EURAMET
European Association of National Metrology Institutes

Title: Metrology for Energy Harvesting

Abstract

There are opportunities to tap huge currently inaccessible energy resources through novel approaches by "harvesting" energy from sources such as temperature gradients using thermoelectric materials or from irregular motion (including vibration) using micro generators. To push these developments, reference materials and precise and traceable measurements of the thermoelectric figure of merit and of small electrical quantities are needed. Joint Research Projects (JRPs) submitted for this topic should aim to develop metrological methods for assessment and improvement of integrated micro-/nano-generator systems.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008 [1], section on "*Grand Challenges"* related to *Energy* on pages 8 and 23.

Keywords

Thermoelectric materials, nanostructured materials, energy harvesting, thermal energy, mechanical energy, electrical energy, thermoelectric figure of merit, Seebeck effect, piezoelectric effect, reference material, energy conversion, ac-dc transfer, vibration.

Background to the Metrological Challenges

Nearly all of the world's electrical power, ~15 trillion watts, is generated by heat engines, gas or steam-powered turbines that convert heat to mechanical energy, which is then converted to electricity. Much of this, ~ 10 trillion watts [2], however, is not converted but lost in heat.

Thermoelectric materials have long been recognised for the conversion of heat directly into electricity, but a wide-spread application was limited due to small conversion efficiency. The ability to create nanostructured thermoelectric materials has led to remarkable progress in enhancing thermoelectric properties, making it plausible that thermoelectrics could start being used in new settings in the near future. The efficiency has been improved by an order of magnitude recently using nanostructured materials.

The rapid increase in thermoelectric materials R&D is a consequence of the growing need to increase energy efficiency and independence through waste heat recovery. Thermoelectric materials enable the direct solid-state conversion of heat into electricity, with little maintenance, noise, or cost.

The performance of thermoelectric energy conversion devices depends on the thermoelectric quantities related to the Seebeck coefficient, however, reference materials for the Seebeck coefficient in important temperature ranges are missing. Furthermore, precise and traceable measurement methods for the determination of the Seebeck coefficient are needed. The challenging task will be to establish traceability for the measurement of small differences of relatively large quantities as the efficiency factors of all these effects will be small, in the order of a few percent. The determination of the efficiency is the responsibility of the manufacturers of the devices, but in order to offer their products worldwide they need a strong metrology infrastructure to guarantee the traceability of the key-quantities of their products. Particularly the traceability of time-variant signals needs completely new approaches.

Nanostructured materials along with high permittivity dielectrics also offer the possibility to contribute through other mechanisms. New approaches to energy generation are being developed by harvesting energy from hydro-kinetics, mechanical vibration, pressure, as well as temperature fluctuations. These range from large-scale power generation such as piezoelectric polymers deployed in rivers to self-power for micro- and nano-electronic devices. High permittivity dielectrics and nano-structured materials are the focus of intense current research efforts. There is the need to develop the metrology infrastructure required to support development and commercialisation in these areas.

Measurements of efficiency and effectiveness are usually done as simple power-in/power-out concepts. Metrological approaches to complex systems with multiple energy sources are required. There are at present no agreed metrics describing the performance of energy harvesting devices. The metrological science of dealing with multiple energy sources at a range of length scales is not yet established. A metrology infrastructure relating to the assessment of the effectiveness and reliability of these emerging technologies is required.

Scientific and Technological Objectives

Proposers should aim to address all of the stated objectives below. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol. The objectives are based around the PRT submissions. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

The focus of this topic is the metrological support for the development of electrical generators exploiting all types of conversion of thermal and mechanical energy into electrical energy, with emphasis of small-scale devices. Innovative, even high-risk approaches especially shall be addressed.

The specific objectives are:

1. development and validation of traceable measurement methods for conversion efficiency
2. measurement of material parameters of thermoelectrical and piezoelectrical materials such as electrical and thermal conductivity and Seebeck coefficient with emphasis on novel, nanostructured materials
3. development of AC/DC transfer techniques for small non-sinusoidal signals
4. development of metrological methods for assessment and improvement of integrated micro-/nano-generator systems.

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.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

You should detail the impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”.

In response to the need for standardised measurement techniques you should detail how your JRP results are going to:

- Feed into the development of documentary standards and guidelines through CEN, or other standards developing bodies or other appropriate bodies
- Transfer knowledge to the industry, regulators and policy makers.

Additional Information

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

[1] European Metrology Research Programme. Outline 2008 Edition - November 2008, http://www.euramet.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/docs/EMRP-outline2008.pdf&t=1248796946&hash=9da9ceb781370f04c322ac48068deca5

[2] A Hochbaum et al Nature **451**, 163-167 (10 January 2008) http://www.renewableenergyworld.com/rea/news/article/2008/01/harnessing-waste-heat-for-electricity-51106

[3] “An Energy Policy for Europe”, EC COM(2007) 1 final

[4] “Gadgets and Gigawatts: Policies for Energy Efficient Electronics”, International Energy Agency, 2009

[5] http://www.eatechnology.com/images_archive/Thefutureofenergystorage.pdf

[6] Taylor G.W. et al. “The Energy Harvesting Eel: a small subsurface ocean/river powergenerator”, IEEE Journal of Oceanic Engineering 26 pp.539-547 2001

[7] http://www.post-gazette.com/pg/08210/899996-115.stm

[8] Wang, X.; Song, J.; Liu, J. & Wang, Z. L. Direct-Current Nanogenerator Driven by Ultrasonic Waves Science, 2007, 316, 102-105

[9] Kim 2001 Giant Dielectric Permittivity Observed in Pb-Based Perovskite Ferroelectrics Phys. Rev. Lett. 86, 3404 – 3406

[10] Yole Development Report “MEMS Energy Harvesting Devices, Technologies and Markets”

[11] New Automotive Innovation and Growth Team (NAIGT) report ‘An Independent Report on the Future of the Automotive Industry in the UK’ (www.berr.gov.uk/files/file51139.pdf).