

Important information about these documents

This call is being held ahead of any agreement from the Commission that the relevant funding will be available. At present the relevant legislation is still under discussion in both Council and Parliament, and there is no certainty on the detailed arrangements for funding selected projects. The funding of any selected project, and the terms and conditions of participation in the projects, are dependent on completion of the legislative process and the subsequent contractual processes between the European Commission and EURAMET. Proposers submit to this call at their own risk.

Background

Last year, EURAMET submitted a draft proposal to the EC for a further research programme to be established under article 185 of the Treaty on the Functioning of the European Union (TFEU) to follow on from EMRP and EMPIR. This was published by the EC at https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/european-partnerships-horizon-europe/candidates-digital-industry-and-space_en

The initiative would be called the European Partnership on Metrology and would aim to create, by 2030, a sustainable and effective system for metrology at European level that ensures Europe has a world-class metrology system that:

- Provides metrology solutions, fundamental metrological reference data and methods, offering fit-for-purpose solutions supporting and stimulating European innovation and responding to societal challenges.
- Supports and enables effective design and implementation of regulation and standards that underpin public policies that address societal challenges.

The Commission commissioned an impact assessment into this proposal and 11 others in similar priority areas, and, based on those findings, published their own proposal for the Partnership, their response to the impact assessment and a draft of the Decision on 23rd February 2021. See:

<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:89:FIN>

https://ec.europa.eu/commission/presscorner/detail/en/ip_21_702

<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0035&qid=1614677899327>

That draft Decision is currently under discussion in the European Council and the European Parliament.

Under the assumption that the Council and Parliament pass the basic act which would form the legal basis for this research programme, and that the participating countries named in the Draft Decision submit the required commitment letters, EURAMET is publishing these potential Selected Research Topics and draft guidance notes. These documents are not approved by the Commission nor will they lead to a binding decision by EURAMET e.V. for any further negotiation or funding. All published guides and templates are subject to amendment by the EC and EURAMET e.V. as further information becomes known.

Title: Metrology for hydrogen generation by photoelectrocatalytic water splitting

Abstract

Hydrogen is a candidate energy source for reducing or replacing fossil fuels in transportation. Hydrogen production using photo electrochemical (PEC) cells to split water is a very promising technology with limited environmental impact compared to the widespread steam reforming of natural gases that is currently used for this purpose. Current PEC cells technology faces challenges including the development of efficient materials for water electrolysis, minimisation of internal resistance losses and methods to increase the total sunlight-hydrogen yield. To achieve these, comprehensive and advanced methods for *ex situ* hybrid metrology in combination with *in situ* and *operando* measurement approaches are required.

Keywords

Hydrogen production, water splitting, photo electrochemical (PEC) cells, photocatalysis, photoanode, photocathode, hybrid metrology, *in situ/operando* metrology, nanostructures, light interactions, energy conversion

Background to the Metrological Challenges

On signing the Paris agreement, EU member states agreed to take steps to mitigate global warming and members are targeting a 40 % reduction in 1990 greenhouse gas emissions by 2030. The adoption of the European Strategic Energy Technology Plan is a key step towards this goal and fosters the development of a climate neutral energy system based on low-carbon technologies. Legislative frameworks, 'Clean Energy for all Europeans' and 'Clean Mobility' are driving market transformations based on renewable energies, efficient storage, and low-carbon mobility. Replacing fossil transport fuels with hydrogen generated from the electrolysis of water would provide a fuel with approximately three times the energy content of gasoline (143 MJ/kg versus 44 MJ/kg).

Water photoelectrolysis using TiO_2 that only utilises UV solar light and the strong photocorrosion that occurs using classical semiconductors such as Si or III-V that passivation has yet to address, create efficiency limitations when using these hydrogen production methods. PEC cells coupled photovoltaic-electrolysis systems, and photocatalytic water splitting are alternative hydrogen generation methods. Semiconducting nanowires and porous structures with high surface/volume ratios, and materials with maximised light-matter absorption interactions are leading candidates for industrial scale hydrogen production. To improve the performance of PEC cells knowledge of the correlation between inconsistencies in electrode shape, size, and morphology and differing performance depending on the method of catalyst grafting from single nanostructures to that of nanostructure ensembles (1 cm^2) are needed. In addition, an improved understanding of complex nanoscale light-matter interactions, charge transport at heterogeneous interfaces and degradation in a corrosive environment is needed to provide information on the physical and chemical mechanisms involved during water-splitting reactions. Whilst multidimensional metrological methods are needed for accurate PEC cell functional quality control, traceable light absorption, *operando* X-ray spectroscopies and electrochemical measurement approaches need to be developed and standardised. The reaction of photoelectrode nanostructured materials to photonic, electronic, and electrochemical stimulation need investigation in application-oriented approaches so that universal test machines can be introduced to characterise larger hydrogen production devices. Dimensional metrology is also important in electrode fabrication. Standardisation in this area relies on the mutual comparison of simultaneously measured nano properties in conjunction with models and calculation methods for performance validation purposes.

To facilitate the uptake of hydrogen as a transport fuel, improvements to the efficiency of the solar-to-hydrogen energy conversion, and the derivation of best measurement practice are required as a precursor to standardisation activities by VAMAS, IEC and ISO committees. *In situ*, *operando* and high throughput measurement methods for the quality control of hydrogen produced by electrolysis are needed. Measurement research in this area, by improving new technologies and reducing costs through coordinated collaborative research efforts among EU countries, companies, and research institutions, has the potential to deliver the key objectives of the energy union in line with SET Plan objectives.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of technologies for hydrogen production by water splitting in photo-electrochemical cells based on physicochemical processes.

The specific objectives are

1. To design electrodes and simulate their photocatalytic properties and dimensional requirements and to fabricate innovative photoanode and photocathode nanostructures to catalyse H₂ photoproduction, focusing on cm²-area nanofabrication methods by controlling the size distribution within a 20 nm uncertainty.
2. To validate fabricated nanostructures as calibration samples enabling their use *in operando* vibrational, electron and X-ray spectroscopies by improving traceability and uncertainty levels to below 10 % using SI traceable *ex-situ* techniques. In addition, to characterise the ensemble nanostructures from Objective 1 under photometric-traceable irradiation conditions through hybrid metrology methods that focus on (i) determining light interaction and trapping, and (ii) determining chemical and electronic transport properties at surfaces and interfaces.
3. To develop *ex situ* hybrid traceable measurement methods for determining the doping level, dimensional and photo-electrical properties of single photocatalytic nano-objects to increase the efficiency of PEC cells. These methods are to be suitable for the control of the nano-objects' chemical and physical properties and the correlation of these with its functional properties.
4. To characterise using electrochemical spectroscopies the PEC cell under working conditions through *in situ* and *operando* characterisation monitoring of its charge dynamics and surface kinetic properties relating to hydrogen production. In addition to develop standard protocols to monitor cell solar-to-hydrogen conversion efficiency and also for the mitigation of cell degradation and ageing to increase long-term stability.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (material suppliers, manufacturers of advanced analytical instruments, NMIs and calibration laboratories), standards developing organisations (e.g. VAMAS TWA 2 Surface Analysis, TWA 36 Printed and Flexible Electronics, IEC/TC 113 Nanotechnology for electrotechnical products and systems, IEC/TC 82 Solar photovoltaic energy systems, ISO/TC 164/SC3 Mechanical testing of metals – Hardness testing, ISO/TC 201 Surface Chemical Analysis, and ISO/TC 229 Nanotechnology) and end users (e.g. hydrogen vehicle manufacturers, hydrogen refuelling station operators).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR projects 17IND05 MicroProbes and 19ENG05 NanoWires and how their proposal will build on these.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.2 M€ and has defined an upper limit of 2.7 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the hydrogen fuel energy sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of the potential European Partnership on Metrology to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.