

Title: Energy harvesting

Abstract

Energy harvesting is an innovative new energy technology that uses waste energy to improve energy efficiency. There is strong uptake of European energy harvesting technology in specific applications such as process monitoring and building controls but it has yet to achieve wider mass-market adoption. Energy harvesting needs to be considered in the context of the system which includes the energy source, storage and electronic function such as a wireless sensor. New traceable metrological approaches are required to support industry in the deployment of energy harvesting technology into systems and to support the implementation of emerging new nanostructured materials and sustainable materials supply.

Conformity with the Work Programme

This Call for JRP's conforms to the EMRP Outline 2008, section on "Grand Challenges" related to Energy and Environment on pages 8 and 23.

Keywords

Energy harvesting, efficiency, vibration, piezoelectric, thermoelectric, thermoelectric figure of merit, magnetostriction, industry, energy.

Background to the Metrological Challenges

In 2011 \$700 million was spent on energy harvesting components and this is expected to rise to just under \$5 billion by 2022. 1 million units were sold in 2011 for powering wireless sensors in buildings, with a 10-fold growth forecast by 2017. The market drivers include the large reduction in installation costs with maintenance free operation, whilst industrial process monitoring, asset condition monitoring and sensing (e.g. rail) are major growth areas. A number of automotive companies are developing prototype harvesters to use waste heat to power vehicle electronics but the existing technology is bulky. Energy harvesting or wireless recharging technologies are set to become important for consumer electronics and wearable electronics where the requirement to charge multiple devices is becoming unmanageable. Within Europe there is a drive to reduce battery consumption [EC Directive 2008/98/EC (Waste)] and to eliminate the need for re-charging. This is impeded by the massive proliferation of battery-powered devices, however energy harvesting technology can reduce dependency on batteries e.g. an energy harvester with an output of 100 μ W would generate 63 kJ over a 20 year lifetime.

A range of new nanostructured energy harvesting materials is currently being developed to overcome these obstacles. Successful development of these depends on being able to reliably measure energy conversion at the nanoscale and relate this to performance at the device level. The optimum choice of the energy harvesting device is critical to the commercial success of an energy harvesting application.

To realise the full market potential of energy harvesting technology developers will need to reduce size and weight through improving efficiency and power output. To achieve this will require both the development of new, more efficient materials at the same time as reducing losses and improving system efficiency.

In order for commercial deployment in energy harvesting systems there is therefore a need to develop metrological solutions for assessment of energy harvesting performance in real systems using both new and existing materials technologies. Traceable measurements of the relevant metrological properties with low uncertainties are needed to ensure accurate energy harvesting characterisation. This needs to go beyond the current state of the art to embrace reliable measurement of energy transfer across system boundaries, taking into account the energy source, materials and device coupling (including nanoscale effects), and

energy transfer to the load. In magnetostrictive, capacitive and electromagnetic energy harvesting systems a bias field must be powered as an additional systems component. For electromagnetic energy harvesting technologies the use of high energy density sustainable magnetic materials will reduce dependency on rare materials.

EMRP JRP ENG02 developed reference materials with relative uncertainties for the figure of merit less than 20 %, however this is still too large for many commercial applications. Since the accuracy of the figure of merit is directly related to the efficiency of thermoelectric materials this will also reduce the uncertainty of the efficiency of thermoelectric modules for industrial applications. EMRP JRP ENG02 demonstrated the key role of losses in energy harvesting systems and the need to measure efficiency as well as effectiveness. ENG02 set up the metrological infrastructure for measurement of energy harvesting efficiency, power and losses under well-defined conditions. This work showed that energy transfer from the materials into the energy conversion and storage system can incur severe losses and that further work is required to extend the metrology of energy harvesting to include interfaces to the energy source and the energy conversion and storage elements. ENG02 showed that magnetostrictive energy harvesting systems, though experimental as yet, can deliver high power density, but improved understanding of losses and source coupling is required to develop this technology.

Scientific and Technological 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 in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

The JRP shall focus on the traceable measurement and characterisation of electrical, mechanical, dielectric, thermal and magnetic parameters for energy harvesting applications.

The specific objectives are

1. To develop metrological techniques to characterise losses (electrical, mechanical, dielectric) and their impact on energy efficiency. These techniques should quantify coupling to energy source and load, and measure losses associated not just with the energy harvesting transducer, but also with energy transfer across the system boundaries.
2. To develop capability for the traceable measurement of losses and interfacial effects in nanostructured thermoelectric and piezoelectric materials and the metrological links between losses at the nanoscale and the macroscale.
3. To reduce the uncertainty of measurement of the thermoelectric figure of merit by a factor of two to 10 % by developing improved techniques which enable the simultaneous measurement of thermal and electrical conductivity and the Seebeck coefficient.
4. To develop system level metrology to characterise the nonlinear behaviour of the magnetic materials in electromagnetic energy harvesting systems, including consideration of the use of sustainable magnetic materials for future energy harvesting devices.

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 R&D work, the involvement of the user community such as industry, and standardisation and regulatory bodies, as appropriate, is strongly recommended.

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 EMRP project ENG02 Energy Harvesting and how their proposal will build on those.

EURAMET expects the average size of JRPs in this call to be between 3.0 M€ to 3.5 M€, and has defined an upper limit of 5 M€ for any project. The available budget for integral Research Excellence Grants is 30 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies, such as IEC/TC 113 and VAMAS TWA24
- transfer knowledge to energy harvesting technology developers, building management, automotive and consumer electronics sectors.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] EC Directive 2008/98/EC on waste (Waste Framework Directive).