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Metrology research trends related to temperature and humidity sensing

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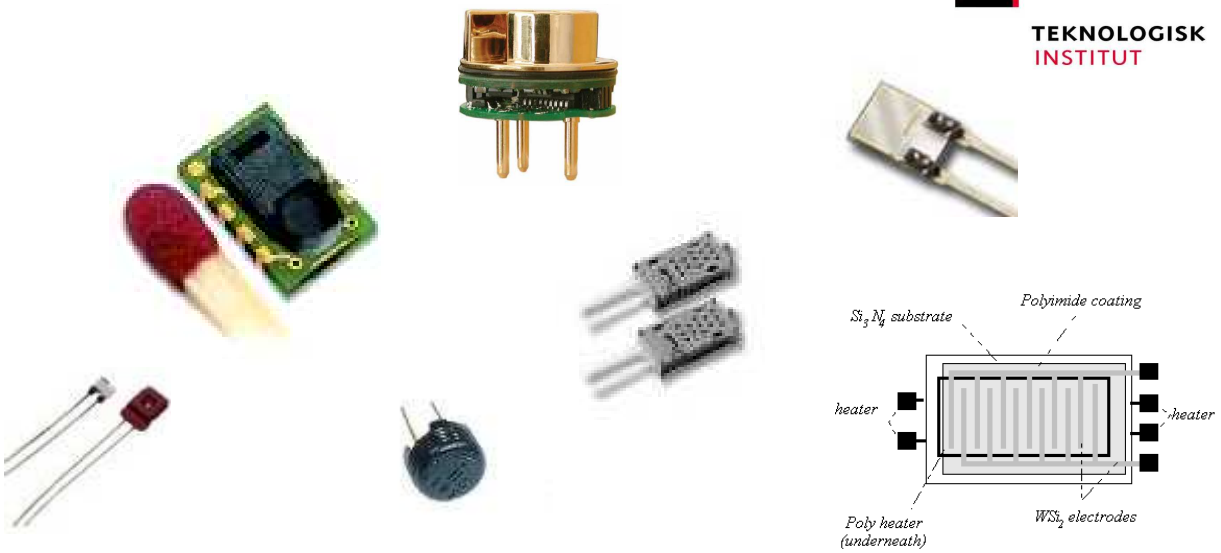
The preconceived plan

- Introduction – what is metrology?
- The organisation of metrology worldwide and in Europe (EUROMET)
- The EUROMET research plans: “The roadmaps”
- Example: The humidity roadmap
- What is asked for by Metrologists, related to sensors?
- What do the new sensors ask for from metrology?
- Issues to think about

Introduction



What do we want:

- To measure
- To control

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- We wish know if of our measurement meet our demands (accuracy)
- We wish to linearise the sensor output (for control)

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- We need to calibrate the sensor!

Metrology

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Metrology is the science of measurement

Metrology, attempts to **validate** the data obtained from measurement equipment by determining the **metrological quantities** (attributes that may be distinguished qualitatively and determined quantitatively)

A core concept in metrology is **traceability**. Traceability is most often obtained by **calibration**, i.e. establishing the relation between the output of a sensor and the value of a measurement standard. An integral part of establishing traceability is evaluation of **measurement uncertainty**.

Metrologists characterise sensors, relate input to output, determine the uncertainty and effect of influencing factors:

They make the sensor-output make sense!

Organisation of international metrology

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The Hierarchy of Metrology:

- Système International d'Unités, or the International System of Units (**SI**)
- The SI is maintained under the auspices of the Metre Convention and its institutions, the General Conference on Weights and Measures, or **CGPM**, it executive branch the International Committee for Weights and Measures, or **CIPM**, and its technical institution the International Bureau of Weights and Measures, or **BIPM**.

Regional organisations of "National laboratories"

Euromet TC's & roadmaps

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EUROMET have a number of Technical Committees:

- Acoustics, ultrasound & vibration
- Electricity and magnetism
- **Flow**
- Ionising radiation
- Length
- Mass & related quantities
- Metrology in Chemistry
- Photometry & Radiometry
- Time & Frequency
- **Thermometry incl. Humidity and thermophysical properties**

Danish Technological Institute participates in the thermometry (and flow) TC.

The Humidity area has been selected here as an example. This field is less developed than thermometry and relates closely to IAQ applications

EUROMET Members

EUROMET Roadmaps

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All EUROMET TC's have produced roadmaps to enable coordination of metrology research.

= The financing possibilities are limited ➔ we need increasing impact from national investment in European metrology R&D.

More layers:

- **Triggers** – Social and economic drivers
- **Targets** – Key targets stemming from the triggers
- **Experimental realisation** - Outcomes/targets at the national laboratory/standards level
- **Metrological applications of basic science** - Steps on the route from Enabling Science/Technology to the outcomes/targets at the national laboratory/standards level
- **Enabling science and technology** – what do we have ? What do we expect to get?

Roadmap for humidity and moisture

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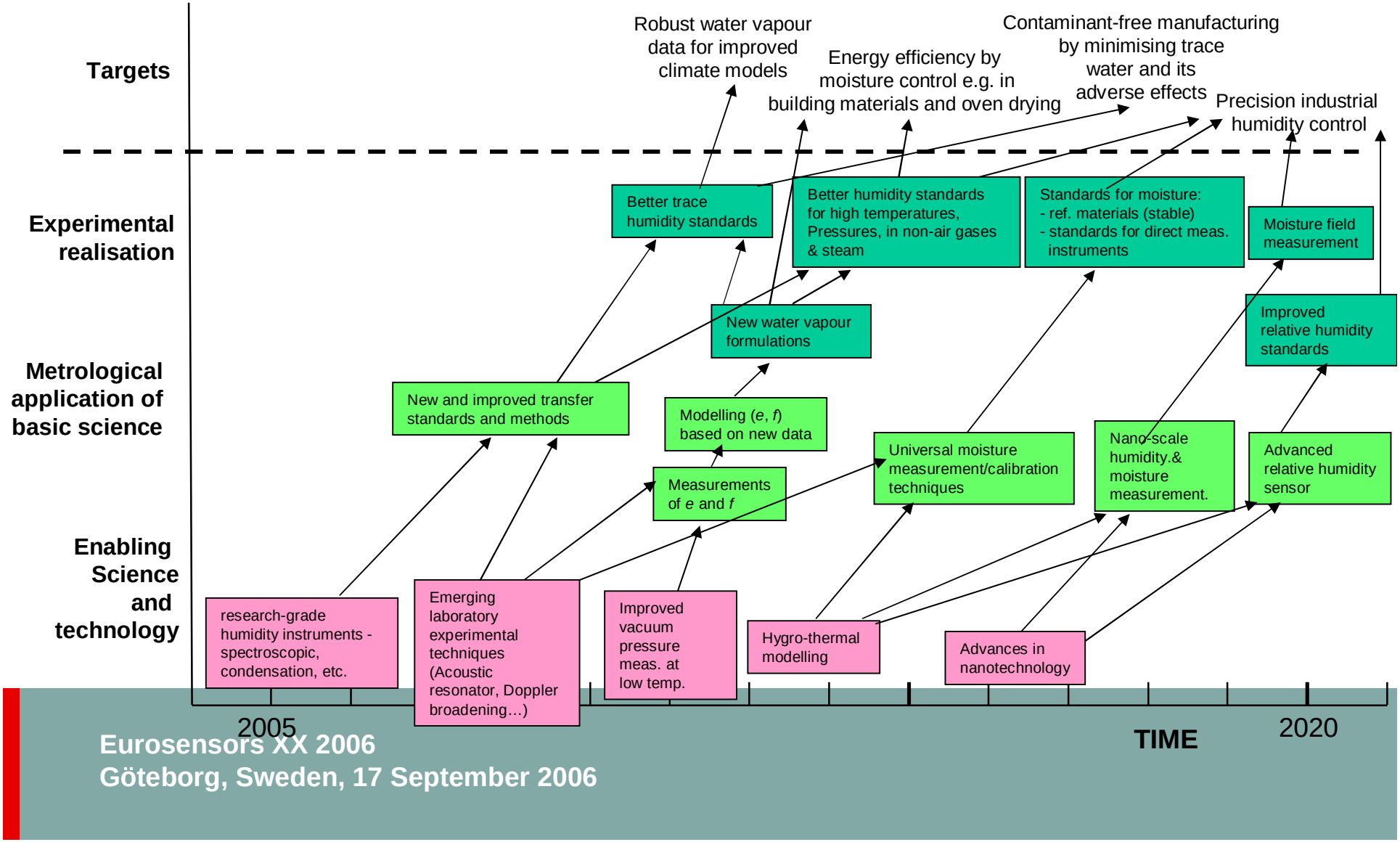
Triggers Actions against global warming (energy efficiency, climate research) require better humidity measurements. Higher performance manufacturing will require better humidity process control and global interoperability



Example Hydrogen fuel cells

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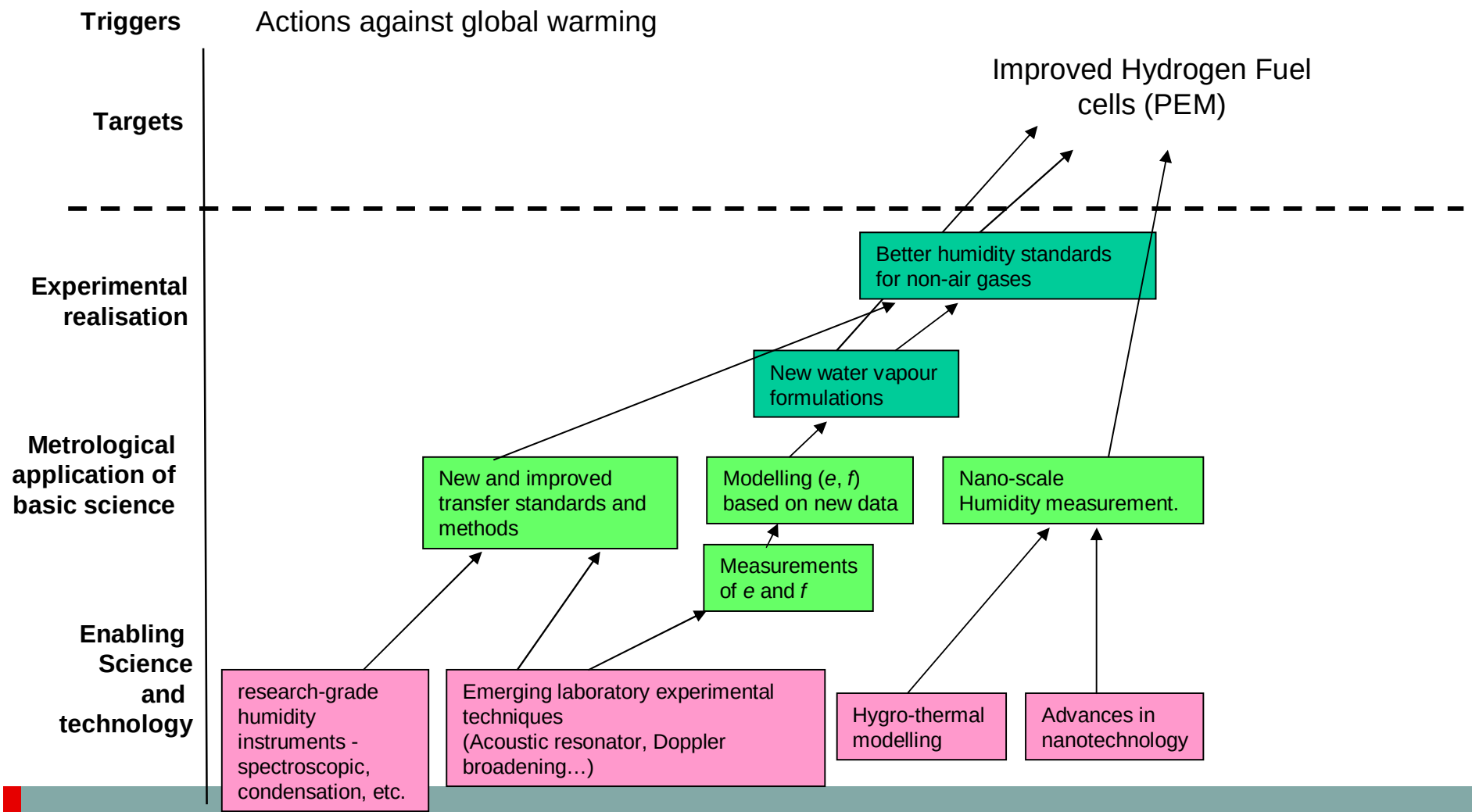

Summarising research trends - humidity

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Triggers: Global Warming, Higher performance manufacturing

- **Humidity measurement to optimise combustion and heat-treatment processes across all industries: "Intelligent humidity monitoring"**
- **Precision measurement for process control: various gases, pressures, contaminants**
  - WE NEED SENSORS ROBUST ENOUGH FOR THESE APPLICATIONS
  - WE NEED AN ADVANCED, ROBUST, STABLE, DRIFT-FREE, HIGH-RESOLUTION RELATIVE HUMIDITY SENSOR
- **Human comfort/ Energy efficient buildings:**
  - Building humidity (micro-/multisensors)
  - Moisture content of building materials
  - Water vapour flux measurement
  WE NEED CHEAP MULTISENSORS, AND WIRELESS SENSORS TO BE ENCAPSULATED IN BUILDING MATERIALS
- **Contaminant free manufacture such as silicon substrate**
  WE NEED RELIABLE TRACE MOISTURE SENSORS FOR THE PPT RANGE

Summarising research trends - humidity

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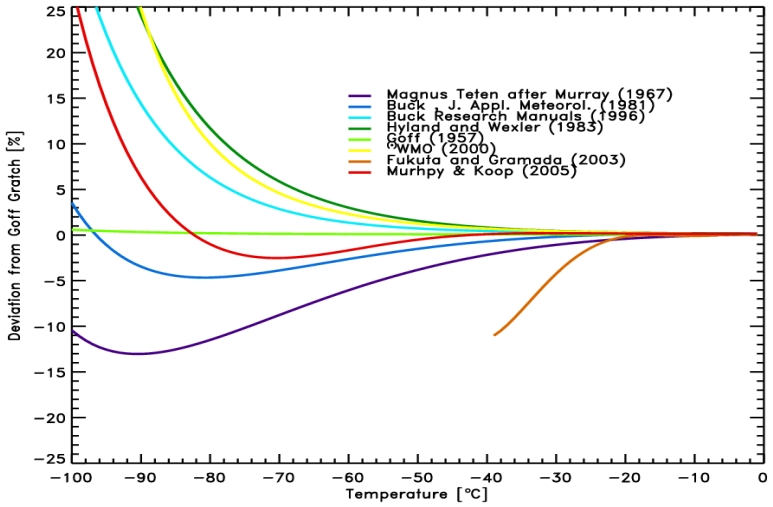
Metrological application of basic science:

- Better trace humidity standards
- Better standards for high temperatures, pressures in non-air gases and steam
- Moisture field measurement (moisture movement, profile, surface moisture, bulk moisture content)
- Improved relative humidity standards
- New water vapour formulations, modelling (*e*, *f*) based on new data, measurements of *e, f*



Issues

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- We need standards to be able to characterise the sensors in real world conditions (high pressures, other gases than air, high temperatures)
- We need new water vapour formulations (the existing are based on measurements and formulations from the sixties).
- Especially for relative humidity measurement the sensors still suffer from hysteresis, cross sensitivity problems, drift, instability and sensitivity to contamination.
- The problems tend to increase as the sensor size decrease!
- As the sensors becomes small and cheap, there is not an economical basis for calibrating every single sensor → we have to consider cloning of calibration data.
- To build in sensors i.e. in building materials we need to improve robustness lifetime, power-consumption and incorporate wireless communication.

Thermometry is an old-timer but humidity measurement is still **Black Magic**