# A European roadmap for humidity and moisture

Fernicola, V., Bell, S., Benyon, R., Bose, N., Georgin, E., Heinonen, M., Hudoklin, D., Sargent, M.

### Abstract

A technical roadmap for humidity and moisture has been developed by the EURAMET Technical Committee for Thermometry (TC-T). The roadmap identifies the key triggers that need to be addressed including societal grand challenges and innovation triggers. Several targets that help the triggers to be addressed are formulated in order to provide a future research direction to the scientific community in Europe. The roadmap represents a shared vision of how the humidity and moisture measurements and standards should develop over the next 15 years and identifies the humidity and moisture metrology and the underpinning science required to meet the targets.

### 1. Introduction

In 2006 the EURAMET produced roadmaps for thermometry [1] and humidity and moisture [2]. This exercise formed part of a larger process undertaken by the European metrology community to roadmap their technical areas and to provide useful inputs to the EMRP programme [3]. The roadmaps were meant to be active documents needing periodical updates. For this reason, in 2010 the EURAMET TC-T decided to revise the above roadmaps. It was decided to divide the technical areas to be roadmapped in three groups: 1) thermometry, 2) humidity and moisture and 3) thermophysical properties. A workshop was held at NPL on 30<sup>th</sup> March 2011 with three parallel sessions. About 10 experts, mainly from the EURAMET TC-T, were invited to participate in each roadmap session. The roadmapping process started by identifying the key societal and economic challenges (the triggers). This led to the formulation of a number of targets to provide a research direction to the humidity and moisture community and to identify both the metrology and the underpinning science required to meet those targets.

The roadmap was completed and eventually presented at the EURAMET TC-T plenary meeting in Istanbul on 19<sup>th</sup> April 2012 and endorsed by the committee. The humidity and moisture roadmap described here is meant to suggest the future direction for humidity and moisture measurements and standards research in the European area and to supply strategic input for the preparation of the forthcoming EMPIR programme [4] and for the EURAMET 2020 strategy. Roadmaps for thermometry and thermophysical properties are described elsewhere [5, 6].

### 2. Grand challenges and innovation: The Triggers

The group of experts identified four main triggers that are expected to be contributed by the scientific area of humidity and moisture:

- *Climate change* a need for a larger quantity of data and significant improvement in the quality and understanding of the data was identified.
- *Energy efficiency* a need to support the production, consumption and conservation of energy at several stages of its supply chain was identified.

- *New developments in manufacturing* innovations related materials, processes and quality control in many industrial areas are expected to be limited by the current humidity and moisture understanding, observation and control.
- *Consumer protection* (including Health and legislation) needs for advancements in accuracy and methods for disseminating traceability in humidity and moisture measurements were identified for improved customer protection and patient safety. Routes of healthcare and legislation are also included.

### 3. Addressing the triggers: The Targets

Having identified the grand challenges where the humidity and moisture scientific area could contribute, three specific targets were envisaged that could address, at least partially, these challenges. They are as follows:

- a) *Improved humidity data to support climate models* water vapour is a main greenhouse gas and climate models strongly depend on the accuracy of airborne humidity and its vertical profile, ground-based data of air humidity and ground moisture content. This target, which also includes thermal measurements [5, 6], impacts on the Climate change trigger.
- b) Humidity and moisture measurements to support production, consumption and conservation of energy i) accurate humidity and moisture monitoring can optimise baking, curing, drying, and other heat treatment processes involving water transfer; whenever end points are promptly detected, energy consumption can be minimised; ii) the measurement of humidity content in energy carrier gases is central for the safety of the pipeline infrastructure and for the consumer protection, e.g. fair energy billing; iii) air humidity, moisture content, and moisture flux strongly impacts on thermal properties of insulation and building materials, not only to meet building regulations but also to improve the indoor environment quality of workplaces and dwellings; iv) monitoring and controlling moisture content have a key role in optimizing the solid and liquid biofuel based energy production and reducing harmful particle emissions. This target impacts on the Energy efficiency and Consumer and Health protection triggers.
- c) *Humidity and moisture measurements and control for industrial processes* they include manufacture of pharmaceuticals, foodstuffs, micro-electronics, and other high value goods and equipments: i) high-purity manufacturing processes used in microelectronics industry rely on the measurement and control of trace moisture to levels below the part per billion; ii) product manufacture, packaging and storage in the pharmaceutical and food industries requires traceable, on-line, measurements of water activity, moisture content, moisture flux and permeability; iii) harsh processing environments, such as aluminium welding and surface bonding calls for robust and stable in-situ sensors. This target mainly impacts on the New developments in manufacturing trigger.

It is important to note that several further needs were considered to be critical in the successful development according to any plan addressing the above triggers. These are global requirements and should form part of all progress in the humidity and moisture scientific area:

- *Dissemination of knowledge* this is critical to ensure that the end user can purchase the right device, use it appropriately and interpret the results appropriately. This will also underpin appropriate calibrations.
- *Legislation* European and member state legislation and local rules exist in all industries, and the measurement of humidity and moisture is critical to many of these; although the authorities do not often identify this. There is a strong need for support, and thus achieve a traceable measurement infrastructure.
- *Air temperature measurements* this area is currently underdeveloped. Advancements in this area would be incorporated into all areas of activity, but especially in meteorological and indoor environment applications.

## 4. Experimental realisation: meeting the targets

Specific experimental realisations were identified to meet the targets. They are as follows:

- <u>Humidity realisation at low pressure and low temperature</u> existing humidity standards mostly span from sea-level atmospheric pressure to higher pressure; there is a need to cover the low pressure, low temperature, range found in the upper atmospheric layers to support the climate and meteorology research.
- <u>Better understanding of material properties and moisture transport</u> to control moisture processes in materials, significant advances are needed for measuring and modelling water transport, moisture profile as well as bulk moisture content and surface permeability.
- <u>Moisture standards</u> there is a need of harmonisation of the existing measurement methods and of improved standards; the development of a traceable "universal" moisture calibration method was identified as a challenging endeavour.
- <u>Humidity realisation in different carrier gases and conditions</u> current measurement traceability is mainly in air (or nitrogen) at atmospheric or slightly higher pressure; provision must be extended to non-air gases (e.g. hydrogen, methane, etc.) and to real industrial process conditions.
- <u>Transfer standards for on-line measurements</u> reliable, drift-free, humidity sensors are still demanded by the industry. To address the target of humidity and moisture measurements and control for industrial processes, "advanced" sensors and sensor networks with self-validation/self-calibration capability are needed.

### 5. <u>Metrological applications of basic science and enabling science and technology</u>

The final session of the roadmapping process focused on the steps to be made from the enabling science and technology to the outcomes at the NMI level in order to meet the foreseen objectives.

Improved water vapour pressure measurements and understanding of impurity effects. For accurate humidity calculations, accurate data of fundamental properties of water vapour must be measured. Besides, the effect of dissolved impurities on the saturation water vapour pressure and the impact of the matrix gas on the enhancement factor (especially at high pressure) call for further investigations.

Advanced techniques in heat and mass transport technologies, development of standards for moisture and understanding the effects of different matrices. To better

measure and control moisture processes in materials, significant advances are needed in the present capability of modelling and detecting the moisture profile, its time evolution, and the correlation between the heat and the moisture transport in solids. Besides, traceable "field" measurements of moisture content in different materials call for a harmonisation of several existing measurement methods, including better sample management procedures, and the development of new transfer standards. A universal calibration method is not around the corner, but it must actively looked for because of benefits for industry of such methods would be extensive.

<u>Data on the effect of various conditions on hygrometers.</u> Robust, fast and stable sensors that may be based on new materials are required to properly address the targets. Significant advances in industrial process control would be achieved if in-dept studies on the effect of the environment and the operating conditions were carried out. In-situ sensor stability studies could be greatly simplified by the availability of accurate in-situ calibration equipments and suitable calibration methods.

It was recognised that some of these objectives requires a large-scale approach and a crossdisciplinary collaboration spanning chemical and physical metrology, involving other relevant scientific communities which share the same interests in the study of the water properties and its interaction with the matter.

### 6. Conclusions

Roadmaps are live documents and, at agiven time, they are just a snap shot of requirements and routes to achieve them; they have the objective to advise the direction of metrological research and to highlight the opportunities for collaboration in the broad metrology community. The present exercise indicates that significant research and development is needed in the field of humidity and moisture measurements. To remain useful, a roadmap needs periodic updates to keep the pace with the short-term advances in science and technology and their long-term implications. It is envisaged that the research areas identified by this roadmap will guide the direction on humidity and moisture research in Europe over the next decade.

### Acknowledgements

The authors thank Claire Elliot of NPL for having facilitated the roadmapping workshop and for the construction of the roadmap.

#### <u>Reference</u>

- 1. Bojkovski, J., et al., Int. J. Thermophys., 30, 1-8, 2009
- 2. Bell, S., et al., Int. J Thermophys., 29, 1537-1543, 2008
- 3. EMRP Outline 2008, <u>http://euramet.org</u>
- 4. Outline for a European Metrology Programme for Innovation and Research EMPIR, EURAMET GA 2011; The cornerstones of EMPIR, EURAMET GA, 2012
- 5. Machin, G., et al, A European roadmap for thermometry, EURAMET TC-T, 2012
- 6. Filtz, J-R., et al., A European roadmap for thermophysical properties metrology, EURAMET TC-T, 2012.

