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Metrology for a stronger Europe

A European Metrology Agenda for the next decade

Summary

This paper outlines the EURAMET vision of a European Metrology Agenda for the decade 2030 to 2040. It calls for a coordinated European metrology response building on the needs arising from the transition of the energy supply, protection of the environment, a strong, sovereign, and competitive European industry, digital transformation, circular economy, developments of the health system, and resilience of European infrastructures.

In a greatly changed world, Europe is facing challenges that will create needs for metrology capabilities in the next decade: climate change necessitates the transition to carbon neutrality while simultaneously the war in Ukraine is straining European energy resources with long-term impacts. Europe needs an industrial green and digital transition, a resilient and sovereign industry, competitive industrial innovation, robust supply chains, global cooperation, and open trade. The health area is facing challenges arising from the aging society and rapid technological (digital) developments.

Metrology is an enabler of these ambitions. In addition, it is important for societal cohesion that European citizens widely trust measurements leading to political decisions, potentially affecting their lives or economies. The metrology capabilities responding to all these challenges cannot come from the third countries, they must be developed in Europe.

1. Background

The core mission of the National Metrology Institutes (NMI) and Designated Institutes (DI) is to provide national systems for measurement science and measurement standards. They provide metrology-related services for industry and stakeholders including traceability of measurement results to the international system of units (SI) under the Metre Convention and conformity assessments in regulated areas. Metrology, standardisation, accreditation, and conformity assessment together form the Quality Infrastructure that is fundamental for stakeholders from industry, society, and academia. EURAMET e. V., the European Association of National Metrology Institutes with 120 NMIs and DIs from 39 countries, is the key organisation for international cooperation under the Metre Convention and the European Quality infrastructure.

Metrology at the level of National Metrology Institutes combines the highest-level R&D and technology with a public service mission. Comprehensive research and development – in collaboration with each other and with other research and technology organisations, universities, and industry – keeps the measurement capabilities of the NMIs and DIs at the scientific-technical forefront and ensures alignment with stakeholder demands.

The National Metrology Institutes provide the infrastructure, technologies, and methods for “metrology-grade” (reliable, accurate, traceable, highest-level) measurements, which are key for industrial production, quality control, innovations, and compliance to regulation. Member States have a permanent mission to develop their metrological capabilities and solutions in response to the needs of their stakeholders. Metrology institutes cooperating within EURAMET, including widening countries, have strongly benefitted from the joint research¹ conducted in the framework of the current European Partnership on Metrology and its predecessors. However, the anticipated challenges in these key areas will have a dimension and complexity that requires a coherent European agenda for metrology in the next decade.

The current and previous research programmes have had and continue to have a strong impact on the national metrology infrastructure developments in Europe. Research supported by the EU has created scientific excellence and has brought European metrology research into an internationally leading position in the spearhead fields. In addition, research programmes have leveraged national investments; it is estimated that about half of the national investments in the capabilities of metrology infrastructures are triggered or influenced by the joint projects and the joint Strategic Research Agendas of the European Metrology Networks and Committees.

As a horizontal discipline, metrology is key in supporting stakeholder communities. The European Metrology Networks, established as permanent entities under EURAMET and temporarily supported by the Metrology Programmes, have proven to be an effective tool to interact and deliver research impacts to a broad range of stakeholder communities, including other European partnerships and initiatives. Figure 1 schematically shows the liaisons already established by the European Metrology Networks with other European partnerships and initiatives.

The benefit of metrology to European citizens is most obvious in regulated areas, where many EURAMET Technical Committees and European Metrology networks are active. In regulated areas, citizens rely on and trust in the conformity of regulated products or processes, e.g.,

¹ “Involvement and use of European Metrology Programme for Innovation and Research EMPIR in the Czech Metrology Institute – a positive example of the use of European Cooperation,” J. Tesar et al., *Ukrainian Metrology Journal* vol 2, pp. 33-39 (2023).

when paying for fuel or being exposed to hazardous radiation or chemicals. The benefit of Metrology for European industry is most obvious in quality control or innovative high-tech products. The European Metrology Networks have added a proven way to interact with industry and societal stakeholders on a European level, in addition to the traditionally mostly national interactions of the metrology institutes.

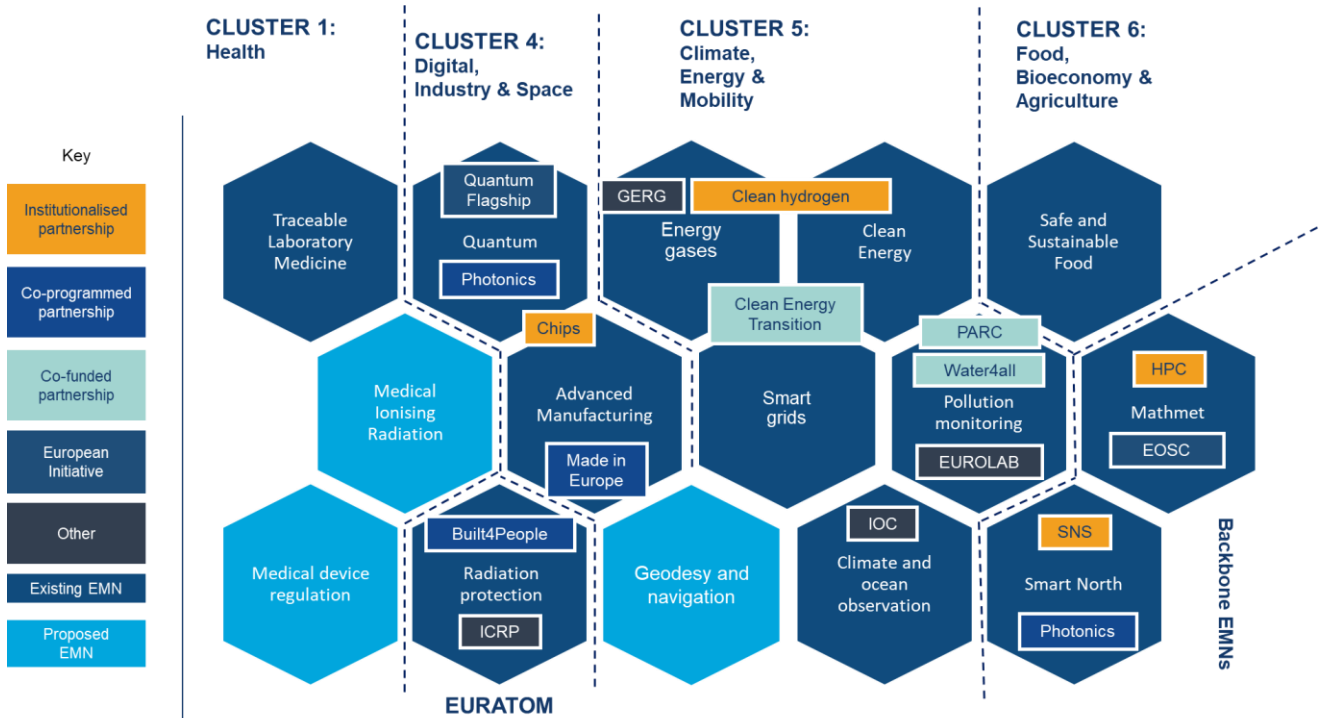


Figure 1. European Metrology Networks, Horizon Europe Clusters, and liaisons with other European Partnerships and Initiatives.

Previous metrology research programmes have been essential in structuring the community and have enabled National Metrology Institutes and Designated Institutes to enter new fields that would not have been possible without the EU co-funding. The European Metrology Research Programme (EMRP) brought consensus on a Strategic Research Agenda on European Metrology and developed a common understanding of project management principles. The European Metrology Programme for Innovation and Research (EMPIR) allowed the metrology community to reach out to a wider stakeholder community, enabling greater external participation from industry and academia, and capacity building in the widening countries. The current Partnership on Metrology builds on the previous programmes, but has further emphasis on regulation, policy making, standardisation, and outreach to European Partnerships and other European and international stakeholder communities through the European Metrology Networks.

An important new dimension in the Metrology Partnership is the Steering Group, advising the Metrology Partnership on work programme priorities through identification of emerging technologies, innovations, markets, and industrial applications where metrology research and innovation is relevant. Further, the Steering Group has proven effective in identifying research areas contributing to the EU’s goal of achieving climate neutrality, including to relevant

regulations and standards. The Steering Group has also proven an effective tool to crossbreed research ideas between Metrology Networks and other partnerships.

EURAMET has established a Research Council to provide strategic advice and an independent opinion on the future needs for metrology in Europe. The Research Council is a EURAMET advisory board composed of institutional and personal members of high standing, drawn from the external stakeholder community of EURAMET. Council members represent industry, research, and academia, and they are appointed for their experience and expertise. The response of the European metrology community to the challenges of the decade 2030 – 2040 will build on the achievements of the previous programmes and recommendations of the Research Council

2. European dimension in metrology

Metrology underpins almost all aspects of economic and societal infrastructure. EURAMET has identified four key areas that will generate needs for a comprehensive, strategic, and coordinated metrology agenda for Europe in the decade 2030 to 2040:

- 1) Green Deal
- 2) Competitive and resilient industry
- 3) Health
- 4) Cohesion and infrastructure.

The European Metrology Agenda described below is aligned with the broader European agenda and addresses European countries' needs in the four identified key areas. This agenda includes capacity building actions to help European countries to meet their national needs and coordinated investment in hard infrastructures to increase cohesion across Europe. A major objective of the agenda is to support the competitiveness of European industrial ecosystems through metrology. This agenda also calls for the metrology community to work together with other partners of the European Quality Infrastructure in standardisation, regulation, legal metrology, and conformity assessment.

Globally, other regions are investing significant amounts in their metrology systems to meet the needs arising from global challenges and to support their industry. In Europe, a similar level of investment can only be reached through coherent joint European action.

In the United States, the National Institute of Standards and Technology (NIST) budget linked to NMI activities, from provision of measurement services to advanced research, is roughly \$400M per year. This figure does not include NIST's Information Technology Laboratory that has significant activities in research and standards related to other emerging technologies such as artificial intelligence, cybersecurity, and privacy. Additionally, the United States Chips Act allocates up to \$700M over five years to address the metrology needs of the semiconductor industry alone.

In China, the National Institute of Metrology (NIM) budget in 2023 is roughly \$180M, out of which direct government funding is \$100M. The level of government funding is expected to remain stable for 2024. China has a distributed metrology system with municipal metrology institutes that are funded through the local governments. Their combined government funding is estimated to be comparable to the funding NIM receives.

In Japan the National Metrology Institute of Japan (NMIJ) budget is \$50M per year. In addition, NMIJ has proposed a national Research Development program to vitalise the national economy and industry, contribute to the net zero emissions policy, and prevent pandemics.

In contrast to these countries, Europe has a complex structure. The success of EURAMET lies in their role to pool and coordinate capabilities, and support capacity building to improve coherence in Europe. European NMIs and DIs are committed to continue their close cooperation.

In view of the above-described international benchmark, it will key to keep the scientific-technical capabilities of the European metrology community at the forefront of measurement science. Any response to the challenges of the next decade must be underpinned by opportunities for fundamental measurement research.

2.1 Green Deal

Need

The European Green Deal, including green transformation of the energy infrastructure, tackling climate change and loss of biodiversity, and mitigating its effects, will be of highest priority for Europe in the coming decades². These challenges call for new measurement technologies and improved reference standards underpinning green industrial innovation and the development and implementation of technologies and products with smaller life cycle footprints, especially in the areas of energy production and energy-intensive industrial processes. These will require control through associated regulation. Tackling climate change and preserving the environment will call for more difficult and complex measurement capabilities such as for pollutants, climate and ocean variables and comprehensive, systemic views on them. Furthermore, measurement and understanding of the global and regional effects of actions against climate change will have huge impact as societies spend huge amounts on mitigation.

The Green Deal Industrial Plan calls for global cooperation and open trade for the green transition, under the principles of fair competition. Metrology is a key enabler for open trade and a way to reduce technical barriers to trade through the Mutual Recognition Arrangement. Europe must be active in developing the necessary metrology solutions to enable Free Trade Agreements and other forms of cooperation with the EU's partners to support the green transition.

The Net-Zero Industry Act of the Green Deal Industrial Plan aims to identify goals for net-zero industrial capacity and provide a regulatory framework where the role of measurement is evident. Linked to the Green Deal, the REPowerEU plan addresses the need to end the Europe's dependence on gas, oil and coal, while accelerating the energy transition and strengthening the security of supply and storage of energy. The main actions in the REPowerEU package include energy saving, diversification of supplies, substitution of fossil fuels, and investments and reforms. The regulatory measures of the

² https://commission.europa.eu/system/files/2020-11/rtd_sp_2020_2024_en.pdf

REPowerEU³ will include regulatory measures to increase energy efficiency and a regulatory framework for hydrogen, both requiring new measurement solutions.

The EU's biodiversity strategy for 2030, which is a long-term plan to protect nature and reverse the degradation of ecosystems, and the Farm to Fork Strategy, aiming at making food systems fair, healthy and environment-friendly, will also reach into the next decade. These challenges will require a strong and new chemical metrology capabilities.

Metrology response

Objectives include:

- Enable the green energy transition through improvements in measurement for production of electricity, heat, and carbon neutral gases and fuels including CO₂ derived products.
- Measurement solutions for energy transport, storage, metering, and efficient use in increasingly diverse, coupled, and complex energy systems with significant micro-generation and new requirements on grid stability and security.
- Support the regulatory frameworks of the European Green Deal and the REPowerEU plan where measurement data is relevant.
- Develop improved measurement solutions for climate and ocean variables.
- Support evidence-based policy making to mitigate the effects of climate change, ensuring quality of data used in policy making and assessment of the effectiveness of policy actions on regional and global levels.
- Develop measurement capabilities for fresh air, clean water, and healthy soil, including improved monitoring of priority and emerging pollutants and effects from the local production of energy.
- Underpin trust in the measured values by seamless sharing of digital data and metadata and methods for propagation of uncertainty through complex digital processing chains as relevant, e. g., for complex measurement and modelling scenarios.

2.2 Competitive and resilient industry

Need

Europe needs a resilient, competitive, and sovereign industry. Consequently, the Commission has initiated actions to promote the EU's long-term competitiveness on strategic technologies for Europe, focusing on digital and deep technologies, clean technology, and biotechnology⁴. In addition, there are six Key Enabling Technologies identified by the Scientific Foresight Unit of the European Parliamentary Research Service as critical for Europe to reach technological sovereignty. These technologies are Advanced Manufacturing, Advanced (nano) Materials, Life-science technologies, Micro/nano-

³ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

⁴ https://commission.europa.eu/strategy-and-policy/eu-budget/strategic-technologies-europe-platform_en

electronics and Photonics, Artificial Intelligence, and Security & Connectivity technologies⁵. These Strategic and Key Enabling Technologies, including quantum technology that is very relevant to metrology, are measurement intensive and/or need new metrological competences and capabilities for Europe to achieve or maintain a position of global leadership, and the ability to turn research and development into market products. Circular economy and a robust supply of critical raw materials will also be key for Europe's ambitions towards resilience and sovereignty.

Strategic technologies for Europe underpin the competitiveness, resilience and security of the European economy and are critical to keeping and developing the European industry base. As the European Commission President Ursula von der Leyen said in her State of the Union Address, "*Let's make sure that the future of our industry is made in Europe.*" Manufacturing industry in Europe is the largest customer and stakeholder community for EURAMET. Industry needs services delivered by EURAMET members for their production, development, quality control, and conformity assessment. For example, there would not be European high-end lithography tools for microelectronics manufacturing without traceable sub-nm length measurements and capabilities at extreme ultraviolet wavelengths. Wide availability of metrology services and infrastructures on the Strategic and Key Enabling technologies will create significant savings and competitive advantage for industry, and these capabilities shall be provided in Europe.

The transition to digital systems is common across all aspects of the economy and society. The most fundamental technical change associated to the digital transformation is the introduction of artificial intelligence, ubiquitous connectivity, distributed systems, and edge/cloud computing. Systems including these technologies require totally new metrology concepts for quality control and safety, and confidence in their outputs requires new approaches to assessment of the quality of data at an individual and collective level. These developments are expected to continue with pace.

Metrology response

Objectives include:

- Strengthen the European industrial ecosystems⁶ through new metrology capabilities and services for key enabling technologies that are strategically important for the European industrial value chains and competitiveness of Europe. Metrology for advanced manufacturing, micro- and nanoelectronics, quantum technology, and biotechnology are among the most important topics to address.
- Support development of new standards and technical regulations in international standardisation bodies to promote the competitiveness of the European industry.
- Support the digital transformation for example through methods for quality control of data in general, metadata, AI training data and algorithms.
- To directly deliver the SI at the point of use, by utilising quantum and digital technologies to provide primary realisations of the units within an industrial or other users facility.

⁵ "Key enabling technologies for Europe's technological sovereignty," a study by the Panel for the Future of Science and Technology, Scientific Foresight Unit (STOA), European Parliamentary Research Service, PE 697.184 – December 2021

⁶ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

- Advanced manufacturing metrology to support design for circularity, and reliability of circulated materials, reducing the carbon and material footprint of industrial production.
- Support to quality infrastructure for the circular economy.

2.3 Health

Need

“One Health” is a comprehensive approach promoted by WHO to optimize the health of people, animals and the environment⁷. This approach aims at preventing, predicting, detecting, and responding to global health issues through horizontal collaborative actions across multiple sectors. In addition to legislation and policies, cross-disciplinary research is needed to achieve the goals of One Health. Areas of work include food safety, laboratory services, environmental health, control of diseases and antimicrobial resistance.

The One Health approach is particularly relevant for fighting pandemics, like the COVID-19 pandemic, which demonstrated vulnerabilities in protecting Europe’s citizens and economy. COVID was a trigger for the EU’s policy thinking towards more sovereignty. A better preparedness in the future will generate metrology needs to underpin quality control in diagnostics, clinical analytics and the health and pharmaceutical industries in Europe. Metrology is particularly important when data from different countries are combined, which requires known accuracy and uncertainty of underlying measurements. This also has a major impact on the activities of the European Health Data Space.

In parallel, the effect of the aging population on European health systems will be accelerated. The decade 2030 to 2040 will be the decade in which a baby-boomer generation will retire, straining the available resources. This necessitates a shift from a ‘one size fits all’ approach towards taking into account individual differences and better utilising the accumulating data to manage health. Respective metrology needs will include quantitative measurements with high precision to detect individual differences, quality-assured digital tools, support for the manufacture of novel pharmaceuticals and medical devices for personalised treatments as well as quantitative measurements for assessing individual treatment responses.

Significant effort is required to support innovations through health care regulatory frameworks (EU- IVDR and MDR). In particular, new approaches are required to exploit the potential of digital health technologies and artificial intelligence by accelerating regulatory approval in the EU (AI-Act).

Metrology response

Objectives include:

- Metrology for quality control in the health domain, including (nano-based) pharmaceutical production, medical imaging, diagnostics, analytics, therapy, medical devices; ensuring the reliability of individual health plans.

⁷ <https://www.who.int/europe/initiatives/one-health>

- Metrology support to the health care regulatory frameworks such as for in-vitro diagnostics and medical device regulation.
- Metrology for the assessment of quality of data and data management in Health Data Spaces, algorithms and the use of artificial intelligence in healthcare and metrological support to the EU AI Act regulatory framework.
- Development of new reference materials and laboratory practices for healthy and affordable food.

2.4 Cohesion and infrastructures

Need

The disparities among the European countries are still significant. In addition, several new countries seek membership of the EU. The EU's cohesion policy underpins European solidarity and focuses on the less developed European countries and regions to help them to reduce the disparities⁸. Many European NMIs and DIs represent the cutting edge of global measurement expertise, having a leading role in supporting the global competitiveness of the European economy as well as the development of measurement technologies required by a modern society. Other national institutes are in the early development stages, more service-oriented, or have very limited resources but still must keep up with their stakeholders' needs.

The current Metrology Partnership already responds to these challenges. However, strengthening the scientific and technical capabilities of small and emerging NMIs, capacity building activities and infrastructure improvements aimed at smart specialisation at national or regional level are vitally important to many European Countries and will need to continue beyond the time frame of the current programme. Digitalisation, e. g., is a preferred area to overcome disparities as the uptake of new technologies is associated with relatively moderate resources.

Metrology response

In line with the EURAMET strategy⁹ this agenda aims to bridge the gap between emerging and well-established members, thus developing a balanced and integrated metrology system for Europe. The 39 EURAMET member countries include many European countries beyond EU member states, such as Ukraine, Georgia, and countries in the Balkans. EURAMET is in an extraordinary position to contribute to cohesion.

Objectives include:

- Development of individual and institutional capabilities to reduce disparities. This would include hands-on experience, training, and mentoring through secondments and researcher mobility in technical areas where high infrastructure costs, low availability of experienced staff, or lack of scientific excellence is a barrier for a developing institute to work in the field.
- Correcting imbalances in the metrological scientific excellence between the EURAMET

⁸ https://ec.europa.eu/regional_policy/policy/what/investment-policy_en

⁹ <https://www.euramet.org/about-euramet/strategy-2030>

member countries and regions through an implementation structure that allows participation of the less advanced metrology institutes in large research projects of high scientific excellence.

- Support of the quality infrastructure in Ukraine and its development towards EU standards in close cooperation with CEN/CENELEC, EA, and WELMEC.

European Metrology Networks under EURAMET contribute to the structuring of soft and hard metrology infrastructures in Europe. However, there are limited national resources to invest in new hard infrastructures, and a dedicated European initiative towards coordinated development of physical infrastructures in new technology areas would leverage the benefits of the research partnership. Such infrastructures would support and motivate provision of coordinated services, enable capacity building, and provide means for the NMIs and DIs to respond to needs arising from the security and defense sectors. For example, the metrology infrastructure for the European quantum industry is covered by the European Quantum Measurement and Testing Infrastructure. Similar infrastructure initiatives could be envisioned, e.g., towards metrology for AI and quality of data where metrology capabilities are still very sparse.

3. Conclusion

Metrology is a cross-cutting science, which has strategic importance to Europe – without modern metrology infrastructure and capabilities for industry and society, Europe will not remain competitive to other regions in the world and will lack critical capabilities to respond to the societal challenges that need to be addressed globally. This European Metrology Agenda is aligned with the broader European agenda and addresses Member State metrology needs towards the Green Deal, competitiveness and resilience of industry, health, cohesion, and infrastructures.

Other regions of the world are investing significant amounts in their metrology systems to meet the needs arising from global challenges and to support their industry. In Europe, a similar level of investment can only be reached through a coherent joint European action. Manufacturing industry in Europe is the largest customer and stakeholder community for EURAMET. Metrology is key part of the quality infrastructure that is essential for industrial manufacturing, innovation, competitiveness, standardisation, trade, and access to global markets.

Scientific excellence is the key to meeting the objectives of this agenda. Scientific excellence can only be reached through cutting-edge joint research, expertise, capabilities, and fit-for-purpose hard infrastructures. Strengthening the scientific and technical capabilities of the small and emerging NMIs, capacity building activities, and infrastructure improvements aimed at smart specialisation at national or regional level are vitally important to many European countries. The European Metrology Networks have proven to be an effective tool to interact and deliver research impacts to a broad range of stakeholder communities, making services and capabilities readily available. Wide availability of metrology services and infrastructures on the Strategic and Key Enabling technologies will create significant savings and competitive advantage to the European industry.

As laid out above, the next decade will provide major challenges that require a joint, coordinated response of the European metrology system. The NMIs and DIs are committed to continue their cooperation under EURAMET.

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