs) are in charge of this work and implement it on the basis of institutional funding from central government agencies or ministries. The NMIs, some of them in operation for more than 100 years, are additionally charged with ensuring that the international system of measurement functions appropriately, and are firmly imbedded in the mechanisms of the Metre Convention[3]. Most national measurement research programmes and activities are stretched as they respond to external demands and the need to improve their capabilities to respond to an ever increasing, diverse range of applications and techniques to measure to greater accuracies.

The complexity and scale of requirements for quality-assured measurement in industry, and those associated with the grand societal challenges such as energy, environment and health, cannot sufficiently be covered by the traditional, nationally fragmented system. Only a coherent and integrated European approach can ensure the necessary coordination between national research programmes, achieve critical mass, reduce duplication and fragmentation and allow common European inputs to standards and regulations.

EMRP – a joint European Metrology Research Programme

The current EMRP initiative is a joint European programme of coordinated R&D that facilitates closer integration of metrology research programmes implemented by the NMIs and DIs. It is based on Article 185 of the Treaty on the Functioning of the European Union (TFEU), which, in implementing the multiannual Framework Programme, makes it possible to coordinate national research programmes. The current programme has a total public budget of € 400 million for a duration of five years with matching contributions from the participating countries and the European Union. The interim evaluation has recognised the value of the initiative. A main achievement is that an estimated 50% of the dedicated national investments in metrology research are now influenced and coordinated by EMRP. This reduces fragmentation, avoids unnecessary duplication and allows achieving critical mass by concentrating resources on areas with highest relevance through close collaboration of best researchers. EMRP projects deliver European measurement solutions for major societal challenges and provide common European inputs into standards and regulations. It has established the European Metrology Research System as a global reference.

The Horizon 2020 proposal allows for continuation of existing public-public partnerships, provided they address Horizon 2020 objectives, they meet the criteria laid down in Horizon 2020 and they have shown to make significant progress under the Seventh Framework Programme for Research, Technological Development and Demonstration (FP7). A successor to EMRP is specifically foreseen in the proposal for the Specific Programme Implementing Horizon 2020. The public-public partnership on metrology fulfils the criteria laid down in the proposals for Horizon 2020 and the Specific programme and has consequently been included in the Commission Work Programme 2013 as part of the initiative for reinforced partnering in research and innovation under Horizon 2020.

[3] The Metre Convention was signed in 1875 by 17 states. It was the first international diplomatic treaty. The signatory states, today 56, agree to adopt the metric system.

1. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

This impact assessment (IA) report accompanies the Commission proposal for a decision on the participation by the European Union in the European Metrology Programme for Innovation and Research (EMPIR). It details the findings of the impact assessment required for legislative proposals and represents the ex-ante evaluation[4] required for proposals occasioning budgetary expenditure.

1.1. Organisation and Timing

The Commission's Directorate-General for Research & Innovation (DG-RTD) is the lead DG for this initiative[5]. In 2011, the Interim Evaluation on the European Metrology Research Programme was carried out. In 2012, the mandate of the existing interservice group on EMRP has been extended to function as Impact Assessment Steering Group (IASG) and all relevant consultations and gathering of evidence has been conducted.

1.2. Consultation of the IA Board

In February 2013, the Impact Assessment Board reviewed and approved the report. In its opinion it requested improvements of the impact assessment report which have been taken into account. In particular the report now better explains the specific problems and the underlying drivers and the relation between objectives and targets. The description of the new programme in comparison of the running initiative was improved in order to better clarify how the new programme will tackle the identified weaknesses.

1.3. Inter-service Impact Assessment Steering Group (IASG)

Three meetings of the IASG were convened between September 2012 and January 2013.[6] The IASG contributed to the IA planning, the preparation of the public consultation and to the IA report. The final report has been endorsed on 23 January 2013 and the minutes of the meeting are submitted to the IA board together with the report.

The existing interservice group for EMRP is expected to be continued with a revised mandate covering also a future initiative and ensure its linkage to relevant services.

1.4. Consultation and Expertise

A comprehensive set of expertise gathering and consultations with relevant stakeholders parties have been carried out at different stages of the preparation of this impact assessment, covering:

1. Interim Evaluation on the European Metrology Research Programme (EMRP)
2. Public online consultation on a European Metrology Research Programme under Horizon 2020
3. Public consultation: stakeholder meeting on 22 January 2013

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[4] Article 21 of Commission Regulation (EC, Euratom) No 2342/2002 laying down detailed rules for the implementation of Council Regulation (EC, Euratom) No 1605/2002 on the Financial Regulation applicable to the general budget of the European Communities (OJ 2002/L 357/1).

[5] CWP, EMPIR Roadmap http://ec.europa.eu/governance/impact/planned_ia/roadmaps_2013_en.htm#RTD

[6] The following Commission DGs had been invited to join the IASG: AGRI, CLIMA, CNECT, ENER, ENTR, ENV, JRC, MOVE, SANCO, SJ. In addition thematic directorates of DG RTD participated in the meetings. Meetings were held on: 20 September 2012, 20 November 2012 and 23 January 2013.

4. Expert group supporting the preparation of the impact assessment

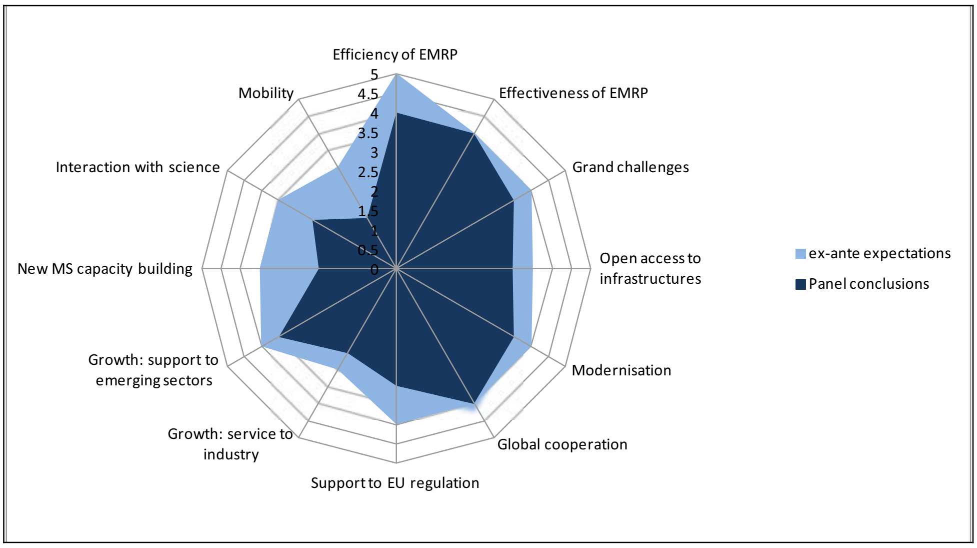
This impact assessment regards the follow up to an already existing programme. The consultations have been focussed on involving the key stakeholders (researchers, industry, SME, civil society, citizens and governments) as well as participants of the running initiative and funded projects.

1.4.1. Interim evaluation of EMRP

An Interim Evaluation of the EMRP[7] was carried out by an Expert Panel after three years of running of the programme. The report was adopted by the Commission in April 2012. The **midterm evaluation of EMRP** recognised the value of the initiative and indicated in particular considerable progress on coordination of research: "*pooling excellence in metrology research' had been achieved and this has contributed to a large share of European research programming in the metrology field. The evidence of integration is clear as some 50% of dedicated national funding for metrology research has been jointly 'programmed' through the central prioritisation and evaluation processes*."

The 12 point framework of the ex-ante impact assessment was used by the Panel to structure its qualitative conclusions on the impact of the EMRP. This had two advantages. It allowed a direct comparison with the expectations and minimised the risk of appearing to be over-critical in areas where the potential impact was not expected to be so great.

Figure 1: Overview of Impacts for EMRP (mid-term evaluation)



Although it is a subjective and qualitative assessment it allowed the panel to conclude that:

- The EMRP is performing well in relation to most of its original expectations
- There are significant gaps between expectation and reality in relation to three qualitative impact indicators: capacity building, interaction with the wider scientific community and mobility

[7] http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/mtr_report_final.pdf, http://www.euramet.org/index.php?id=emrp

- Any future initiative should include dedicated instruments to support industrial exploitation and innovation and a better support for standardisation and regulatory work

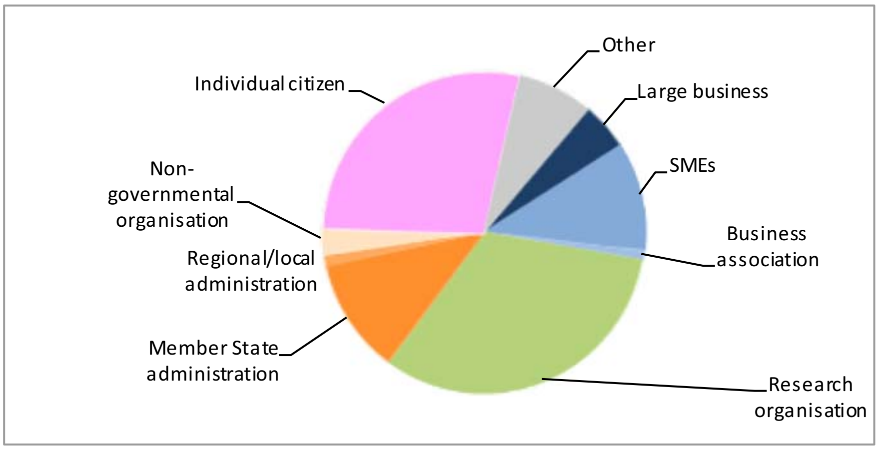
The main recommendations of the interim evaluation relevant for a future initiative that could not be implemented by EMRP were:

- Twin track innovation and policy driven approach including separate instruments to enable advancement of new knowledge and exploitation of existing knowledge
- Develop a more practical instrument to enable better access to the best centres of excellence in the wider research community
- Help developing NMIs and DIs to build scientific capacity that aligns with their national growth strategies through the use of both the EMRP and Structural Funds
- Foster Joint Research Projects that promote inclusion and development of embryonic centres of excellence consistent with European strategies
- Explore options to exploit the well-known and successful Marie Curie instrument.
- Introduce dedicated calls to support regulatory and/or standardisation roadmaps
- Widely open foresight workshops to identify metrology-related barriers to the safe and rapid exploitation of new technologies

1.4.2. Public online consultation

An online consultation collected input on the state of play of the European metrology research system and the challenges it is facing. The online survey was open for submission for 12 weeks (1 October – 23 December 2012) and received 624 contributions from more than 40 countries. The synthesis report on the public consultation was published in January 2013[8] (Annex IV: summary of results). 72% of the responses came from organisations and 28% from individual citizens. The main contributions from organisations were received from research organisations (32%) and businesses (16%, of which 69% SMEs).

Figure 2: Distribution of responses according to type of organisation



The stakeholders responding confirmed the high relevance of metrology research for (a) addressing Grand Challenges, (b) for the European economy and industrial competitiveness and (c) for European policies, standardisation and regulatory work (97% indicated very relevant or relevant for

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[8] See http://ec.europa.eu/research/consultations/pdf/empir-survey-final-report.pdf for the full report

all three). The majority of respondents agreed strongly with 15 specific underlying problems (chapter 2 and Annex IV).

1.4.3. Public consultation: stakeholder meeting

The consultation meeting on 22 January was attended by around 30 participants representing major stakeholder organisations. The main outcomes of the consultation meeting are the appraisal of the success of EMRP in coordinating and integrating European Metrology Research, the confirmation of the problem definition for the European Metrology research system and the validation of objectives for a future initiative[9].

1.4.4. Expert Group

An expert group has provided analytical support and further evidence in supporting the preparation of the impact assessment report between September 2012 and January 2013.

The Commission's minimum standards for the consultation of interested parties during the Impact Assessment have been met.

9 Report: http://ec.europa.eu/research/consultations/pdf/stakeholdermeeting.pdf

2. PROBLEM DEFINITION

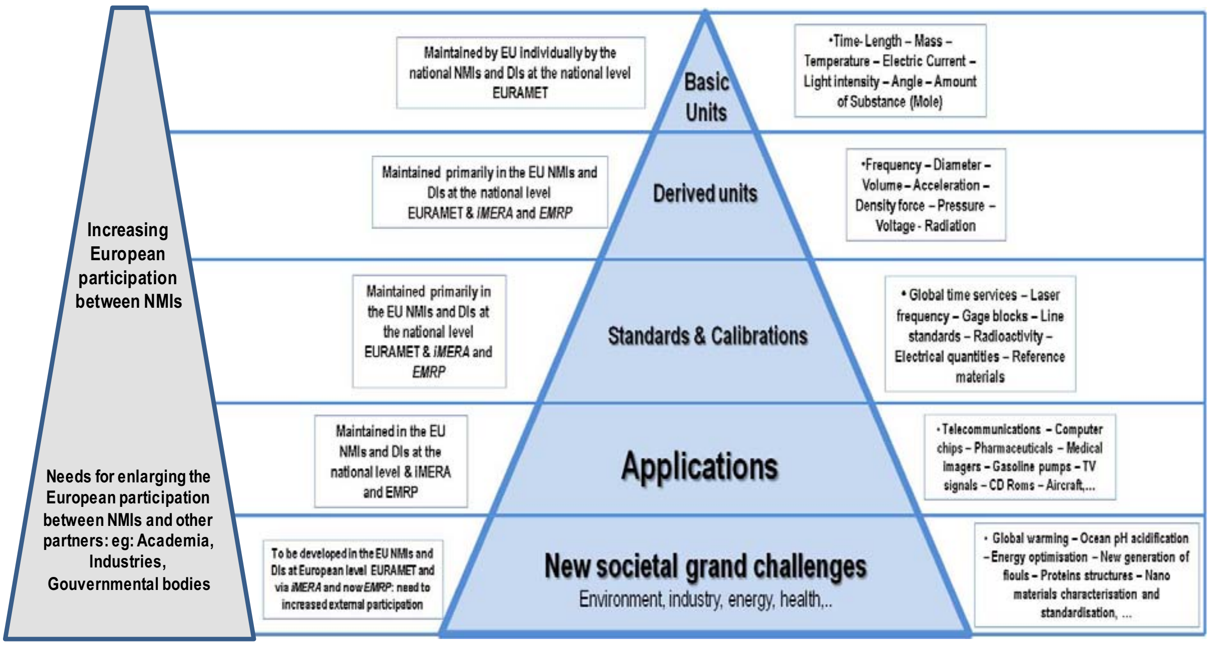
2.1. Responding to the metrology research & innovation challenge

2.1.1. Metrology research for innovation and industrial competitiveness

Metrology, the science of measurement, is a hidden, often invisible infrastructure of services that support fair trade, quality of life and environmental protection. This is achieved by ensuring traceability to the International System of Units, referred to as the SI, and covering the base units (second, metre, kilogram, ampere, kelvin, mole, and candela) and the derived units. Internationally compared and harmonized standards on primary level ensure that measurements, which are traceable to them, are comparable in absolute terms. This comparability of measurements and interoperability is crucial, with obvious examples being the atomic clocks that form the basis of international time keeping, and with it communications, banking, navigation etc. Another example is industrial innovation and production process control: precise and traceable measurements allow to assemble, e.g., a motor block from parts delivered by different ancillary factories.

The hierarchy of modern metrology activities from the primary measurement standards to the application of knowledge for the benefit of industry and society is shown in the following figure.

Figure 3: Hierarchy of Metrology



This shows the hierarchical metrology chain from the basic physical units, via primary standards and calibration methods, to the applications in industry and commerce. It also highlights the need for a more open and inclusive approach to scientific metrology with stakeholders from the NMIs, DIs, the wider scientific community and government bodies that are concerned with societal regulations and standards. All of these can now be considered as stakeholders of the European Metrology Research Area.

Metrology is a General Purpose Technology with strong spill-over effects across many sectors of the economy and society. Thus the socio-economic effects are substantial but difficult to quantify. The qualitative data that is available underlines strongly the impact of improved measurements:

- Reports by the U.S. Commerce Department's National Institute of Standards and Technology[10] demonstrated that the cost-benefit ratio of investments in measurements and standards is conservatively estimated at 1:3. Many individual examples of successful metrology research projects demonstrate significantly higher cost-benefit rations (1:15 – 1:25 and more). E.g. the semiconductor design and manufacturing requires cutting edge measurement technologies. Between 1996 and 2006, the US industry is estimated to have spent $12 billion on measurement services, generating $51 billion in economic benefits.

- Countries advanced in industrial economy invest between 3 to 6% of GDP for measurement and measurement-related operations.

- Reducing measurement uncertainty has significant economic impacts: The annual value of trade measurement transactions in modern industrial societies is about 50% of GDP and a decrease in the average error of measurement of 0.1%, would create an "economic benefit" of 0.05% of GDP. Such an amount is significantly greater than the expenditure by governments in maintaining the national trade measurement systems.

- A striking result of a recent study[11] is that measurement knowledge is more strongly associated with novel than with 'catch-up' innovation; that is, it underpins cutting edge product and process innovation creating high-value jobs.

Figure 4: Example on economic impacts

Saving £50 million for mobile network operators in the UK[12]
3G mobile phone technology allowed to carry large amounts of data quickly so users can view stream video and access the internet from handsets. To support 3G, network operators had to install a new network of antennas. The antenna range, housed in an anechoic chamber at UK National Measurement System, helped network operators such as O2 by providing independent testing services to verify claims made by antenna manufacturers. This helped to ensure that performance data was comparable between products. Improved measurement could provide better estimates of key performance parameters. This lead to substantial efficiency savings through fewer base-stations needed in rural areas, lower masts and less interference between adjacent base-stations in urban areas. Mobile phone networks account for more than 1% of all UK electricity usage, so improvements in network efficiency contribute to substantial energy savings (worth approximately £1 million a year) and the associated carbon reduction. The calibration data improvements supplied could also equate to a 1% one off saving in network capital costs and a comparable saving in operational costs for the lifetime of the network. Since each UK 3G network cost between £5 billion and £10 billion to establish, the minimal one off saving was £50 million.

Standardisation depends to a large extend on underlying measurement technologies. The benefits of standards for the European industry are tremendous. Standards lead to cost reduction or cost savings derived mainly from economies of scale, the possibility to anticipate technical requirements, the reduction of transaction costs and the possibility to access standardised components. Well designed and timely European standards can support innovation in a number of ways. Existing standards can codify and spread the state-of-the-art in various technologies. They can also facilitate the introduction of innovative products by providing interoperability between new and existing products, services and processes, for example in the field of eco-design, smart grids, energy efficiency of buildings, nanotechnologies, security and eMobility.

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10 NIST (2007a): An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation. NIST Special Publication 1048, Gaithersburg. http://usms.nist.gov/usms07/usms_assessment_report_2006.pdf

11 Paul Temple, Economic Impact of the National Measurement System, Evidence Paper, Department of Economics, University of Surrey, July 2010,

12 Economic impact of the national measuremtn system, Ray Lambert

2.1.2. Metrology research for major societal challenges

Solving major societal challenges often rely on metrology solutions. This is most prominently the case in the areas of health, environment and energy, but applies also to other areas, e.g. transport (automated guided vehicles, emission reductions), agriculture (food safety) or secure societies (chemical and radiation measurements, improving data security).

Metrology for Health delivers directly to understanding the determinants of health by providing a better reliability and comparability of measurements. Accurate and reliable measurements are a necessary prerequisite to decide on the correct diagnosis and therapy. The economic impact of measurements related to medical diagnosis and treatment is very large. Most industrialized states spend some 10% of their GDP on health. In the US, it is close to 15%. Studies have shown that as much as 30% of the costs of medical care are in measurements and tests related to diagnosis and therapy.

The potential impact of **metrology on the environment and climate** is pervasive as the use of measurements, reference materials and tools are applied in many sectors including environmental technologies and energy efficiency. Reliable, comparable measurements are required in order to identify and control pollutions of water, air and soil, embedded in European Directives aiming at the protection of our environment.

Metrology research for energy contributes in several areas to the transformation and sustainability of European energy systems. Metrology supports maintaining the stability of the energy system and the transformation of gas and electricity networks into "smart networks". The further development of effective and efficient energy sources itself requires metrological support.

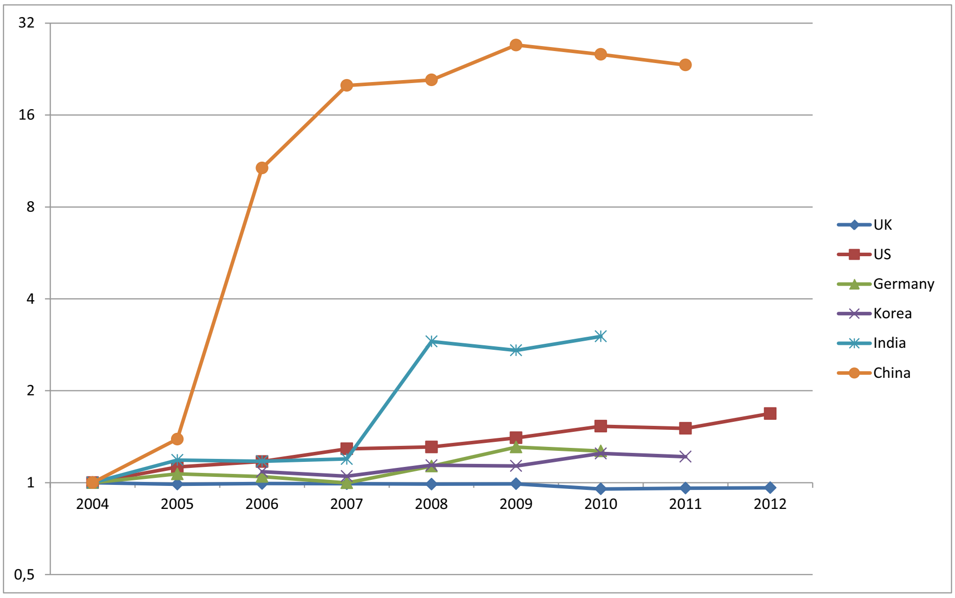
2.1.3. Call for coordinated action at EU level

All governments in advanced technological countries support a metrology infrastructure because of the benefits it brings and its strong character as a public good that justifies public intervention due to market failure:

- **Metrology research has important externalities** that make it unlikely that a socially valuable project will privately profitable to make the investment.
- The **fixed costs of each metrology research project are relatively high** but the marginal costs of spreading the knowledge to users for wide application is small.
- **Metrology has large network effects** with the benefit of the metrology infrastructure being greatest when the number of users is as large as possible.
- **Metrology requires impartiality and integrity and** are therefore traditionally defined by public authorities entrusted with this role.

Major economic powers in the world are increasing their investment. China, for example, increased the national investment in metrology R&D between 2001 and 2007 by a factor of 25 – albeit from a low base. Figure 5 shows the strong increase of metrology investment in some major countries over recent years. Taking account of the level of investment in metrology and its role in promoting scientific excellence and industrial competitiveness, a single Member State or several acting on their own would fail in competing in the global context.

Figure 5: Investment in metrology: comparison of change (internal data NPL, UK)



The overall volume and rate of increase of investment of the US in the metrology infrastructure is substantial and based on the clear recognition of the role of the National Institute of Standards and Technology (NIST) for strengthening the conditions for economic growth by promoting innovation, entrepreneurship and competitiveness. The 2011 budget proposed a funding level of $918.9 million, a 7.3% increase over the 2010 appropriations for the agency. This is underlined by the following quotes of Commerce Secretary Gary Locke: *"While the President's budget request freezes most domestic spending, NIST needs this increase to ensure we're making the kind of future-oriented science and technology investments that ultimately create high-wage jobs and jump-start the economy"* and NIST Director Patrick Gallagher: *"The President's request for NIST recognizes the critical role that measurement science and standards play in fostering innovation and economic growth," ... "The budget also maintains the President's commitment to double the NIST laboratory budget by 2017 to support and enhance our world leadership in the physical sciences and technology."*

The economic benefits for a coordinated approach have been demonstrated in a study[13] examining the economic impact of Mutual Recognition Arrangement (MRA) between NMIs in establishing mutual recognition multilaterally through central coordination rather than bilaterally. It was estimated that there was a notional saving to participating NMIs of €75.000 Euros per annum in the cost of establishing and maintaining mutual recognition and the total notional saving to the community of NMIs was of the order of € 85 Million.

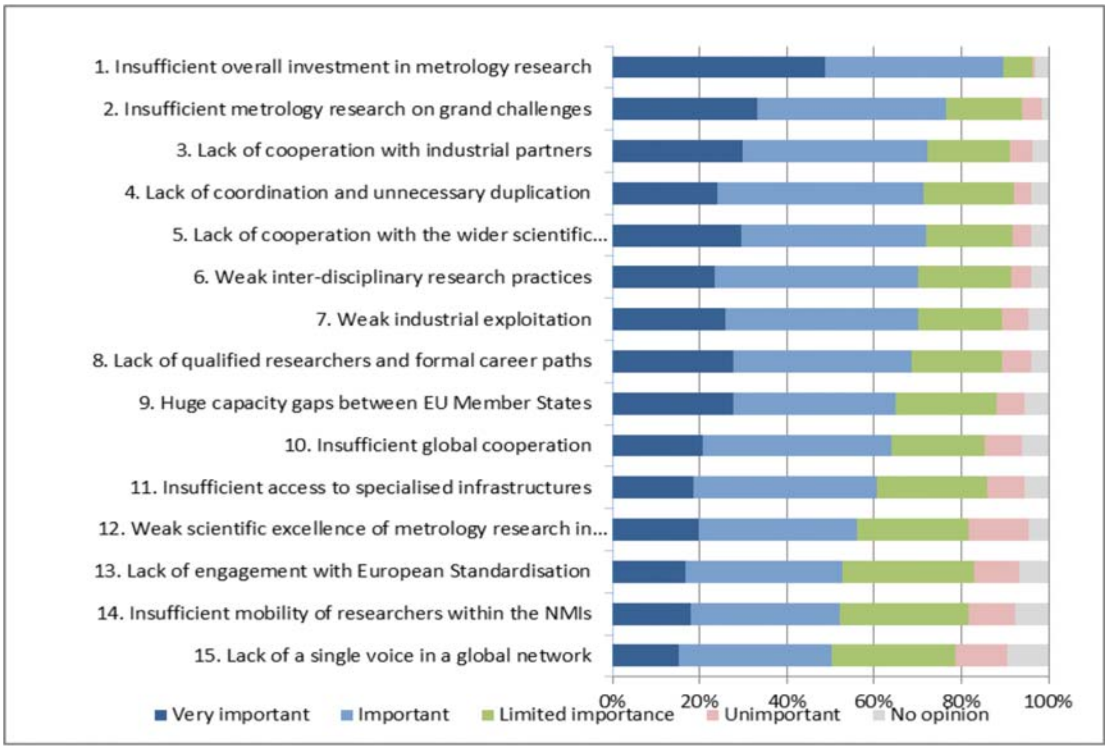
2.2. Key problems and their drivers

The result from the Public Consultation has provided clear feedback on the outstanding problems both in general and for different stakeholder groups and confirms the results of the mid-term evaluation of EMRP.

There was almost unanimous agreement (97%) on the **importance of metrology research** for addressing grand challenges; for the European economy and industrial competitiveness; and for European policies, standardisation and regulatory work. The majority also agreed with **15 specific underlying problems** (50% to 90% agreed important or very important).

[13] KPMG, Potential Impact of the CIPM mutual Recognition Arrangement, April 2002

Figure 6: Results from the public consultation: problem statements for the European metrology research system in order of importance



The view on the importance of the problems showed some significant differences[14] across the different types of respondents. Compared to the researchers, **industry** attaches significantly more importance to the following problems:

- Weak industrial exploitation (+20%)
- Lack of engagement with standardisation (+17%)
- Insufficient access to specialised infrastructure (+15%)

Those **countries with small metrology research contributions to EMRP**, compared to the five biggest contributors (France, Germany, Italy, Spain, UK) attach significantly more importance to the following problems:

- Huge capacity gaps between EU Member States (+21%)
- Lack of cooperation of NMIs with the wider scientific community (+17%)
- Insufficient mobility of researchers within the National Metrology Institutes (+16%)
- Lack of engagement with European Standardisation (+13%)
- Lack of a single voice in a global network (+12%)
- Insufficient global cooperation with leading metrology research programmes (+12%)
- Insufficient metrology research oriented towards grand challenges (+11%)
- Weak scientific excellence of metrology research in Europe (+11%)
- Lack of qualified researchers and formal career paths (+11%)
- Weak inter-disciplinary research practices (+10%)
- Weak industrial exploitation (+10%)
- Insufficient access to specialised infrastructure (+10%)

[14] Based on the difference (minimum 10%) in responses for very important or important

EU12 countries, compared to EU15, attach significantly more importance to the following problems:

- Huge capacity gaps between EU Member States (+22%)
- Lack of qualified researchers and formal career paths (+21%)
- Insufficient mobility of researchers within the National Metrology Institutes (+22%)
- Insufficient access to specialised infrastructures (+20%)
- Insufficient global cooperation with leading metrology research programmes (+13%)
- Weak scientific excellence of metrology research in Europe (+12%)
- Lack of cooperation of NMIs with the wider scientific community (especially beyond physical sciences) (+10%)

The two main problems that a future initiative has to address can be summarised as follows:

2.2.1. Underexploited potential to have a greater impact on growth and socio-economic challenges

As mentioned before the national, European and global metrology infrastructure already makes a vital, but mostly unrecognised, contribution to economic development, quality of life and environmental protection through the development and application of precise and harmonised measurement methods. The core function of the NMIs is to develop and maintain the hierarchical chain that links primary standards to the validated measurements that underpin trade and commerce. This knowledge base also has the potential to better support technological innovation, both directly and indirectly, through increased collaboration with other actors in the European innovation system including industry, the wider scientific community and public services. The key issues and underlying drivers are:

Metrology needs to make a greater contribution to economic development, through post-research activities that reduce the barriers and risks to exploitation of metrology research through new-to-market products. Industry generally benefits from metrology via improved quality and increased productivity of new and existing products and services. There is however a lack of cooperation between NMIs and industry and insufficient access of industry to related infrastructure. This insufficient support for measurement-related product and process innovation results in weak industrial exploitation of metrology results and underexploited potential for economic growth[15].

Technology transfer traditionally is concentrated on national programmes and there are huge differences of industrial strength and access to technology transfer mechanisms among the European countries. This results in geographical limitations of industrial exploitation and hampers broader spill-over effects.

Weakness of cooperation with industrial partners and weak industrial exploitation are regarded as important problem areas that could be addressed by a European metrology innovation and research programme with specific activities aimed at supporting industrial uptake.

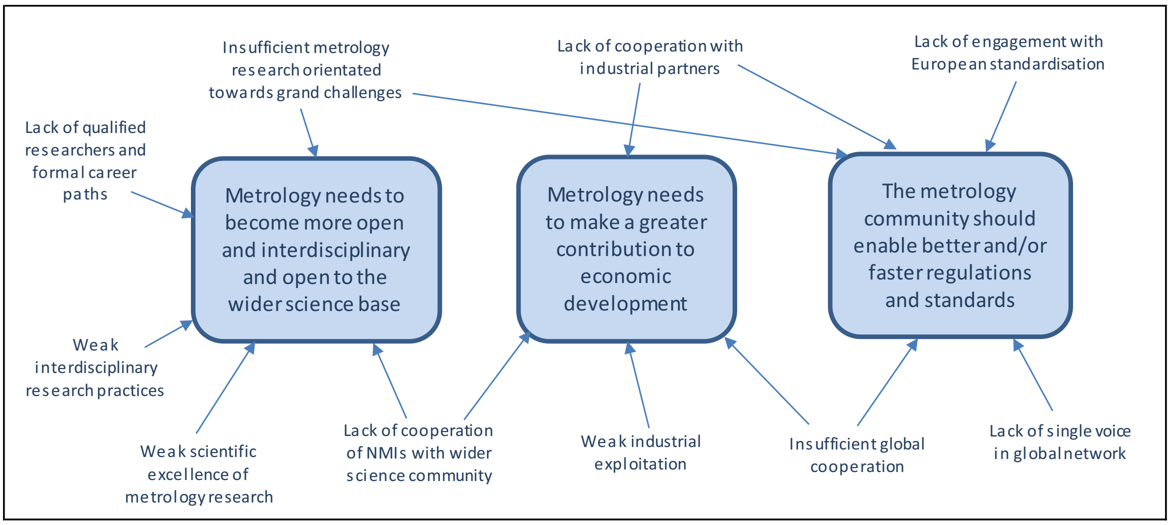
The metrology community should enable better and/or faster regulations and standards, by providing the often missing independent scientific input on measurement methods and their limitations. The benefits of standards for the European industry are tremendous. Standards lead to

[15] This is underlined by the responses to the public consultation: 72% consider "lack of cooperation of NMIs with industrial partners" an important or very important problem, 70% conclude the same for "weak industrial exploitation.

cost reduction or cost savings derived mainly from economies of scale, the possibility to anticipate technical requirements, the reduction of transaction costs and the possibility to access standardised components. Well designed and timely European standards can support innovation in a number of ways. Existing standards can codify and spread the state of the art in various technologies. They can also facilitate the introduction of innovative products by providing interoperability between new and existing products, services and processes, for example in the field of eco-design, smart grids, energy efficiency of buildings, nanotechnologies, security and eMobility. The European metrology community provides an important input to standardisation committees and working groups through the participation of individual experts. What is missing is the strategic engagement leading to the development of mutually supportive scientific roadmaps for pre-normative and policy-related research.

Metrology research needs to become more interdisciplinary and open to the wider science base, only further modernisation of the metrology system towards interdisciplinary and opening to the wider science base can ensure that it will deliver better measurement technologies for societal challenges such as health, energy and the environment. However, channels of cooperation between NMIs and the wider science community, that may already have the relevant scientific capacity, are insufficient. More openness will improve scientific excellence, give the NMIs better access to qualified researcher across disciplines, and thus create a more effective and efficient innovation system[16].

Figure 7: Underexploited potential to have a greater impact on socio-economic challenges – underlying problems and drivers



2.2.2. *Fragmentation and structural weaknesses of the European metrology research and innovation system*

Critical mass of metrology research can only be achieved with coordination and integration of national and European efforts. There is a constant need to improve the efficiency and effectiveness of public investments via better cooperation and coordination while there is in addition the need to continuously re-focus research efforts and to invest more in public metrology research to cover the increasing number of research needs, in particular towards grand challenges. The key issues and underlying drivers are:

16 This is underlined by the responses to the public consultation: 70% consider "Lack of cooperation with the wider scientific community" and "Weak inter-disciplinary research practices" an important or very important problem.

The development and exploitation of new measurement technologies in Europe needs to be more coordinated and inclusive, to reduce unnecessary duplication and allow the less research–intensive NMIs to reduce the knowledge gap and thus better position themselves to support national socio-economic development priorities.

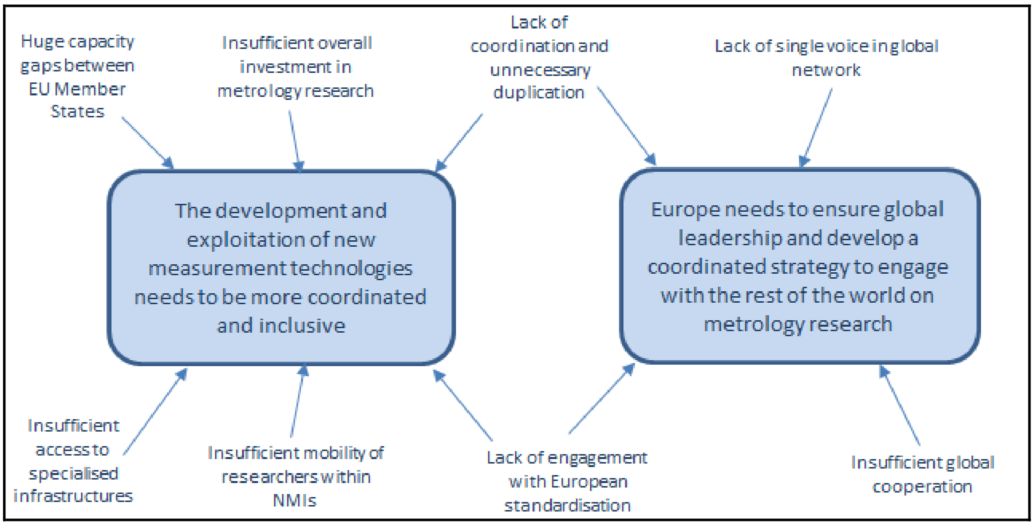
There are two main problems. The first is that scale and complexity of metrology requirements call for investments that go beyond the core research budgets of the European NMIs, resulting in the risk of under investment, in particular for challenge driven metrology research. Critical mass of metrology research for the increasingly complex measurement requirements can only be achieved with better coordination and deeper integration of national efforts. The problem is reinforced through the fact that in times of limited public investments - in particular in countries with lower metrology capacities - additional financial support through the EU is needed to achieve critical mass and stabilise national investments.

The second is that the metrology research in European NMIs is concentrated in just a few countries and EMRP, through its focus on excellent research, has not contributed to a more inclusive metrology research system. It is interesting to note that there are significant differences in the relative importance of certain problems between the more research-intensive countries (eg EU15, top five EMRP contributing countries) and the others. The survey responses indicate that the less research-intensive countries are more concerned about capacity gaps, mobility and lack of qualified researchers. There is a need to reduce the knowledge gap and better position the currently less research–intensive NMIs to exploit metrology research and support national socio-economic development priorities.

Europe needs to ensure global leadership and develop a coordinated strategy

Europe does not have a single centre of excellence for metrology, unlike NIST in the US, and relies on the structure of NMIs and DIs across Member States. The approach to global engagement is multi-lateral with individual NMI/DI operating in a way that is consistent with their national strategy. Europe needs to develop a coordinated strategy to cooperate at programme level with the rest of the world on metrology research in a way that provides broader economic advantages and enables Europe to speak with one voice and demonstrate leadership in addressing global metrology challenges.

Figure 8: Fragmentation and structural weaknesses of the European metrology research and innovation system – underlying problems and drivers



2.3. EMRP: Key achievements and lessons learned

The existing European Metrology Research Programme (EMRP) is one of four Art.185 initiatives foreseen in FP7. The General Agreement, to provide up to € 200 million of Union funding, was signed between EURAMET[17] and the Commission in December 2009 following the Decision by Parliament and Council[18]. This was matched by in kind and cash contributions from 19 EU Members States and three Associated States valued at € 200 million, bringing the total nominal budget to € 400 million. The aim of EMRP is to:

"Support scientific development and innovation by providing the necessary legal and organisational framework for large-scale European cooperation between Member States on metrology research in any technological or industrial field."

EMRP is a multi-annual joint R&D programme organised into five annual calls from 2009 to 2013. These included specific targeted programmes related to societal challenges, metrology for industry and basic metrology research. Proposal selection is based on common evaluation with international peer review. EURAMET reports that 117 Joint Research Projects with a value of € 351 million are funded following the annual calls 2009 - 2012. These research projects involve also 155 unfunded partners (approximately 50% industry, 50% research organisations). In addition, they have been enhanced through the funding of 224 associated researcher grants with a total value of around € 27 million. On average more than 10 organisations contribute to each individual project.

Figure 9: Pilot action iMERA Plus and its outcomes

The implementation of a joint metrology programme was tested in a first step in 2007 as an ERA-NET Plus action (iMERA-Plus) with co-funding from FP7, with the funded projects just being finalised in 2012. A joint call resulting in 21 collaborative Joint Research Projects totalling € 64.6 million was undertaken in four thematic areas, with just over two thirds of the funding provided by the participating member states and about one third co-funded by the EC. These projects resulted so far in NMIs producing about 300 peer reviewed papers and 390 presentations at high level conferences as well as more than 110 novel devices developed, potentially relevant for industrial application. Commercialisation potential is further underpinned by 37 resulting projects with industry and three patent applications.

The current EMRP initiative has provided a major opportunity to cooperate across Europe, thereby creating critical mass and leveraging investments. The main achievements of EMRP can be summarised as follows:

- A strong financial integration by jointly programming 50% of dedicated national funding for metrology research
- A strong and very efficient centralised management integration under EURAMET governance with grant management almost identical to FP7 rules
- A strong scientific integration oriented towards grand challenges with jointly developed roadmaps underpinning the long-term research needs and high scientific excellence of selected projects
- EMRP projects deliver European measurement solutions rather than many national ones and common European inputs into standards and regulations
- EMRP has a broader impact on a European Research Area in metrology, with nine national metrology research programmes that have been established since 2007 in order to enable countries to participate in the initiatives
- EMRP is considered as the leading metrology programme worldwide with many partners from NMIs beyond Europe participating in projects

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17 EURAMET e.V. is the legal entity that was established to implement the EMRP

18 Decision No 912/2009/EC of the European Parliament and the Council of 16 September 2009

Figure 10: EMRP projects related to societal challenges and expected outcomes (see also Annex V)

<u>**Health**</u>

Increase access to Magnetic Resonance Imaging: Approximately 10 % of the population with medical implants are excluded from MRI because of the inability to properly quantify the risk for these patients. The project will improve risk assessments for MRI scans and also remove any unnecessary safety margins due to insufficient knowledge, leading to improved diagnosis and shorter scan times.

Supporting a faster detection of infectious disease: An accurate and rapid diagnosis of infectious diseases is vital to protect public health, as they account for 20% of human deaths on global scale. By assessing quality, comparability and traceability, the project supports building up a superior – and faster – measurement infrastructure (sequence analysis) as compared to conventional microbiological methods.

<u>**Environment**</u>

Better climate models through better measurements: Measurements of pressure, temperature, humidity and airspeed are key to understanding the climate of the Earth – but current measurement techniques lack sufficient accuracy, e.g. for determining the (low but important) levels of water vapour in the stratosphere. This project aims to improve climate models by improving these measurements.

Measurement standards for critical water pollutants: Reference standards for some of the most important water pollutants, e.g. tributyltin (TBT), polybrominated diphenylether (PBDE) and polycyclic aromatic hydrocarbons (PAH) will be developed to understand how these pollutants interact with each other and with other chemicals. This will allow accurate monitoring of pollutants and delivers to the European Water Framework Directive (WFD).

<u>**Energy**</u>

Making power plants more efficient: Reducing the measurement uncertainty of the important control parameters (temperature, flow, thermal energy and electrical output) of power plants. The research will allow for an overall additional enhancement of energy efficiency of 2-3 % for all types of large power plants, resulting in a comparable amount of reduction of emissions.

Fuels for the future: To support market take-up of biofuels, they need to be able to mix with traditional fuels and form blends that can be used without affecting vehicle engine performance, reliability or safety. The project delivers accurate measurements results, and a greater understanding of biofuel properties, to improve public confidence in low-carbon fuels.

There are however clear limitations of the current initiative EMRP in addressing the challenges the European Metrology Research system is facing:

Figure 11: EMRP contributions and limitations in addressing the challenges

Challenge	EMRP contributions and limitations
Lack of industrial cooperation and weak industrial exploitation	EMRP has established some level of industrial cooperation with two calls for industrial metrology. Lack of post-research activities and dedicated instruments for industry driven research supporting innovation result in limited possibility to addressing the challenge.
Underexploited potential for better and faster regulations and standards	EMRP projects generate a coordinated input to standardisation, but rather as a spin-off. Pre- and co-normative metrology research driven by priorities of standardisation bodies and regulators cannot be addressed by EMRP.
Metrology research needs to become more open and interdisciplinary	EMRP researcher grants have achieved only limited opening of the system. Full participation of the wider research community is not possible with the current programme structure, number of participation limited.
Development and exploitation of metrology in Europe needs to be better coordinated and inclusive	Large contribution to coordination of research (50% of dedicated national metrology research). No contribution to capacity building.
Europe needs to ensure global leadership and develop a coordinated strategy	No coordinated strategy at programme level due to project based international cooperation of EMRP.

2.4. Baseline scenario

The baseline scenario, presented as the 'business-as-usual' option, would be the continuation of EMRP. This means a future joint programme on metrology research would be co-financed by the national participants and the EU (Horizon 2020) with matching contributions. The scope of the EMRP follow-up programme would remain the same in 2014-2020 and focus on metrology research oriented towards basic metrology and grand challenges and some topics dedicated to industrial projects, with a similar annual budget (€ 80 Million) for a duration of seven instead of five years, thus resulting in a total volume of € 560 Million compared to the running initiative with € 400 Million.

2.5. The EU's right to act and the application of the subsidiarity principle

The initiative is embedded into the Treaty's objectives to strengthen the EU's scientific and technology bases (Art. 179.1 TFEU), and to develop a European research area based on cooperation among researchers across borders (Art. 179.2 TFEU), such as through the EU participation in research and development programmes undertaken by several MS (Art. 185 TFEU[19]).

The European strategy for smart, sustainable and inclusive growth – EUROPE 2020[20] – sets the agenda for European research & innovation for the coming years. Several of the flagship initiatives of that strategy are affected by metrology research, including "Innovation Union", "A digital agenda for Europe", "Resource efficient Europe" and "An industrial policy for the globalisation era".

In this respect, the added-value of public intervention at EU level lies in the EU's capacity to bring together compartmentalised national research programmes, help design common research and funding strategies across national borders, and achieve a critical mass of actors and investments required for tackling the challenges the metrology research system is facing. This would contribute to achieving the European Research Area in the field of metrology research, thereby increasing the cost-effectiveness and impact of European activities and investments in this field.

The Commission's proposal for Horizon 2020 provides an opening for a possible continuation of the EU's participation and co-funding of the new programme. The actual budget allocation will be subject to the outcome of the Horizon 2020 decision.

In the current initiative EMRP Member States and their NMIs together with the dedicated implementation structure EURAMET have proven that a lightweight governance structure can deliver efficient and effective implementation of the programme. The improved successor programme EMPIR would also respect the subsidiarity principle, as the Member States would be responsible for developing their joint strategic work programme and all operational aspects. The role of the EU is to ensure improved coordination, to help achieving critical mass and aligning national and European strategies, raising efficiency of public spending, as well as ensuring synergies with and contribution EU policies and to the priorities of Horizon 2020.

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[19] Article 185 TFEU (ex Article 169 TEC): "*In implementing the multiannual framework programme, the Union may make provision, in agreement with the Member States concerned, for participation in research and development programmes undertaken by several Member States, including participation in the structures created for the execution of those programmes*"

[20] COM(2010) 2020 final Europe 2020 A strategy for smart, sustainable and inclusive growth

3. OBJECTIVES

3.1. General Objectives

In line with the Europe 2020 strategy, the Innovation Union flagship initiative, Horizon 2020 and ERA, the overarching goal of the future initiative is to address the challenges the European Metrology Research System is facing and to fully exploit the benefits of improved measurement solutions for Europe. Thus the general objectives are to:

- **Provide appropriate, integrated and fit-for-purpose metrology solutions** supporting innovation and industrial competitiveness as well as measurement technologies addressing societal challenges such as health, environment and energy including support to policy development and implementation (GO1)
- **Create an integrated European Metrology Research system** with critical mass and active engagement at regional, national, European and international level (GO2)

3.2. Specific objectives

In order to achieve the general objectives and to assure in all relevant activities a high level of scientific, financial and managerial integration as well as a high impact, the following specific objectives and related benchmarks have been set:

- **Boost industrial uptake and improve standardisation**
  - At least €400m of European turnover from new or significantly improved products and services that can be attributed to the research activities of EMPIR and its predecessors
  - At least 60% of CEN/CENELEC /ISO/IEC Technical Committees and equivalent standardisation bodies with potential to benefit directly from EMPIR projects to engage with the programme
- **Underpin a coherent, sustainable and integrated European metrology landscape** to fully exploit the EU potential
  - Maintain a level of at least 50% of dedicated national metrology research investments in Europe being coordinated or influenced via the programme
  - All European NMIs and their designated institutes interact with the programme
  - European leadership in at least 20% of international metrology committees[21]

3.3. Operational Objectives

From the above Specific Objectives follow six Operational Objectives, each with concrete and measurable targets:

- **Establish common agendas with strong integration** of basic as well as challenge-oriented metrology research via common priorities and joint calls with excellence based projects selection (OO1)
- **Support innovation related activities** through the development of new technologies, industry-driven joint research projects and industrial uptake
  This requires a systematic technology screening of projects and at least 20% industry driven research (no dedicated module under the present EMRP) (OO2)
- **Increase immediate relevance for policy makers and standardisation bodies**
  At least 10% is dedicated to normative research, compared to 0% in EMRP (OO3)
- **Open the programme** to the relevant scientific communities and raise awareness and involvement of European technology and research organisations. This means to at least double the participation of non NMI/DI scientists in the programme (OO4)

[21] E.g. in the committees of the meter convention: www.bipm.org/en/committees

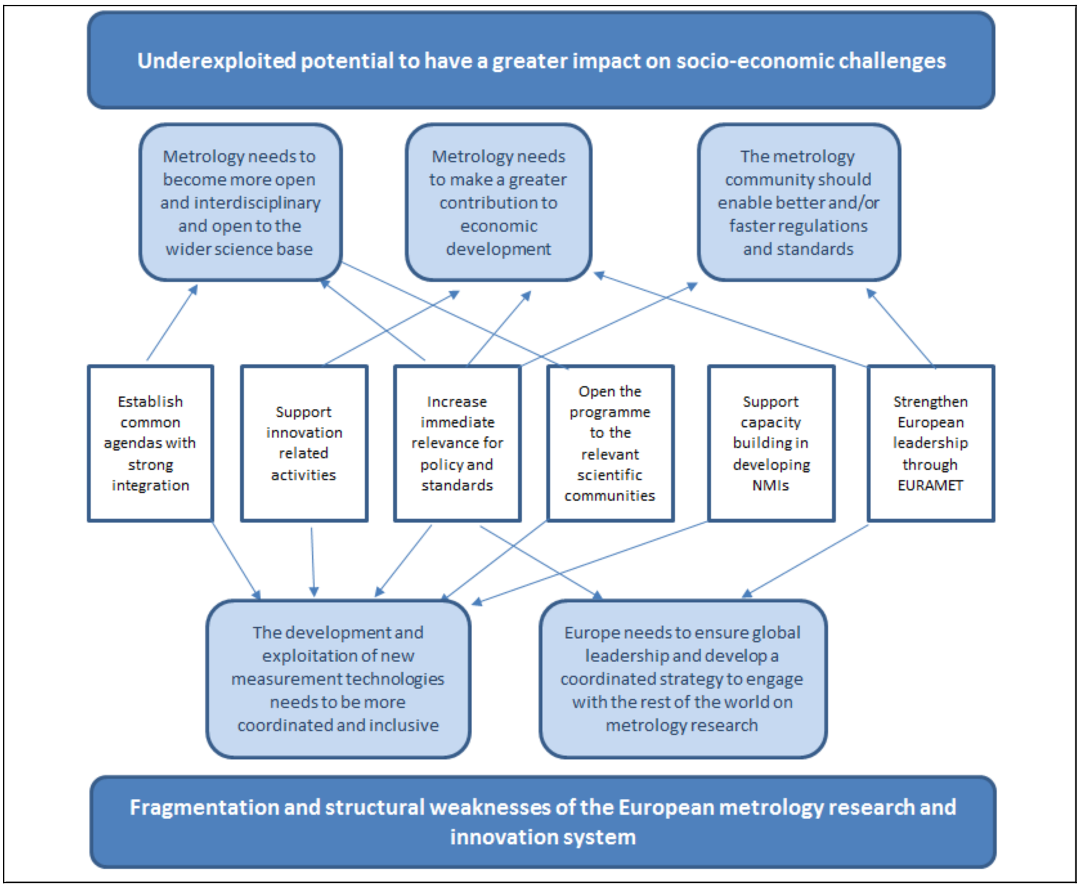
- **Support capacity building** in developing NMIs, in particular by assisting national authorities to fully exploit the use of structural funds and other relevant programmes. The expectation is to increase the leverage of EU structural funds and other programmes, from 0% to 10% of the co-investment in EMPIR (OO5)
- **Strengthen European leadership** through EURAMET and **foster global cooperation**. It should lead to at least two structured cooperations with major metrology actors outside Europe (e.g. US, Canada) (OO6)

The objectives and targets are designed in a way that supports the changes required compared to the current programme in order to address the identified problems. On the one hand they reflect the need to shift part of the research budget into new areas and provide targets for the allocation, e.g. around 20% of the programme budget dedicated to industry driven research or 10% for the pre- and co-normative research. On the other hand they provide ambitious, yet feasible targets that support the necessary structural changes, like the opening of the programme aiming at doubling the participation of external researchers. This expected to lead to around 15% of the budget going to non-NMIs/DIs. The target on the leverage into structural funds and other programmes takes into account the relevance of metrology for smart specialisation. The indicator for the turnover has been developed under the assumption that programme investments in research at NMIs/DIs for basic/challenge driven and industrial research (€ 400 million) should at least yield the same amount of new products/services as a directly attributed outcome.

The specific targets for the operational as well as for the specific objectives have been validated in discussions with the expert group that supported the impact assessment.

The link between the problems and the operational objectives is shown below:

Figure 12: Relationship between the problems and the operational objectives



4. POLICY OPTIONS

4.1. Options

The following three main policy options have been identified for a successor to EMRP:

4.1.1. Policy Option 1: "No dedicated EU action"

Discontinue the EU participation and financial contribution to this initiative after the end of its current funding phase in 2013. Furthermore, no dedicated provision would be made in EU research policies, programmes or funding to support EMRP objectives. Access to EU funding would be limited to competition for ad hoc project funding through Horizon 2020 for topics that include aspects of metrology.

4.1.2. Policy Option 2: "Business-as-usual – EMRP2"

Continue with an identical initiative that is focussed entirely on coordination of research (EMRP2). A new Article 185 continuing the EU participation and financial contribution to a successor programme would be adopted, based on the same terms as for the current programme. EURAMET would continue to be the dedicated legal entity and the work programme would focus mainly on fundamental and challenge research. This would include, as now, some calls on industry relevant topics. The un-tackled recommendations of the mid-term evaluation could not be addressed under this option.

4.1.3. Policy Option 3: "Improved Article 185 initiative – EMPIR"

Build on the success of the EMRP by implementing a more ambitious and inclusive Article 185 initiative that is aligned with ERA and Europe 2020 objectives as a ***European Metrology Programme for Research and Innovation (EMPIR).*** This would still have a significant proportion of the budget (around 50% compared to around 70% in EMRP) dedicated to fundamental and challenge driven research. The improvement from EMRP to EMPIR consists of:

- Stronger focus on innovation and industrial uptake including new actions to help bridge the innovation gap and leveraging private investments. This will include more industry driven research and post-research (technology transfer) activities supporting the exploitation of existing knowledge as well as new research. Industry is expected to mainly participate as unfunded partners in the selected projects. This will increase leverage and lead to additional private sector investment.
- Entirely new dedicated module to support standardisation, with a link to the European standards developing organisations and to other actors incl. industry. It is primarily aimed at pre and co-normative metrology R&D, where the vast bulk of research effort is needed. It will support demand driven metrology R&D (e.g. specified by CEN/CENELEC) needed for the implementation of European legislation, whether through Directives or Regulations.
- Opportunities for those countries with small, medium or less developed metrology systems to take a greater role in the programme
- Dedicated capacity building and link to other funding sources such as structural funds in order to support participating states with incomplete or emerging metrology systems to allow them to decrease the gap to established metrology systems.
- Accompanying measures addressing both strengthening of organizations and human capacity development. They include advice provided by EURAMET staff and mobility support from and to the partners. This includes training, on-site help for the establishment of quality

infrastructure, and practical advice. The capacity building will be seen in regional contexts and strictly demand-oriented.

- Wider participation of academia through direct participation in projects (instead of issuing researcher grants), allowing stronger interdisciplinarity and better use of expertise of other research organisations.
- Facilitated participation of key players "beyond Europe" when beneficial for Europe.

The increased scope of the initiative will facilitate the broader participation of all NMIs and reduce the metrology divide. Participating countries have presented financial commitments in excess of € 300 Million (Annex II). With matching contributions from the EU this would result in a € 600 Million programme with calls over 7 years. The annual budget would increase by 7% (€ 85,7 Million per year). This increase would be sufficient to support the additional activities with only a small reduction of current core activities.

Figure 13: Overview on the options and their main features

	Option 1: No dedicated EU action	**Option 2: Business as Usual EMRP2**	**Option 3: EMPIR**
Coordination framework	None	Article 185, 22 countries[22]	Article 185 28 countries[23]
Coordination entity	EURAMET	EURAMET	EURAMET
Basic research	Ad hoc	Integrated	Integrated
Challenge research	Ad hoc	Integrated	Integrated
Policy/normative research	No	No	Coordinated
Industrial research	Ad hoc	Two Calls	Coordinated
Support for innovation	Ad hoc	No	Coordinated
Support for capacity building	No	No	Coordinated
Support to Horizon 2020 priorities	No	Partially	Coordinated

4.2. Discarded Options

An option that has been discarded from early on is the **top-down EU indirect action by reinstalling a dedicated metrology priority under Horizon 2020**. This approach was previously abandoned after the "Measurements and testing" activities under Framework Programme 5[24] (0,5% of FP5 budget), since the specific needs of the community and the horizontal character of metrology research could already then only be met with stronger efforts for coordination between national programmes and actors.

A further option that has been excluded is a **single European research programme to be implemented by the Institute for Reference Materials and Measurements (IRMM) of the Joint**

[22] Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom (all EU Member States with a Metrology Research Programme participate)

[23] In addition Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Ireland and Serbia join the programme. All EU Member States with an existing Metrology Research Programme participate.

[24] An independent expert panel recommended as part of their 5 year assessment of FP5 in 2000 a strong coordinating character and increased budgets.

Research Centre as a fully institutional programme at the level of the Commission services. The option was considered under the impact assessment for the current initiative but not maintained for comparison since it was not viable to address the problems stated (isolation from NMI work and national metrology needs, level of investment and staffing needed, no effect on modernisation of NMIS, no effect on openness of the system etc.). Given the level of coordination and integration of national efforts that have been achieved with EMRP the option is now even less realistic.

5. ANALYSIS OF THE IMPACTS OF THE OPTIONS

Chapter 5 assesses the impacts of each option against the degree they allow achieving the operational objectives. In addition they are assessed in their economic, social, environmental and other impacts. The links between the three levels of objectives logically support each other with operational objectives feeding the achievement of the specific objectives and via the specific objectives feeding the achievement of general objectives.

5.1. Impact on achieving the operational objectives

The following figure summarises the overall impacts of the options on the six operational objectives that have been defined.

Figure 14: Assessing the potential impacts of the options in in achieving the operational objectives

Operational objectives	Option 1 No dedicated EU action	Option 2: Business as Usual - EMRP2	Option 3 EMPIR
1) Common agenda with strong integration	▪ Collaboration between NMIs beyond their national needs and strategies comes to a halt ▪ EURAMET falls back to a purely co-ordinating body of NMIs without any forum for joint research programming ▪ Only strong NMIs will participate in individual thematic Horizon 2020 projects ▪ No common agenda setting and coordination of metrology research	▪ The successful experience of the first EMRP will be continued and adapted to the extended Societal Challenges of Horizon 2020 ▪ EURAMET will remain a powerful body to promote the collaboration of NMIs and their programmes ▪ An increasingly strong integration of research will be achieved due to the concentration on coordination of fundamental and challenge driven research	▪ Agenda setting and support for research projects to address basic and challenge driven metrology will continue with improved efficiency due to the experience gained in EMRP ▪ Additional modules will however divert resources and efforts into other areas, thus resulting possibly in a lower overall coordination compared to option 2 ▪ Participating States are fully (financially) committed to the new programme with the extended scope.
2) Support innovation	▪ Few individual Horizon 2020 projects addressing metrology with weak links between NMIs and industrial users ▪ Individual projects of high scientific level with potential for breakthrough technologies ▪ Limited wider impact of NMIs on innovation across industries ▪ No European coordination of metrology in relation to industrial needs and related standardisation	▪ EMRP will remain focused on basic and challenge oriented metrology research ▪ There will be no dedicated action to foster innovation and technology transfer beyond opening up to industry to express their needs and individual calls for industry driven research ▪ The individual NMI/DIs will need to make an effort to improve their technology transfer activities	▪ EMPIR will set up dedicated post research activities to support innovation in emerging fields and in traditional industrial sectors ▪ Much higher impact on innovation by building a strong interaction with the demand side ($\geq$ 20% industry driven research) and leverage of private investment ▪ Increasing impact on industrial standardisation needs will improve market position and trade

Operational objectives	Option 1 No dedicated EU action	Option 2: Business as Usual - EMRP2	Option 3 EMPIR
			opportunities of European firms
3) Increase relevance for policy makers and standardisation bodies	▪ Mainly bilateral connection of NMIs and standardisation bodies ▪ Metrological research activities are not coordinated with standardisation/regulation efforts ▪ Fragmented research in different MS often too late for mandated standards from legislation ▪ Missed opportunities for Europe in setting industrial standards, especially in areas of emerging technologies, or regulations with global importance, affecting Europe's competitiveness in open world markets	▪ Basic and challenge oriented metrology research will eventually lead to diffusion of knowledge into the European standardisation system ▪ Missed opportunities for Europe in setting industrial standards, especially in areas of emerging technologies, or regulations with global importance, affecting Europe's competitiveness in open world markets ▪ No direct and early influence on standardisation and related regulation	▪ EMPIR includes a specific module engaging with regulators and standardisation bodies ▪ EMPIR will support European standardisation through early involvement and demand driven research ▪ Dedicated research to pre-normative research and working groups of standardisation bodies with relevance to metrology ▪ Early involvement will increase timely metrology research for regulations relying on measurements
4) Open up the programme to relevant scientific communities	▪ No incentive for NMIs to work with the wider scientific community to support further modernisation of the overall European metrology system ▪ Metrology issues within research projects addressing Grand Challenges will play a minor part in the overall research projects	▪ The efforts to encourage opening to the wider science community in order to speed up modernisation of the national institutes have shown first results and has improved since the mid-term Review took place ▪ The current system of researcher grants does not allow adequate participation of relevant research organisations. Projects are designed and implemented by the NMIs. External researchers participate as individuals.	▪ With the target to at least double the number of non-NMIs, non-DI scientists, the programme will necessarily have to open up to strongly to scientists from outside the current communities ▪ EMPIR would allow for participation of research organisations (instead of individuals) as full partners in funded projects, making their participation more attractive and fully integrating their expertise.
5) Capacity building	▪ Stronger NMIs will develop some European activities in project specific consortia, raising the entry barrier for weaker NMIs ▪ NMIs focus on national priorities ▪ No possibility to design and implement an integrated European metrology system ▪ No incentives to share expertise and capacity building within the European	▪ EMRP remains mainly a strategic tool to ensure international recognition of the measurements of different NMIs ▪ Nevertheless the gap among the different members is still evident. Consequently maintaining a similar strategy means the gap will continue to exist ▪ No dedicated action to make linkages with the Structural	▪ Broader thematic scope will increase the points of entry for partners in Member States with weaker NMI infrastructures ▪ Dedicated actions will reduce the divide in capabilities, taking into account smart specialisation ▪ Dedicated actions reinforce the interaction with the Structural Funds, although decisions remain outside the

Operational objectives	Option 1 No dedicated EU action	Option 2: Business as Usual - EMRP2	Option 3 EMPIR
	metrology system as	Funds	control of EMPIR
6) Strengthened leadership & global cooperation	▪ Only limited collaboration between EURAMET or strong NMIs and third countries ▪ Only few bilateral international research projects with fragmented exploitation of the benefits ▪ No coordinated international research efforts in metrology ▪ No single European voice	▪ No global co-operations beyond individual projects ▪ Continuity in project based international cooperation with some of some of the large international NMIs ▪ No strategic approach to global cooperation	▪ EMPIR can drive international cooperation in a strategic manner and address multiple objectives (scientific exchange, mobility researchers standardisation) ▪ Research collaboration can be established as part of a dedicated long-term strategy for Europe ▪ Global cooperation integrated in EMPIR road mapping exercise

5.2. Economic, social, environmental and other impacts

5.2.1. The economic impacts

The broader economic impacts of metrology have been illustrated in chapter 2.1. A good synthesis of the existing literature on the economic impacts of metrology is made by Ray Lambert[25] (2010) and Peter Swann (2009)[26]. They conclude that use of measurement can increase the productivity of organisations, that is supports innovation (directly particularly in the measurement tools industries and also indirectly by giving innovators the tools to demonstrate the better performance of their novel products) and that is reduces transaction costs. A full overview of underlying mechanisms is provided in Annex III.

Due to a lack of models that would allow a quantification of economic impacts of metrology research in the four options the economic impacts have been assessed according to the degree they allow addressing the challenges and the achievement of objectives.

The **economic impacts** on growth and high quality jobs of the options would be particularly expected to stem from successfully addressing objectives at all three levels. In particular: (GO1): “Provide appropriate, integrated and fit-for-purpose metrology solutions supporting innovation and industrial competitiveness as well as the solving of societal challenges and better regulation; and (SO1): Boost industrial uptake and improve standardisation and OO2 and OO3 the support of innovation related activities and the increase of immediate relevance for policy makers and standardization bodies.

25 Ray Lambert, Department for Business, Innovation & Skills, Economic Impact of the National Measurement System, Evidence Paper, July 2010

26 Peter Swann, The Economics of Metrology and Measurement, Report for the National Measurement Office, Department for Business, Innovation & Skills, Innovative Economics Ltd, October 2009.

Figure 15: Economic impacts of the three options

	Economic impacts
Option 1 **No dedicated EU action**	Metrology research will continue via individual initiatives at national level and contribute to strengthening of the scientific and technological basis of some NMIs and indirectly the ability for industry to benefit. Economic impact will be on a smaller scale compared to initiatives with a coordinated approach and budgets (Option 2) or, in addition, dedicated activities supporting industrial exploitation and uptake in standards and norms (Option 3). Little effort is made to align metrology with national and European regulation and thus negatively affect Europe's competitiveness in open world markets and weaken the promotion of social and environmental values.
Option 2 **Business as usual** **EMRP2**	Metrology research will continue to be conducted in a European joint programming initiative similar to the current EMRP. This will contribute to strengthening of the scientific and technological basis and thus indirectly support the ability for industry work with standardised measurements and include these in their innovative products. Increased coordination of the national metrology research will lead to a pre-selection of most relevant and most promising areas. Projects will be of higher excellence via competitive selection mechanisms and will be implemented with large consortia (in EMRP on average 10 organisations participate in a project) instead of in national isolation. Thus the economic impact will be on a larger scale compared to project-by-project initiatives as in Option 1. A limited number of calls with industrial relevance will only make small contributions to innovation. A lack of post-research activities will hamper the broader exploitation of results and not allow industry to fully benefit from cutting-edge metrology for new and improved products and processes. Overall, direct impacts on industry will be substantially smaller than in option 3. Collaborative metrology research will eventually diffuse knowledge to support standardization. Influence on standardisation and regulation will be delayed compared to option 3 that offers a coordinated and demand riven input. This can mean that European industry will not benefit from a 'first mover advantage'.
Option 3 **Improved Art.185 initiative** **EMPIR**	There will be deliberate modules and actions to involve industry and to develop technology transfer activities. Compared to Option 2 the direct involvement of industrial users will be fully developed and result in direct economic impact through the industrial uptake. Individual industry driven projects will allow short term impacts. Post research activities will create a technology push into European industry by exploiting cutting edge measurement technologies from on-going and past EMRP and EMPIR projects as well as NMIs in general. This will increase substantially the use of improved measurement technologies for new and improved products and services and overall accessibility for industry[27], thus boosting competitiveness of the industry by cutting-edge metrology. Given the explicit capacity modules in Option 3, the potential access of (industrial) users to high quality metrology services and infrastructures across European countries will be improved, thus widening the geographical scope of the potential economic impact of individual projects. Proactive early involvement in European and international standardization will be supported. This supports leading positions of European companies on the global markets. These activities will serve European innovation especially in highly accelerated areas of emerging technologies or areas in which the value of metrology is increasingly being recognized for standards, e.g. chemistry, clinical medicine or food safety. Thus the scope of potential economic impacts with regard to economic sectors and industries is greater than in the more narrowly defined metrology activities of Options 1, 2 and 4. A strategic approach to global networks combined with a proactive approach to standards and regulation will provide competitive advantage to European industrial actors who have been involved in the related metrology research projects from an early phase.

[27] A recent example is Luminanz, a UK high technology start up (founded in 2007) which has pioneered a number of light emitting diode (LED) lighting innovations. Vital to the accurate prediction of lifetimes is accurate measurement of junction temperatures of LEDs. NPL provided a brief consultancy in related measurement methods. The company invested significantly in implementing the advice given, an estimated £10,000. The identified commercial benefits were in the order of £250k - giving a cost-benefit ratio of 1:18.

5.2.2. The social impacts

The **social impacts** of the three options will potentially stem from a wider dissemination and access to metrology knowledge and expertise across all MS. This will underpin the cohesion and indirectly the capabilities of people and organisations to benefit from metrology as an enabling technology. This is particularly related to the general objective of creating an integrated European Metrology Research system (GO2), underpinning a coherent, sustainable and integrated European metrology landscape (SO2) and in particular the Operational Objective to support Capacity building (OO5). Social impacts also stem from the contribution to Grand Challenges such as health and environment, benefiting citizens as well as creating high quality jobs. With accurate assay methods and metrological calibrated measurement instruments the risks of erroneous diagnosis will decrease, which will lead to improved health and reduced health costs. Thus the option most capable of addressing the Grand Challenges by opening up to new scientific communities (OO4) will generate more societal impacts.

Figure 16: Social impacts of the options

	Social impacts
Option 1 **No dedicated EU action**	Integration will be limited to individual Horizon 2020 projects. Compared to Option 2 and 3, Option 1 is less inclusive as it is likely that the countries with the strongest NMIs and well-positioned DIs will be more successful in Horizon 2020. There are no specific modules in Horizon 2020 to support capacity building or establish linkages between metrology research and Structural Funds.
Option 2 **Business as usual** **EMRP2**	By means of a more coordinated research agenda setting and an inclusive membership in EMRP the chances for a coherent system are better than in the Option 1 as the achievements of EMRP have shown. Involvement of NMIs from all member countries in the strategic programming and expert groups will have an effect on dissemination capacities across Europe. This has however only led to an overall increase of capacities and capabilities for the strong and for the less capable NMIs, the gap as such has not decreased but rather increased. EMRP2 will have a similar effect due to the lack of focus on capacity building and not allow widening the geographical scope of the potential social impact of individual projects. The contribution of Option 2 to social impacts is comparatively high, as EMRP2 would dedicate its activities to addressing societal challenges, and this would involve inclusion of relevant scientific communities.
Option 3 **EMPIR**	Dedicated attention to capacity building is required to contribute to closing the gap. EMPIR foresees a module with targeted activities for capacity building explicitly focused on assisting national authorities to use Structural Funds in building up metrology capacity. This will allow a more inclusive metrology landscape necessary for the full exploitation of measurement benefits across Europe. In addition it will contribute to influencing the national/EU policy agenda. EMPIR will increase the overall contribution to addressing societal challenges by opening the programme up to new relevant scientific communities that have the competences often not available in NMIs.

5.2.3. The environmental impacts

Environmental impacts will likely occur if metrology is applied to tackle the Grand Challenges related to sustainable energy, climate change, eco-innovation and other environmentally relevant areas. Another route to environmental impact is through its effect on sustainable industrial processes to make them cleaner and energy/resource efficient. The latter is thus best addressed in the options with most active industrial participation.

Figure 17: Environmental impacts of the options

	Environmental impacts
Option 1 **No dedicated EU action**	The explicit matching of research institutes from different communities and from different disciplines is less likely to happen as the consortia are formed in a bottom-up fashion and the calls under Horizon 2020 are not geared to addressing underlying measurement challenges, as there is no dedicated metrology programme foreseen in Horizon 2020. While individual projects at national level will obviously continue to have positive environmental impacts, the coupling of measurement challenges with environmental problems will be less systematic and happen in an ad hoc manner.
Option 2 **Business as usual** **EMRP2**	Projects in the domain of climate change and sustainable energy have been launched in EMRP. These projects will contribute to a more sustainable environment and energy efficiency. Nevertheless there is still a large emphasis on basic research in the traditional metrology disciplines and domains in EMPR, thus the contribution to tackling environmental challenges would be at a slower pace than in Option 3.
Option 3 **EMPIR**	EMPIR will provide a clear strategy on measurement for environmental challenges in combination with an even stronger objective to open up to relevant scientific communities with an ambition to double the participation of non-NMI/DI scientists in the programme. This would give better opportunities to address the specific research projects and competence building needed to tackle these emerging topics. The speed and scale of Option 3 compared to Option 2 would be more optimal. Option 3 is also better equipped than the other options to involve industry and their customers in measurement and calibration activities, leading to cleaner and more efficient manufacturing processes

5.2.4. Impacts on European Research and Innovation Policy

Figure 18: Impacts on European Research and Innovation Policy

	Impacts on European Research and Innovation Policy
Option 1 **No dedicated EU action**	National metrology research will be detached from European Research and Innovation policies. Contribution to Horizon 2020 priorities would be limited to selected collaborative projects in which NMIS participate. No alignment of national and European roadmaps and strategies. Little contributions can be expected to relevant flagship initiatives as "Innovation Union", "A digital agenda for Europe", "Resource efficient Europe" and "An industrial policy for the globalisation era".
Option 2 **Business as usual** **EMRP2**	An alignment of national and European metrology research agendas for some of the Horizon 2020 challenges can be achieved. EMRP2 will directly contribute to achieving the objectives of Horizon 2020 by include in its workprogrammes topics of direct relevance for a number of Horizon 2020 priorities including excellence of research and the challenges health, environment and energy. Some contributions can be expected to relevant flagship initiatives as "Innovation Union", "A digital agenda for Europe", "Resource efficient Europe" and "An industrial policy for the globalisation era".
Option 3 **EMPIR**	Strong alignment of national and European metrology research agendas for some of the Horizon 2020 challenges and other priorities (key enabling technologies, future and emerging technologies) EMPIR will strongly contribute to achieving the objectives of Horizon 2020 by including in its workprogrammes topics of direct relevance for a number of Horizon 2020 priorities including excellence of research, challenges health, environment and energy, key enabling technologies, future and emerging technologies. Dedicated pre-and co-normative research will provide additional input to relevant flagship initiatives as "Innovation Union", "A digital agenda for Europe", "Resource efficient Europe" and "An industrial policy for the globalisation era".

5.2.5. *Efficiency and administrative burden*

Figure 19: Efficiency and administrative burden of the options

	Efficiency and administrative burden
Option 1 **No dedicated EU action**	The Art 185 initiative will be dismantled. This will reduce the administrative burden for both EURAMET and the scientists involved in preparing proposals for Joint Research Projects. However, it will significantly increase the bureaucracy and reduce the overall efficiency for those in the metrology community that are committed to collaborative research in Europe. This is due to the fragmented nature of national research and the relatively high competitive intensity of the EU Framework programme (for ad hoc collaborative projects).
Option 2 **Business as usual** **EMRP2**	EURAMET has established an elaborate, but highly efficient, management process for organising the annual joint programming, EMRP Calls and negotiating/monitoring funded projects. This is subject to continuous improvement. A maximum 4% of the total EMRP budget is allocated to the central managements system and this is financed by cash contributions from the participating countries. Option 2 would therefore have a similar level of bureaucracy but the mutual learning from the FP7 programme would mean that further incremental improvements in efficiency would be achieved. Some additional bureaucracy might be required at the beginning to adapt the rules from the FP7 model to those of Horizon 2020 but this should be a one-off investment.
Option 3 **EMPIR**	The structures and processes to define and implement the joint research programme would remain the same. This would ensure a relatively seamless transition to the governance system that has been created by EURAMET. There will be some additional bureaucracy to establish and implement the additional instruments and modules. New parallel processes will be needed for innovation, capacity building and normative research. This will need to include more front-end stakeholder engagement to steer the joint programming and dedicated expertise within EURAMET to help the smaller and less scientific NMIs to secure scientific resources and play an effective role in technology commercialisation. This will significantly increase the start-up costs but the overall increase in management costs should be relatively low (perhaps increasing from 4% to 5%). More importantly there should be quite important efficiency gains for the overall European innovation system and through dedicated and coordinated research and technology transfer activities. Administrative burden for standardization bodies and regulators will significantly decrease. They will be able to specify their priority metrology needs in close collaboration with EMPIR and benefit from a precise and faster input from dedicated pre- and co-normative research. This will substantially reduce resources needed for acquiring metrology inputs.

6. COMPARISON OF OPTIONS

The analysis of impacts on the six operational objectives as well as the analysis of the economic, social and environmental impacts provides the basis for a comparison.

6.1. Comparing the options on contribution to objectives

The following Figure provides an overview of the options on the basis of the foreseen contribution of each of them to the six operational objectives that have been defined for the successor of EMRP. This is based on the set of considerations described in Chapter 5. **It is clear that overall Option 3 is the option that has the highest overall effectiveness in achieving the objectives, with the exception of the first objective (integration of research programming).**

Figure 20 Comparison of impact of the options on the six Operational Objectives (OO)

	Option 1: No dedicated EU action	**Option 2: Business as Usual EMRP2**	**Option 3: EMPIR**
OO1 Integration	Low/Medium	Very High	High
OO2 Innovation	Low/Medium	Medium	High
OO3 Policy relevance	Low/Medium	Medium	Very High
OO4 Opening programme	Low	Medium	Medium/High
OO5 Capacity Building	Low	Low/Medium	Medium
OO6 Global cooperation	Low/Medium	Low/Medium	Medium/High

6.2. Comparing the options on impacts

A similar comparison is made for the options on economic, social and environmental impacts (as discussed in Section 5.2) as well as on the effects on efficiency and bureaucracy for the main stakeholders (as discussed in Section 5.2.5). This again underlines Option 3 as the most favourable option.

Figure 21: Comparison of impact of the options on economic, social, environmental and other impacts

	Option 1: No dedicated EU action	**Option 2: Business as Usual EMRP2**	**Option 3: EMPIR**
Economic Impacts	Low	Medium	Medium/High
Social Impacts	Medium	Medium/High	High
Environmental Impacts	Low	Medium/High	Medium/High
Impacts on European Research and Innovation Policy	Low	Medium/High	High
Efficiency	Very Low	High	Very High
Administrative burden	High	Medium	Medium

6.3. Preferred Option

Option 3 is clearly the preferred option after consideration of effectiveness in achieving the objectives, efficiency as well as coherence across all criteria. This is fully supported by the results of the public consultation (93% of responses rate very suitable or appropriate). The option will build on the previous achievements of EMRP with continuity of current activities and their implementation in the new programme while allowing a smooth integration of additional activities right from the start so as to addressing problems that could not be addressed with the setup of the current initiative. The structural provisions with the dedicated modules for innovation, normative research and capacity building link directly to the main recommendations of the mid-term evaluation, e.g. the need for better industrial cooperation and exploitation is addressed by introducing the annual calls for industry driven research and the additional activities to exploit existing knowledge.

6.4. Risk register for the preferred option

Figure 22: Risk register for the preferred option

Risk	Importance	Probability	Mitigation Strategy for Option 3
Lack of buy-in from research-intensive countries	High	Low	Majority of budget for research
Lack of interest from wider science community	Medium	Medium	Continuing support for basic and challenge driven research
Lack of interest from regulatory and standardisation communities	High	Low	Joint development of metrology roadmaps for regulations and standards
Research not relevant for exploitation	High	Low	Governance system should include external steering of joint programming cycles
Austerity measures make it impossible for some countries to participate at full level	Low	High	Opportunities to participate at a lower level through dedicated innovation activities
Inability to access Structural Funds to support capacity building	Medium	High	Dedicated central function to help develop strategies and influence national policies Implementation of EMPIR does not depend on the structural funds. MS with lower capacities benefit significantly by access to and sharing of results. Access to structural funds mainly will improve overall impacts and long-term structural changes
Inability to influence global metrology community	Medium	Medium	Continuing support for basic and challenge research

Under EMRP the MS have so far fully honoured their financial commitments and it is not expected that the situation under EMPIR would be different. The underlying risk is limited, since the MS commitment is demonstrated during the implementation at the level of individual projects in which NMIs/DIs participate with their in-kind contribution as a prerequisite for the EU contribution to the respective projects.

7. MONITORING AND EVALUATION

Monitoring and evaluation are well established with EMRP: Currently a true cross-European ownership exists with long-term obligations, well-functioning structures, and additional national programmes. Budgets are available or committed for a sound common work-plan, objectives, mile stones in combination with simple but effective governance.

For a successor programme several of the existing generic key performance indicators from EMRP should be employed to establish a robust timeline for long-term impact assessment of metrology. Annual reporting will be done by the DIS and will refer to the indicators on the basis of the expected actions within the programme. The monitoring and evaluation will be accompanied by:

- A mid-term evaluation, carried out by an independent expert panel convened by the European Commission, conducted not later than 2018, with a specific focus on the implementation so far, the quality of the research and innovation, progress towards the objectives and targets set, and recommendations for possible improvements.
- At the end of the Union participation in EMPIR, and not later than 2024, an independent final evaluation reviewing the achievement of objectives, outcomes and impacts.

At a **strategic level** the evaluation will be guided through the two general objectives. The measurement of these two overarching objectives follows from measuring the specific and operational objectives and require a rounded and comprehensive assessment of the European metrology system to provide an answer whether the successor of EMRP has achieved these goals. Indicators at the level of **specific objectives** and operational objectives as well as for the programme efficiency could be

Boost industrial uptake and improve standardisation
Indicators: (a) turnover from new or significantly improved products and services that can be attributed to the research activities of EMPIR and its predecessors [target: EUR 400 Million], (b) share of industry driven research projects [target: 20%], (c) value of business investment in EMPIR projects, (d) share of dedicated normative research [target: 10%], (e) CEN/CENELEC/ISO/IEC Technical Committees and equivalent standardisation bodies with potential to benefit directly from EMPIR projects engaging with the programme

Underpin a coherent, sustainable and integrated European metrology landscape to fully exploit the EU potential
Indicators: (f) share of dedicated national metrology research investments in Europe being coordinated or influenced via the programme [target: 50%], (g) participation of non NMI/DI scientists in the programme [target: double compared to EMRP] (h) level of investments from Structural Funds and other relevant European, national or regional programmes in metrology-related activities (i) European leadership in international metrology committees

Programme efficiency
Indicators: (j) quality of the proposal submission, evaluation and selection procedure, (k) time to grant, (l) running costs for the operation of EMPIR [target: ≤ 5%]

The following Figure has grouped the performance indicators by the **operational objectives**. These would mainly be collected by EURAMET/EMPIR as part of programme implementation (analysis of contractual data), standardised reporting by the projects or via survey of the member organisations (already planned by EURAMET), thus limiting additional costs for the different actors to a necessary minimum.

Figure 23: Performance indicators for the operational objectives

Objectives	Indicator
Integration of basic & challenge based research and opening of programme	% of EMPIR research budget as part of total NMI/DI research budget % "Perceived influence" of EMPIR on national research agendas # of publications in refereed journals # of publications in non-refereed journals incl. books, conference proceedings % of the above with co-authors from more than one country % of projects involving wider science community % of person month and % of budget allocated to wider science community # of different organisations involved in the programme (non-NMIs/DIs) % split of research investments for different research areas
Support innovation	# of companies (incl. SMEs) participating in EMPIR projects % of EMPIR projects with industry participation Value of business investment in EMPIR projects, ' of person month # patents (applied for / granted) # of licence agreements # value of products and services coming from innovation projects
Relevance to policy and standardisation	% of EMPIR budget programmed in partnership with standardisation /regulation # of projects with direct references or impact on standards and regulation, percentage of CEN and ISO projects % of EURAMET working groups with relevance for standardisation bodies
Capacity building	# of Member States and third countries involved in EMRP with financial commitment Increased capacities in MS with low level of metrology capacities, e.g shown by their involvement in committees and projects Value of Structural Funds invested in metrology-related activities # of mobility grants, post docs, doctoral students, postgraduates, guest scientist # of calibrations with new capacities
Strengthening European leadership in global networks	# of unfunded participants from 3rd countries % of EU leadership in committees

8. Annexes

Annex I: List of acronyms and abbreviations

AC	FP6/FP7 Associated Country
CC	Consultive Committees
CIPM	Metre Convention (Comité international des poids et measures)
DI	Designated Institute
DIS	Dedicated implementation structure
ERA	European Research Area
EMRP	European Metrology Research Programme (Art.185 initiative on Metrology under FP7
EMPIR	European Metrology Programme for Innovation and Research
EURAMET	European Association of National Metrology Institutes
FP6	Sixth Framework Programme of the European Community for research, technological development and demonstration activities (2003-2006)
FP7	Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013)
Horizon 2020	Eighth Framework Programme of the European Union for research, technological development and demonstration activities (2014-2020)
IA	Impact Assessment
IAB	Impact Assessment Board
IASG	Impact Assessment Steering Group
MS	EU Member State
NMI	National Metrology Institute
SI	International System of Units

Annex II: National commitments to EMPIR (Mai 2013)

	Country	Commitment max
1	Austria	840.000
2	Belgium	1.000.000
3	Bosnia and Herzegovina	200.000
4	Bulgaria	840.000
5	Croatia	700.000
6	Czech Republic	8.600.000
7	Denmark	2.000.000
8	Estonia	910.000
9	Finland	10.000.000
10	France	27.000.000
11	Germany	90.000.000
12	Greece	160.000
13	Hungary	1.050.000
14	Ireland	350.000
15	Italy	21.000.000
16	Netherlands	16.500.000
17	Norway	3.750.000
18	Poland	2.500.000
19	Portugal	840.000
20	Romania	120.000
21	Serbia	700.000
22	Slovakia	200.000
23	Slovenia	3.000.000
24	Spain	6.000.000
25	Sweden*	2.388.854
26	Switzerland	8.300.000
27	Turkey	12.000.000
28	United Kingdom	87.000.000
		307.948.854

Annex III: Measurement and economic returns

Swann[28] identified a list of 19 mechanisms by which measurement can deliver economic returns. Some aspects are not fully captured (environmental benefits or health and safety benefits):

1. Better decisions	Statistical hypothesis testing recognises Type I and Type II errors. Improved measurement can reduce the probabilities of Type I and/or Type II errors.
2. Better standards and use of standards	Better measurement can help to achieve faster standards development, and better quality standards.
3. Common pools for product innovation	Measurement underpins the use of novel product characteristics for competitive advantage. An open measurement system can help to create a common pool of potential product innovations.
4. Comparability of measurements facilitates trade	The growth of trade requires the reduction of transaction costs, and an essential part of that is the emergence of common standards and measurements.
5. Division of labour - interchangeable parts	Accurate and comparable measurement enables further division of labour, and greater use of interchangeable parts.
6. Dosage issues	For a wide variety of products, precise measurements of product characteristics (or doses) are essential for efficacy and safety.
7. Easier to demonstrate quality and safety	Accurate measurement of product characteristics makes it easier to demonstrate quality and safety, and hence to sustain a price premium for superior products.
8. Enabling a new market	The creation of new forms of market is as important as other types of innovation. Measurement also plays an important role in the reduction of "market failure".
9. Enabling a new process	Measurement is often essential to the control of complex systems that enhance productivity. Better measurement can increased process efficiency, and help to achieve energy savings.
10. Enabling a new product	Measurability of product characteristics promotes product innovation, by making it easier to demonstrate quality, and hence sustaining a price premium for quality.
11. Improved product quality	Improved measurement enables quality control, allows the sorting of products by quality, enables more accurate doses, tighter tolerances and higher purity.
12. Increased productivity / process efficiency	Better measurement can enable the use of new processes and/or increased process efficiency. It enables the implementation of new complex systems that enhance productivity.
13. Patent protection	Measurement has an important role in the patenting process, which in turn enhances the profitability of the patent-owner.
14. Quality control	Improved measurement enables quality control.
15. Reduced costs of meeting regulations	Improved measurement can make it easier and cheaper to ensure regulatory compliance, and can thereby lead to a lower regulatory burden.
16. Reduced damage from externalities	Improved measurement can make it easier to achieve more demanding environmental regulations, and hence reduce the environmental damage from externalities.
17. Reduced transaction costs	The comparability and traceability of measurement reduces some of the risks in trading, and hence reduces transaction costs.
18. Shorter times to market	Better measurement can help companies bring products to market in a shorter time-span.
19. Testing that equipment is working properly	Measurement obviously plays a key role in testing equipment and ensuring it works properly.

[28] Swann G.M.P. (2003) Engineering Economics: Case Studies, Mechanisms and a Micro Model of Measurement Impact, Report for DTI

Annex IV: Public online consultation: analysis of the responses

1. Nature of the consultation

As part of the impact assessment for the preparation of a European Metrology Programme for Innovation and Research (EMPIR), based on Art.185 of the Treaty for the functioning of the European Union, a stakeholder consultation has been carried out. This consultation consisted of an online survey with the results being presented here and a dedicated stakeholder meeting (conclusions documented in a separate document). The survey collected stakeholder views on the state of play of the European metrology research system and the challenges it is facing. The online survey was open for submission for 12 weeks (1 October – 23 December 2012). The annex provides a summary of the analysis, the full report is available on the Research Europe website[29].

2. Profile of respondents

A total of 624 responses have been received, with the vast majority (95%) agreeing to the publication of their contribution. Figure 1 shows the distributions of responses across the different EU Member States (in total 91% of replies), with the largest groups contributing being from France, Germany, Spain and the UK. Replies outside the EU where received from more than 10 different countries ranging from Switzerland, Turkey, Iceland, Serbia, Montenegro and Albania to South Africa, Mexico, China and Thailand.

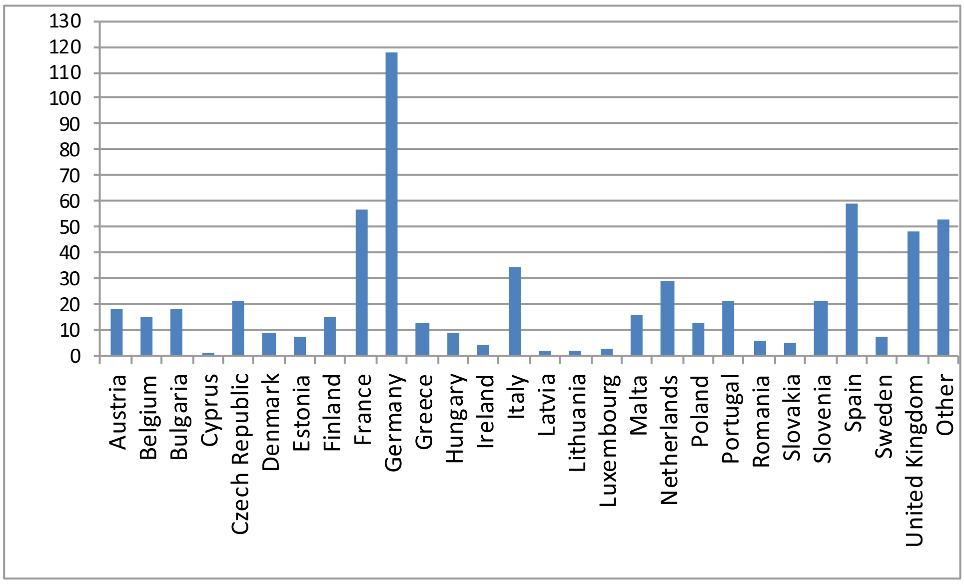


Figure 1: Country distribution of responses

72% of the responses came from organisations and 28% of the responses from individual citizens. The main contributions from organisations were received from research organisations (32%) and businesses (16%, of which 69% SMEs). Figure 2 illustrates the distribution of respondents.

29 http://ec.europa.eu/research/consultations/pdf/empir-survey

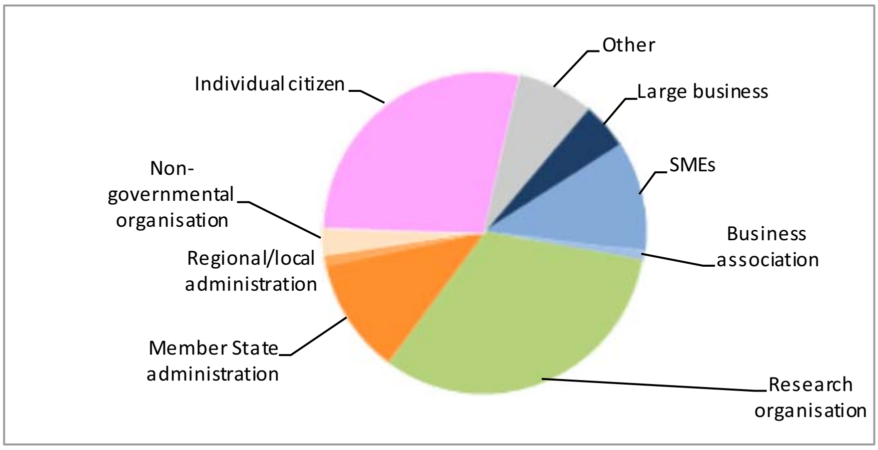


Figure 2: Distribution of responses according to type of organisation

Figure 3 shows the involvement of those responding in the different aspects of metrology, with 61% of the respondents being involved in metrology research and 51% in its uptake. 36% are involved in standardisation or regulatory work. Only 3% of the respondents state to have no involvement in metrology research at all.

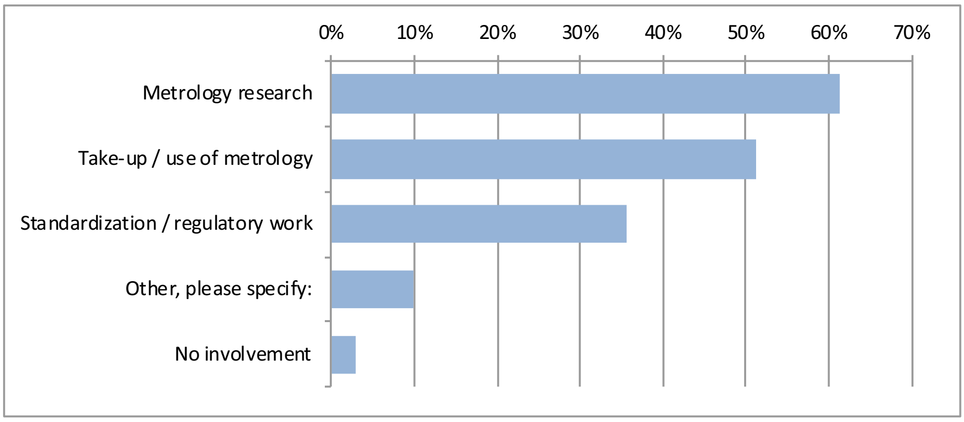


Figure 3: Involvement in the different aspects of metrology [multiple answers where allowed]

The survey reached respondents that are fairly familiar with the running initiative EMRP: 67% claim to be familiar or very familiar (figure 4). Only a minority (34%) has applied for funding from EMRP, 30% successfully (figure 5).

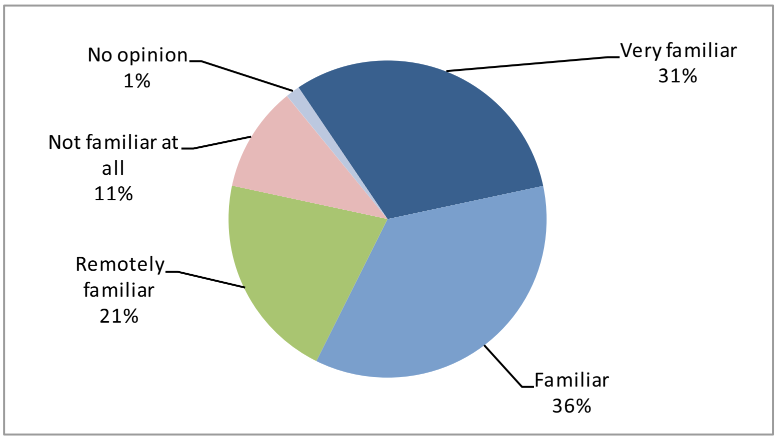


Figure 4: Degree of familiarity with the running initiative European Metrology Research Programme (EMRP)

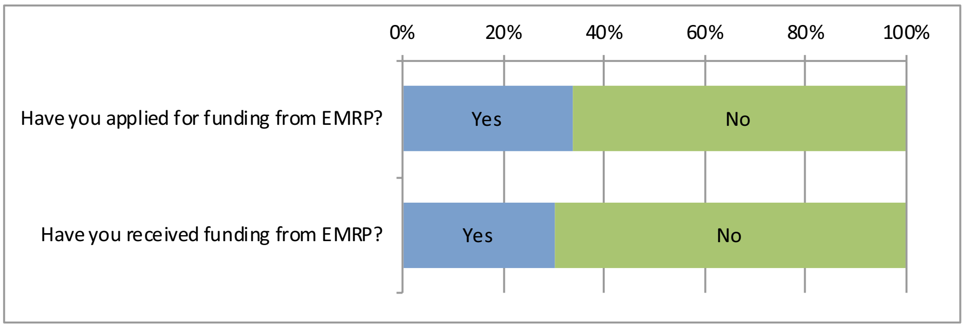


Figure 5: Respondents that have applied for or received funding from the running initiative European Metrology Research Programme (EMRP)

3. Summary of the results

3.1 Importance of metrology research

In a first step participants were asked to give their view on how important metrology research is for (a) addressing grand societal challenges such as health, energy or environment, (b) for the European economy and industrial competitiveness and (c) for European policies, standardisation and regulatory work. The overall assessment shows that respondents see equally strong relevance of metrology research for all three areas (on average 97% answer very relevant or relevant). On the importance of metrology research the replies do not show any distinctive difference for different types of respondents (large versus small research contributors to EMRP, EU15 versus EU12 or industry versus research).

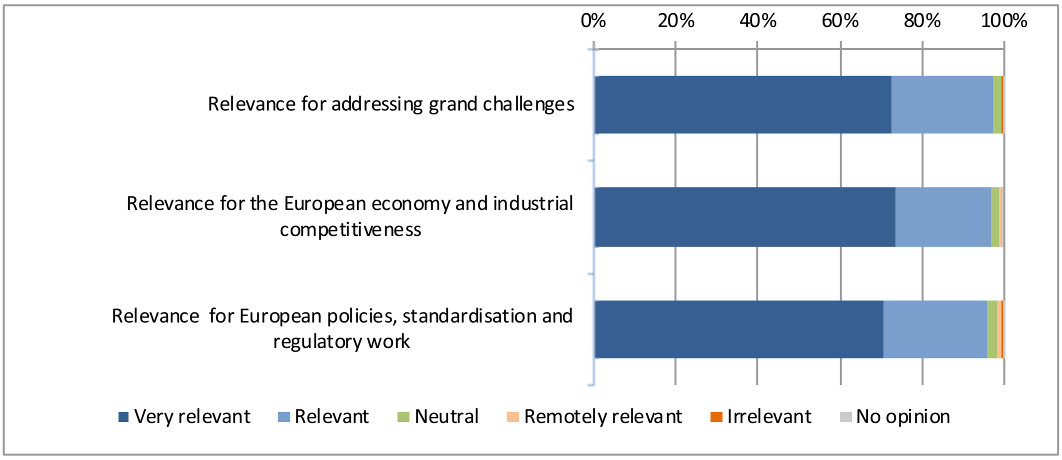


Figure 5: Relevance of Metrology

3.2 Problem definition

In order to better identify and define the underlying problems, respondents were asked to rate the importance of a number of problem statements (figure 6). There was a strong agreement with the overall set of proposed problems (minimum of 50% very important or important).

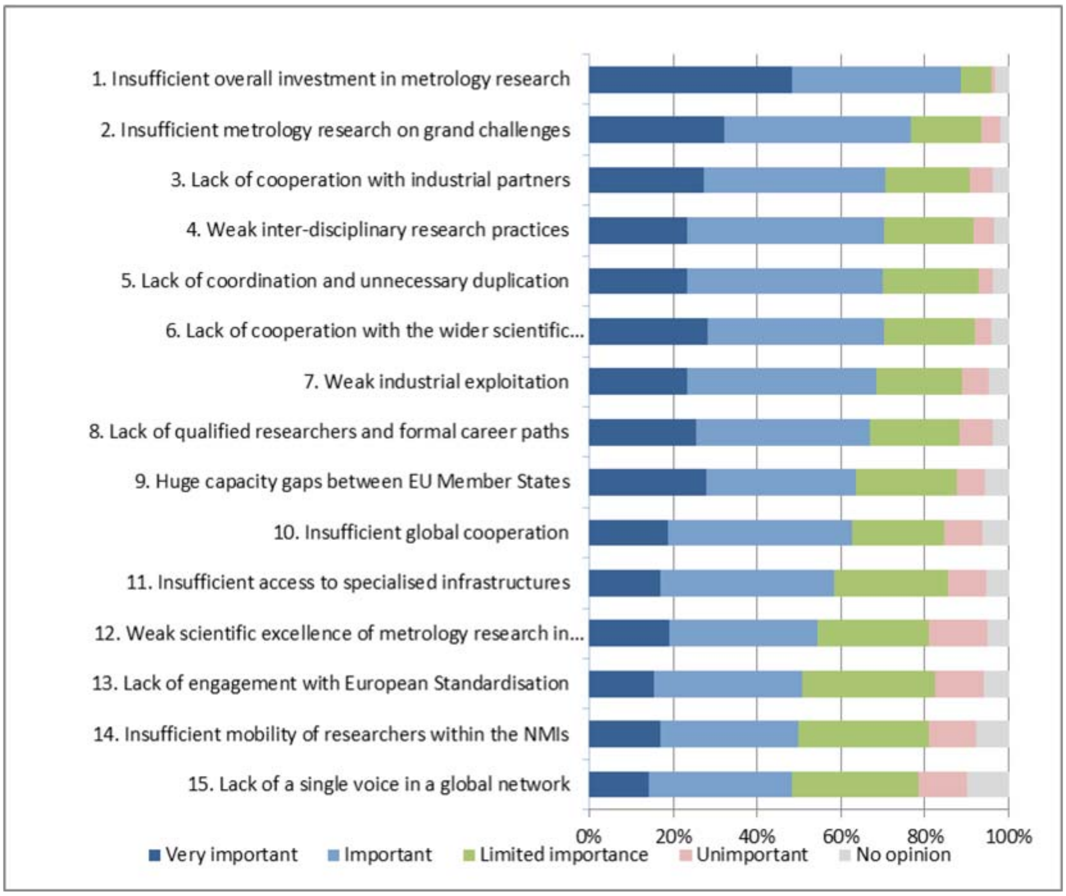


Figure 6: Problem statements for the European metrology research system in order of importance

The view on the importance of the problems showed some significant differences[30] across the different types of respondents. Compared to the researchers, **industry** attaches significantly more importance to the following problems:

- Weak industrial exploitation (+20%)
- Lack of engagement with standardisation (+17%)
- Insufficient access to specialised infrastructure (+15%)

Those **countries with small metrology research contributions to EMRP**, compared to the five biggest contributors (France, Germany, Italy, Spain, UK) attach significantly more importance to the following problems:

- Huge capacity gaps between EU Member States (+21%)
- Lack of cooperation of NMIs with the wider scientific community (+17%)
- Insufficient mobility of researchers within the National Metrology Institutes (+16%)
- Lack of engagement with European Standardisation (+13%)
- Lack of a single voice in a global network (+12%)

[30] Based on the difference (minimum 10%) in responses for very important or important

- Insufficient global cooperation with leading metrology research programmes (+12%)
- Insufficient metrology research oriented towards grand challenges (+11%)
- Weak scientific excellence of metrology research in Europe (+11%)
- Lack of qualified researchers and formal career paths (+11%)
- Weak inter-disciplinary research practices (+10%)
- Weak industrial exploitation (+10%)
- Insufficient access to specialised infrastructure (+10%)

EU12 countries, compared to EU15, attach significantly more importance to the following problems:

- Huge capacity gaps between EU Member States (+22%)
- Lack of qualified researchers and formal career paths (+21%)
- Insufficient mobility of researchers within the National Metrology Institutes (+22%)
- Insufficient access to specialised infrastructures (+20%)
- Insufficient global cooperation with leading metrology research programmes (+13%)
- Weak scientific excellence of metrology research in Europe (+12%)
- Lack of cooperation of NMIs with the wider scientific community (especially beyond physical sciences) (+10%)

3.3 Objectives for the future European Metrology Research

The survey invited the participants to provide their view on the relevance of possible objectives for a future European metrology research system. All the proposed objectives were considered relevant (minimum of 73% consider as very relevant or relevant), with the strongest support (>85%) for the following:

- Support innovation and industrial competitiveness through metrology research activities (94%)
- Support strategic metrology research projects to address basic metrology (93%)
- Support metrology related to the three Grand Challenges - Energy, Environment and Health (93%)
- Establish structured interaction of NMIs with science community to support further modernisation of the overall European metrology system in all concerned EU (86%)

The view on the relevance of objectives showed significant differences between the two country comparisons (small versus large contributors, EU12 versus EU15) for the objective "Support capacity building in MS and link where appropriate to the use of structural funds" (+13%, +14%).

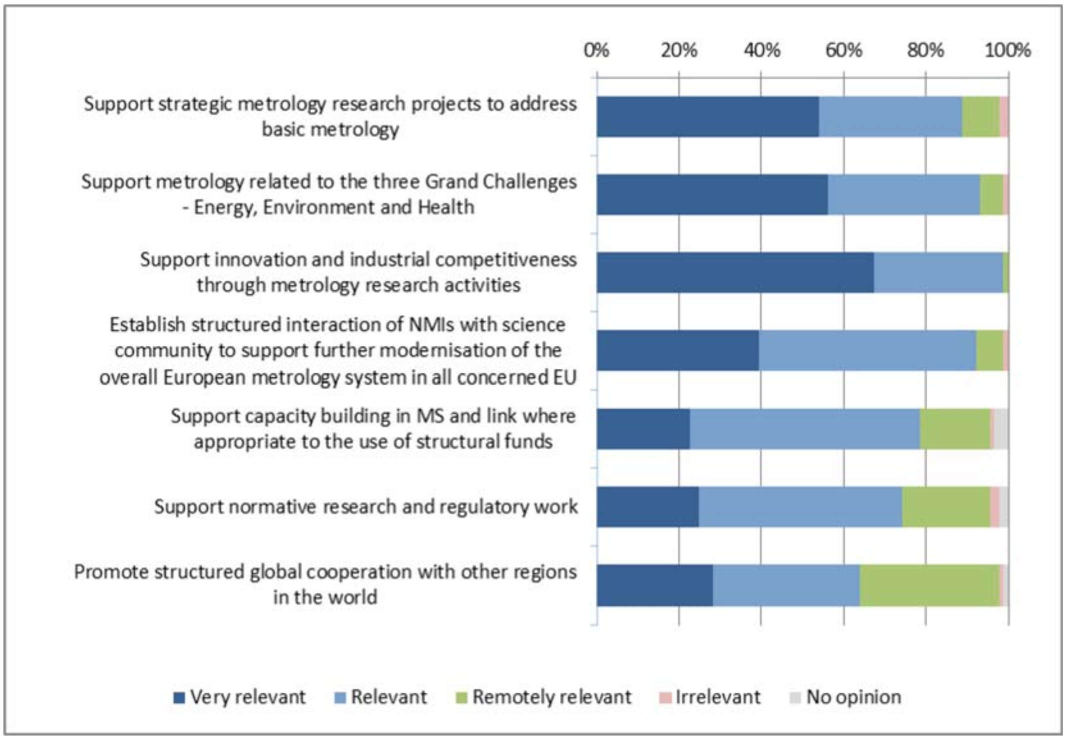


Figure 7: Relevance of possible objectives for the European metrology research system

The view on the relevance of objectives showed significant differences between the two country comparisons (small versus large contributors, EU12 versus EU15) for two objectives "Establish structured interaction of NMIs with science community to support further modernisation of the overall European metrology system in all concerned EU" (+12%) and "Support capacity building in MS and link where appropriate to the use of structural funds" (+12%).

3.4 Policy options

The survey was closed with a question that allowed participants to rate the appropriateness of the different policy options proposed:

- **Policy Option 1: "No EU financing action"**
  Discontinue the EU participation and financial contribution to this initiative after the end of its current funding phase in 2013. Furthermore, no provision would be made in EU research policies, programmes or funding to support EMRP objectives, either in terms of financing or coordination support.
- **Policy Option 2: "Business-as-usual"**
  Same type of Art. 185 programme like EMRP. A new EU decision continuing the EU participation and financial contribution to a successor programme would be adopted based on the same terms as for the current EMRP programme with article 185 of the Treaty on the Functioning of the European Union (TFEU). In this respect, EMRP would remain focused on basic and challenge oriented metrology research.

- **Policy Option 3: "New reinforced Article 185 initiative under Horizon 2020"**
  A new EU decision continuing the EU participation and financial contribution to a reinforced and broadened successor programme of the EMRP to be adopted on the same legal basis, namely Article 185 TFEU. The new programme would intend to fully exploit the EU potential in metrology in order to assure the optimal answers to societal challenges. It would support capacity building much stronger, establish closer links to standardisation and regulation and serve industrial need by addressing innovation and exploitation of research project results.
- **Policy Option 4: "JRC – direct action"**
  A single European research programme to be implemented via the Joint Research Centre of the European Commission (JRC) would be set up to cover all metrology needs at European level. This programme would be a fully institutional programme at the level of the Commission services being fully independent from the existing national metrology systems and capacities.

The results are summarised in figure 8. Responses demonstrate a clear preference for the policy option 3 with a new, reinforced Art.185 initiative under Horizon 2020 (92% very suitable or appropriate). The business-as-usual option is still considered fairly appropriate (69% very suitable or appropriate). For the remaining two options the views are negative: 89% consider option 1 is inappropriate or should be avoided, and 57% conclude the same for option 4 (JRC direct action).

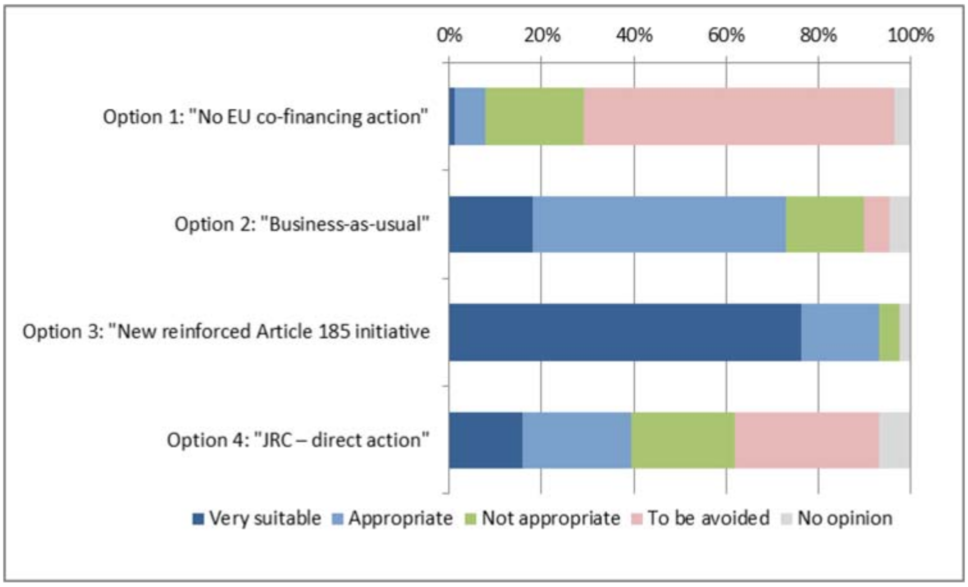


Figure 8: Rating of the proposed policy options

Annex V: Examples of EMRP projects and expected results

Environment

Tackling accidental impact of catalytic convertors - Once thought to be harmless, platinum and mercury elements used in catalytic convertors of cars are now subject of concern for their total amounts released into the environment. Expertise in measuring small particle pollutants will allow to set the appropriate regulatory targets.

What is the impact of solar ultraviolet light? - The measurement of effects of solar ultraviolet light (UV) on the environment through its role in generating substances in the earth´s atmosphere is currently too uncertain for detecting changes of modelling future trends. The project works on a considerable reduction of the uncertainty and a fast dissemination of its results for more reliable UV measurements.

What´s the effect of ocean circulation patterns? - Scientists need to understand water properties such as salinity because they influence ocean circulation patterns, which affect the Earth's climate. Salinity measurements, inferred from the conductivity of water, are currently not traceable to SI units which means that long-term measurement are not necessarily stable. This research allows measurements of salinity to be traced back to SI units, thereby improving confidence in salinity measurements.

Improved data accuracy for better atmospheric models - Some data of atmospheric substances measured with spectro-analytical techniques are not traceable to SI units, which leads to high levels of uncertainty in atmospheric models. The research develops a European spectroscopy infrastructure that is traceable to SI units and a database of the spectral line data for improved atmospheric modelling.

Better climate models through better measurements - Measurements of pressure, temperature, humidity and airspeed are key to understanding the climate of the Earth – but current measurement techniques lack sufficient accuracy, e.g. for determining the (low but important) levels of water vapour in the stratosphere. This project aims to improve climate models by improving these measurements.

Measurement standards for critical water pollutants - Reference standards for some of the most important water pollutants, e.g. tributyltin (TBT), polybrominated diphenylether (PBDE) and polycyclic aromatic hydrocarbons (PAH) will be developed as to understand how these pollutants interact with each other and with other chemicals. This project delivers to the European Water Framework Directive (WFD).

Disposing nuclear waste safely - For a safe and cost effective disposal of nuclear waste, it is necessary to accurately measure the radioactivity of the materials involved. With novel methods, standards, decay data, reference materials and instruments for improved radioactive waste, the project supports to the successful decommissioning of nuclear power plants.

Health

Increase access to Magnetic Resonance Imaging - Approximately 10 % of the population with medical implants are excluded from MRI because of the inability to properly quantify the risk for these patients. The project will improve risk assessments for MRI scans and also remove any unnecessary safety margins due to insufficient knowledge, leading to improved diagnoses and shorter scan times.

Improving treatment by knowing the flow rate of drug delivery - Besides the amount of a drug, its flow rate, i.e. how fast a quantity of drug is delivered, is also vital for safe and efficient health care treatment. This project develops knowledge for low flow rates and multi-pump infusions, thus making drug delivery more reliable.

Supporting a faster detection of infectious disease - An accurate and rapid diagnosis of infectious diseases is vital to protect public health, as they account for 20% of human deaths on global scale. By assessing quality, comparability and traceability, the project supports building up a superior – as faster – measurement infrastructure (sequence analysis) as compared to conventional microbiological methods.

Protect human hearing - New technologies and industrial processes emit infrasound (low frequency) or airborne ultrasound (high frequency) with no clear understanding on their hazardous level for human hearing. The project investigates human perception of non-audible sound and develops new ear simulators for calibration of equipment such as headphones.

Just the right dose for ultrasound treatment - The lack of techniques to standardise the dosage of ultrasound results into non-ability to calculate the right personalised amount for a particular therapy with a risk of over- or under treatment causing harm to the patient. By establishing reference standards, the project supports the increase of promising ultrasound treatments for cancer, stroke and bone repair.

Energy

Making power plants more efficient - The project will reduce the measurement uncertainty of the important control parameters (temperature, flow, thermal energy and electrical output) of power plants. The research will allow for an overall additional enhancement of energy efficiency of 2-3 % for all types of large power plants, resulting in a comparable amount of reduction of emissions.

Fuels for the future - To support market take-up of biofuels, they need to be able to mix with traditional fuels and form blends that can be used without affecting vehicle engine performance, reliability or safety. The project delivers accurate measurements results, and a greater understanding of biofuel properties, to improve public confidence in low-carbon fuels.

Allow biogases to complement natural gases - Natural gas resources in the EU are declining and the public gas networks need to include alternative energy gases, such as biogas. The project develops the measurement infrastructure to characterise the new type of gases for their 100% fit with existing equipment. Measurements include gas composition, calorific value (energy content) and humidity, which are all needed to ensure efficient trade, safe use and transportation.

Make the best power transmission possible - To transport energy from their place of generation, for many renewables quite distant from the place of consumption, High-Voltage Direct Current

(HVDC) is the preferred option as it provides low energy losses, enhanced grid stability and the economically viable transmission of electricity. The project works on reliable measurements for operational and billing purposes, quality monitoring and the determination of losses.

Enabling fair trading of natural gas - For countries outside the reach of a gas pipeline, natural gas is best liquefied for transport in tankers and regasified at its destination. Too high measurement uncertainties for values of volume, density and calorific value cannot guarantee a fair trade – and this project aims to reduce the uncertainty to half its present value.

Replacing toxic batteries by energy harvesting - Every year, only the EU market for batteries is about 800,000 tons of automotive batteries, 190,000 tons of industrial batteries and 160,000 tons of consumer batteries. The project develops the metrological framework, technical capability, and scientific knowledge to enable the development of effective and commercially successful energy harvesting technologies incl. new technologies of micro and nanogenerators for their use in portable electronics and mobile communication devices.

Industry

Enabling more efficient high temperature industrial applications: Temperature measurements above 1000 °C are difficult to make but necessary for many industries such as aerospace and steel production. As industries cannot accurately measure these high temperatures, they often run processes too hot and therefore operate inefficiently. By developing a range of measurement methods, accurate at high temperatures, this project will enable more efficient operation of industrial processes, reduced energy use and lower greenhouse gas emissions.

Measuring high-speed electronics: To cope with the increasingly high operational speeds of modern electronic equipment, new measurement techniques are required to assess the electromagnetic materials used in the fastest applications – at microwave frequencies up to 80 GHz. The improved techniques produced by this project will support innovation in the European electronics industry by enabling reliable measurements at nano, micro and macro scales and less resource-intensive production processes.

Improving high pressure measurements: Advanced high-pressure technologies are frequently used in the petrochemical, pharmaceutical and car industries. In the car industry the application of high, continuously increasing, pressures plays a vital role in the manufacturing of direct injection fuel systems, which have improved petrol and diesel engine performance. The pressures used in some modern systems are higher than the current European calibration capability, which is limited to around 1 GPa (gigapascal). This project aims to develop new standards to extend this capability to 1.6 GPa and to support the continuing use of high pressure technologies.

Improving data security with quantum technology: An ever-increasing amount of sensitive information such as bank details is stored, transferred and accessed over computer networks. Quantum communication technologies such as Quantum Key Distribution (QKD) can improve the security of this data. Their unique feature is that, when implemented correctly, the system guarantees that the encryption key has not been intercepted. It works by transmitting information in a photon in a particular ‘quantum state’ and then detecting if an intruder has disturbed that state. In theory it is extremely effective but there are no agreed methods to demonstrate that practical implementations are robust. This project will develop new measurement techniques to validate the practical use of QKD.

Measuring optical curved surfaces: Measurement of the full 3D form of optical curved surfaces is important for characterising surfaces used in the optics and precision engineering industries as well as in astronomy and science. Currently, two types of measurements are used; imaging or single point scanning – both of which have advantages and disadvantages that limit manufacturing capability. This project will create standards and perform comparisons so that reliable characterisation of a full 3D free-form surface is possible. Once characterised, advanced optical surfaces can be used to calibrate instruments used in precision engineering and scientific projects such as the European X-ray Free Electron Laser (XFEL), which aims to map the atomic structure of viruses and view them at the nanoscale in 3D.

Making measurements of engineered surfaces: An estimated loss of 2 % of GDP in developed countries is attributed to losses caused by friction and wear. Therefore, advances in surface engineering, such as low friction coatings on machine components will improve industrial efficiency and the sustainability of transport, power production and manufacturing. This project will develop advanced measurements from the macroscale to the nanoscale for the assessment of engineered surfaces. This will lead to an improvement of surface engineering, for example reducing downtime and waste in aluminium forging or increasing the lifetime of mining components used to drill for oil. There could also be health benefits, as high durability coatings can eliminate the health risks posed by contamination of food products during processing.

Strengthening industrial vacuums: Historically, vacuum has been an important tool in industry and has been used in many applications, ranging from protecting light filaments from chemical degradation to controlling the flow of current in electronics. The use of vacuum is still important today, in modern lighting, the semiconductor industry and fusion power research. However, vacuum is poorly understood when used outside the laboratory, as traditional measurements are unsuitable and based on the pressures of pure gases in stable conditions. This project will improve vacuum measurements in conditions representative of those found in industry. The improved measurements will lead to a more efficient use of vacuum and better end products.

Understanding chemical reactions at surfaces: Accurate chemical measurements at surfaces are vital for all areas of engineering and industry that rely on surface analysis. This includes microelectronics, the development of corrosion resistant materials in aerospace, the assessment of the toxicity of medical implants and the design of industrial catalysts. The properties of a surface and of the bulk material can be markedly different, with bonding, wettability, cell adhesion and reactivity all radically affected by surface chemistry. This project will provide reference materials and develop methods for the highest priority industrial applications leading to cost and time improvements for many industrial processes across Europe.

Participation of High-tech SMEs

The EMRP programme has already seen a number high-tech SMEs as unfunded research partners. Being fully obliged to all project activities, incl. reporting, the participation is an expression of the high beneficiary expectation of the companies, among them:

- **IDQ** provides innovative and cost-effective solutions that leverage the tremendous capabilities offered by quantum photonics, associated with cutting edge analogue and digital electronics. Founded as a university spin-off in 2001 in Switzerland, the company operates in the fields of network encryption, scientific instrumentation and random number generators with its products being used by customers in more than 60 countries and on every continent.
- Since 1993, the Dutch **IBS Precision Engineering** is a high-tech and innovate company offering a variety of products and services in the area of precision engineering, metrology and high-end mechatronic applications.

- **INFICON**, with its headquarters in Switzerland, is a provider of innovative instrumentation, critical sensor technologies, and advanced process control software that enhance productivity and quality in sophisticated industrial vacuum processes.
- **ION-TOF GmbH** from Germany with more than 55 employees working in Münster and New York offers innovative ion beam technology for surface analysis with different product lines in Time-of-Flight secondary ion mass spectrometry (TOF-SIMS) and low energy ion scattering (LEIS).
- The Dutch company **Kipp & Zonen** provides class-leading instruments for measuring solar radiation and atmospheric properties in Meteorology, Climatology, Hydrology, Industry, Renewable Energy, Agriculture and Public Health.
- Italian **LAZZERO** Tecnologie, founded in 1990, is engaged in the production of the industrial leaktesting units using helium and mass spectrometers. Extensions in 2009 saw a doubling of the production premises to accommodate a large, modern assembly area, a fully equipped workshop, and a modern metrological laboratory for dimensional measurement.
- The German **SCIENION AG´s** product range enables customers to facilitating and improving multiparallel bioanalytics, high throughput screening and high throughput production of microarrays in the genomics and proteomics fields – from early research to manufacturing.
- Founded in 2004, the Dutch company **Xpress Precision Engineering** is a supplier of ultra precision 3D measurement systems for dimensional metrology. With about 60% of staff working in R&D, the main research focus is on improving the measurement uncertainty of our probing systems and facilitating measurements on ever decreasing feature sizes

Annex VI: Metrology landscape in Europe

In October 2012, EURAMET, the European Association of National Metrology Institutes e.V., conducted a survey among its members, i.e. National Metrology Institutes and Designated Institutes, asking for actual data (2011) in relation to

- Scientific Contributions
- Standardisation Activities
- Services (mostly to Industry) and
- International Liaisons

86 NMI and DI from 32 of the 37 EURAMET countries responded to the survey. Before the results are presented in the following, a first chapter describes the membership within EURAMET. The metrology landscape in Europe is very diverse in many respects. 16 of the 37 EURAMET members have a single metrology institute in place, while two countries, France and Slovenia, have each 10 institutes performing official metrological tasks on highest national level. As per August 2012, EURAMET members comprise 108 institutions in total, 37 National Metrology Institutes send formal representatives to the General Assembly, 71 Designated Institutes have an associate member status. The following table indicate the number of institutes per country:

Country	No. of NMI/DI
France	10
Slovenia	10
Denmark	7
Spain	7
Croatia	6
Finland	6
Czech Republic	5
Germany	4
Lithuania	4
Norway	4
Switzerland	4
UK	4
Austria	3
Greece	3
Poland	3
Estonia	2
Italy	2
Portugal	2
Romania	2
Sweden	2
Turkey	2
Albania	1
Belgium	1
Bosnia-Herzegovina	1
Bulgaria	1
Cyprus	1
FYR Macedonia	1
Hungary	1
Iceland	1
Ireland	1
Latvia	1
Luxembourg	1
Malta	1
Montenegro	1
Netherlands	1
Serbia	1
Slovakia	1
SUM	**108**

In addition, the European Commission´s Joint Research Centre Institute for Reference Materials and Measurements (JRC-IRMM) is an associated member of EURAMET.

The individual NMIs/DIs differ quite substantially. Staffs range from just 2 employees (for 3 DIs) to 1925 for the German PTB which is – not only due to its size – an outstanding institution in Europe. In total, more than 6700 persons work in the responding EURAMET organisations. It is likely that this number would go beyond 7000 if all European metrology institutes would have responded. Consolidated figures on national scale, i.e. staff of all NMI and DI in a single country summed up, reveal the following top ten list in terms of staff employed in European metrology institutes:

Country	**Institutions comprised**	**No. of staff**
Germany	PTB, BAM and UBA	2185
UK	NPL, NMO	706
Turkey	UME and 2 DIs	486
Czech Republic	CMI and 4 DIs	395
Italy	INRIM, ENEA	360
Poland	GUM, POLATOM	353
France	LNE and all 9 DIs	340
Spain	CEM and 6 DIs	192
Switzerland	METAS and IRA	166
Slovakia	SMU	140

While a number of EURAMET DIs are quite large in terms of employees, with the host organisation typically being a public research institution, the figures indicated here consider only the personnel that is concerned with metrological activities[31]. The average staffs for all NMI/DI is 114, the median is 22 and the mode is just 4.

Scientific contributions

For 2011, the responding metrology institutions reported more than 2700 **scientific publications**, thereof more than 1000 in refereed journals. It is only that 12 institutions of the 86 respondents have not published any scientific contribution in 2011, while this number increases to 27 for contributions in refereed journals. Four countries (Germany, UK, France and Italy) contribute 80 % to all refereed scientific publications.

More than 2400 **presentations** were given **at scientific conferences.** While it is not possible to judge the quality of the conferences, some presentations were awarded with best paper prices (e.g. for Danish DFM). It is again the NMIs/DIs from 4 countries (Germany, UK, France and Italy) that deliver 75% of all presentations. At the other end, 14 institutions did not give any presentation.

[31] E.g. German BAM has 1750 staff, but only about 250 (counted here) are concerned with metrological tasks.

As for presentations in relation to staff members, Portugal leads this ranking with one presentation for each staff member, followed by Croatia, France, The Netherlands, Italy, Finland and Slovenia. While being cautious in general in interpreting the figures it is probably fair to say that NMI and DI are quite active in "spreading the word" on metrology.

Having asked for qualitative examples for outstanding scientific contributions, individual NMI/DI answers demonstrate a **pro-active role in education**: In France, 52 PhDs were coached in its 10 national NMI/DI institutions in 2011. The small Portuguese DI (IST/ITN with 3 staff) supervised 4 Master theses. UK´s NPL counted 20 visiting professors and Germany´s BAM is engaged in the "Analytic City Adlershof", a Berlin based competence centre bundling university, non-university and industrial expertise available at the Adlershof site that focuses on questions and problems related to analytical chemistry.

NMI and DI are no stand-alone entities but network within their countries and internationally (see also last chapter of this document). They have **formal agreements for research cooperation** (MoU or similar) on national as well as international level, with both figures just exceeding 400 agreements, i.e. with an average of almost 7 per responding NMI/DI. 10 NMI/DI responded of not having such agreements on the national, 24 on the international level. Some NMI/DI report remarkable numbers, though, as e.g. the Czech institute that pursues active scientific cooperation in field of metrology within the framework of intergovernmental industrial and scientific groups with 17 non-European countries, especially with the Russian Federation.

Standardisation activities

NMI and DI contribute substantially to **standardisation working groups**. The responding institutions reported on more than 1850 involvements in standardisation working groups, thereof 956 on the national, 321 on the European and no less than 584 on the international level. These engagements are secured by 1063 staff members.

Activities comprise the implementation or harmonisation of international standards as or with national standards, to refine or revise regulations for legally controlled measuring instruments, and purposefully improve standardisation per se. Also, single NMI translated official documents into their language thus supporting the national standardisation.

Services, mostly to industry

One of the most important activities is the provision of services to industry.

The **number of calibrations**, i.e. comparisons of measurement instrumentation with a national measurement standard hold in an NMI or DI, reached more than 165000 conducted in 2011. This activity has also led to substantial revenues for the NMI/DI of more than 66 Mio. €[32]. All NMI/DI perform calibrations, although the number varies quite considerably: The minimum number was 3 (for a small Finnish DI), the maximum 39630 (for the Czech NMI). The overall annual person-effort for performing calibrations is about 1/6 of total staff´s capacity.

These differences must be seen against different national strategies regarding the role of the NMI. Most NMI/DI act under a subsidiarity principle, i.e. they provide calibrations for (mostly private) secondary-level calibration laboratories and provide service directly to industry only if those laboratories are not available. The secondary-level laboratories then do

32 National currencies were calculated into € by using an exchange rate of Oct. 2012. The figure is deemed to provide a rough orientation only.

the routine calibrations for industry and thus are multipliers the calibrations of NMI/DI. This "pyramid of calibration levels" ensures that an enormous number of measurement devices in industry (many 100 millions) are traceable to the internationally harmonized SI units via factory standards, secondary laboratories and finally NMI/DI.

At the same time, **income generation** from industry related services is perceived differently. While most NMI/DI can keep their income, few others are not allowed so as to not create any incentive of disturbing market based activities.

Calibrations numbers are even topped by the **number of conformity assessments**, with the Czech NMI performing 80% of the total of 230000 assessments. Remarkably, over 30 institutes do not perform conformity assessments at all while the overall staff capacity for this activity is still about 6% across all responding institutes.

About 600 staff members, (~9% of all staff) are involved in **accreditations of other laboratories**, with 85 being active on European and 53 on international level.

330 **agreements with industry** were reported to have happened in 2011, with the German PTB and UK´s NPL accounting for one third of all cases. Agreements comprise research and development projects, i.e. solving a concrete problem at the site of a company, licensing agreements and cases of technology transfer. This kind of endeavour is followed by ¾ of the responding NMI/DI with interesting examples, e.g. that the Hungarian NMI pursues a continuous technology transfer in the field of verification of the measuring instruments (radiation physics) for the national Nuclear Power Plant that accounts for 40% of national energy production.

Other important activities related to industry are conduction of technology conferences, stands at industry conferences, other knowledge transfer activities or PR activities (e.g. regular newsletters) related to industry clients etc. However, EURAMET members differ quite substantially in their attitudes and invested capacities in these activities.

International liaisons

The final section of the survey covered the degree of international, i.e. beyond Europe, liaisons of the NMI and DI. The reported figure of 108 concluded MoUs or similar agreements reveal a high degree of international networking – while 38 respondents, among these 16 NMI, do not cooperate on this level (but of course within EURAMET on the European level).

About 5% of NMI/DI staff (about 320 persons), a vast majority from the NMIs, are involved in Consultive Committees (CCs) of the Metre Convention (Comité international des poids et measures, CIPM). To become a member of a CC, the national laboratory must be active in research, have a record of publications in journals of international repute and also have demonstrated competence for participations in international comparisons. The CC bring together the world's experts in their specified fields as advisers on scientific and technical matters. Among other activities, CC reflect on advances in physics that directly influence metrology and prepare recommendations for discussion at the CIPM. [33]

In addition to these international engagements, several NMI/DI are actively engaged in technical cooperation projects with the aim of helping Developing Countries to establish a national and regional metrology infrastructure that serves their economic and social development. A separate survey from 2009 showed that 10 EURAMET members were involved in 136 projects since 2004.

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[33] See http://www.bipm.org/en/committees/cc/cc_criteria.html for further details