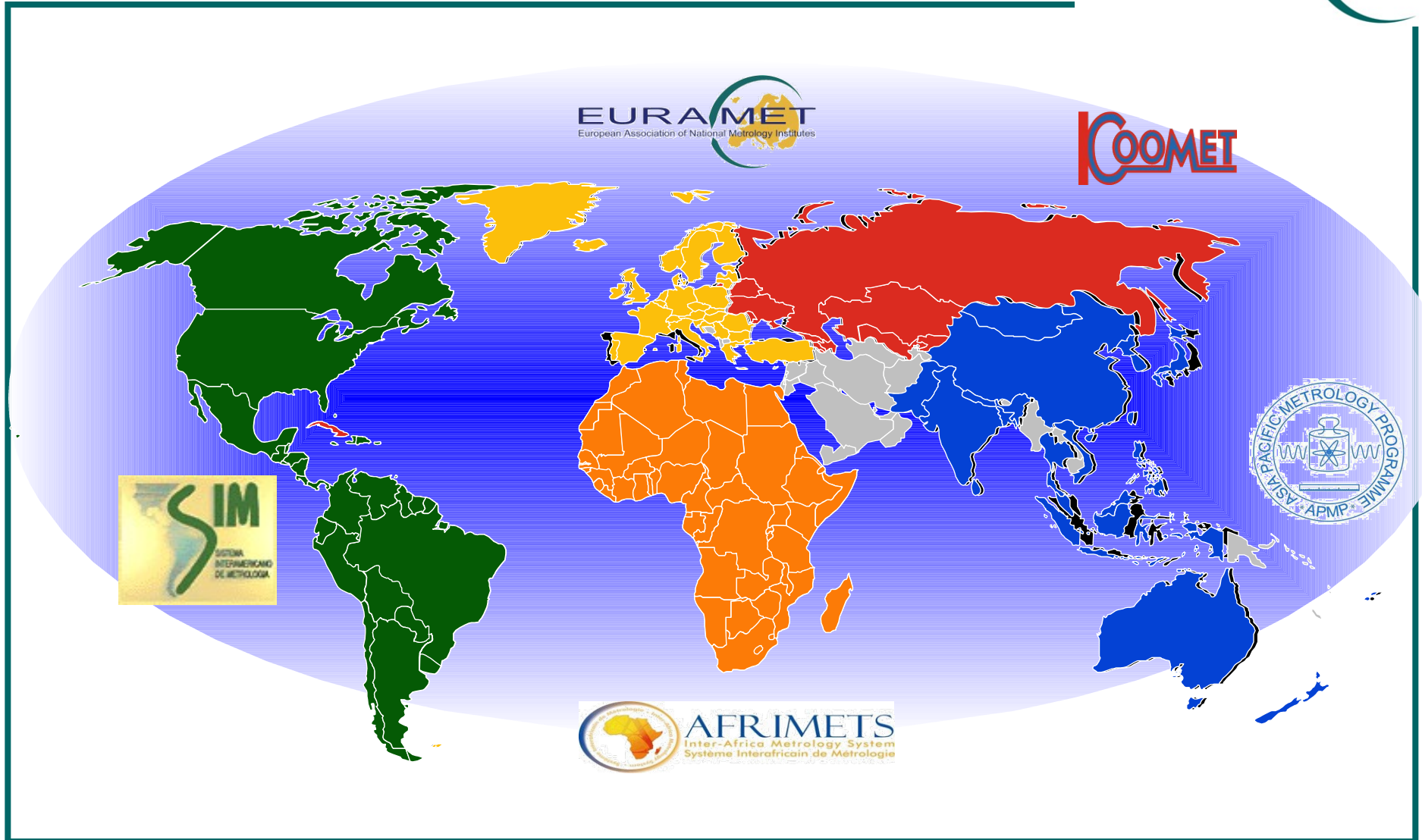


# Strategy for European national (nano)metrology 2020

**Leslie PENDRILL, EURAMET Chairperson**

[chairperson@euramet.org](mailto:chairperson@euramet.org)    [www.euramet.org](http://www.euramet.org)

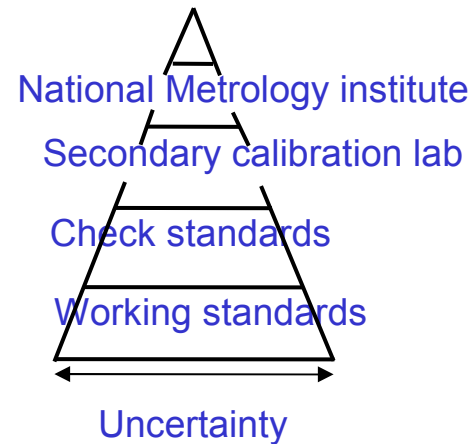
# Regional Metrology Organisations



EURAMET Report to NanoScale 2010

Brno, 27 October 2010

## European Association of National Metrology Institutes



Cooperation quality-assured measurement

# Membership

100+ organisations (NMI, DI)

- employ about 4000 persons
- circa 2000 persons work on R&D activities
- spending about 200 M€ per year (50% of total budget) on R&D activities

*EURAMET new members 2010:*

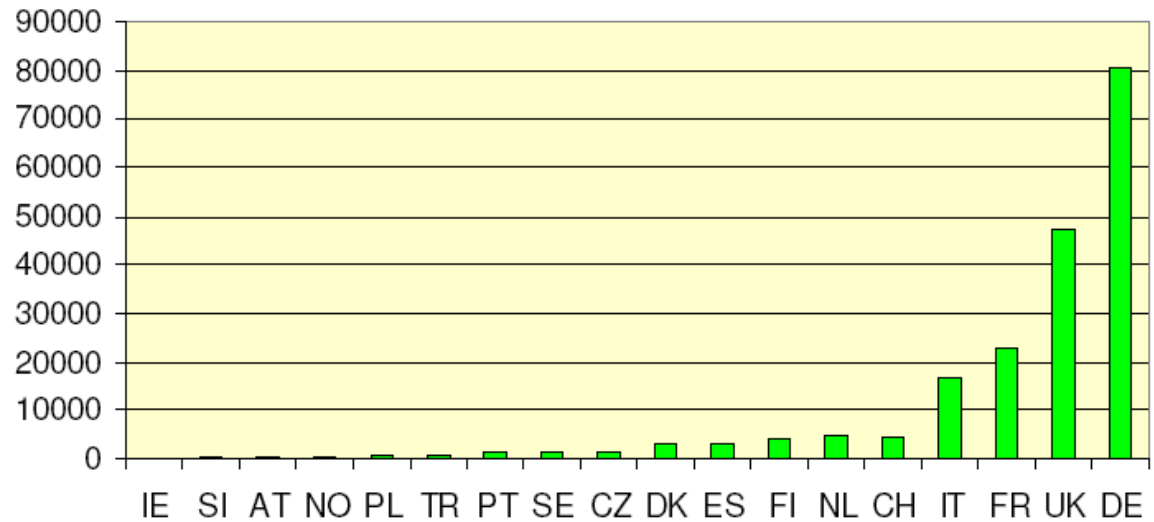
35th: DPM Albania

36th: BoM Macedonia (FYR)

37th: KDM Kosovo



**Metrology R&D budget - k€**



# Metrology – quality-assured measurement

*Traceability => measurements can be compared*

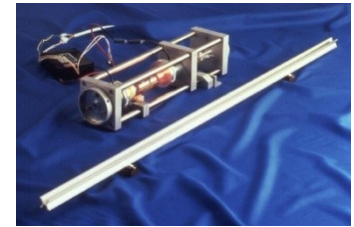
- Under both repeatability and reproducibility
- Even different measurement quantities

*Uncertainty => declared measurement quality*

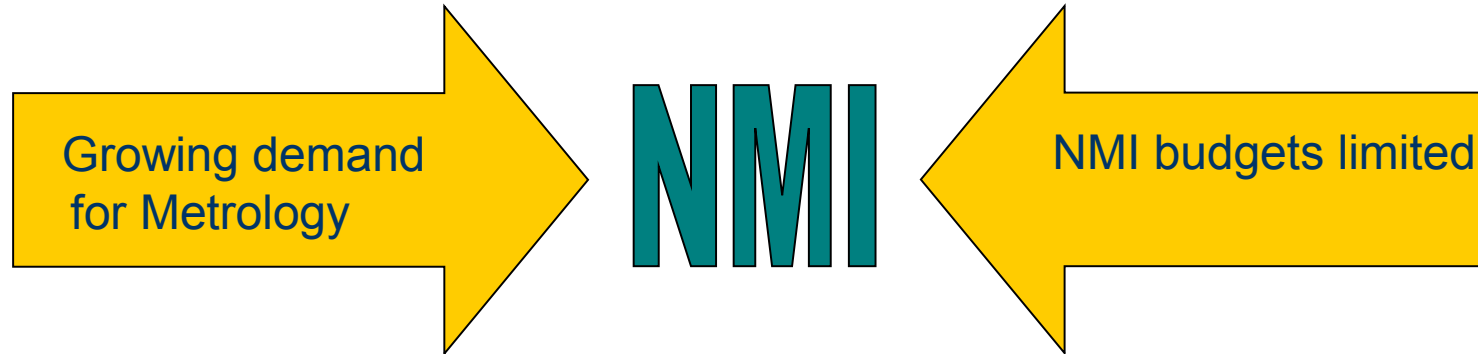
- 'Fit-for-purpose'
- Quantified risks of decision errors

*This gives processes and products which have:*

- Interoperability
- Improved communication
- Can be traded, are safe and lie within specifications



## Need for collaboration



- Traditional areas of industry
  - becoming more complex
  - requiring broader measurement ranges and lower uncertainties

- New areas of technology  
e.g. nano-technology or biotechnology
- Areas in which use of metrology is increasingly recognised  
e.g. chemistry, clinical analysis, food safety, the Grand Challenges,...



# Strategy for European national (nano)metrology 2020

– "Innovation Union" to improve framework conditions and access to finance for research and innovation so as to ensure that innovative ideas can be turned into products and services that create growth and jobs.

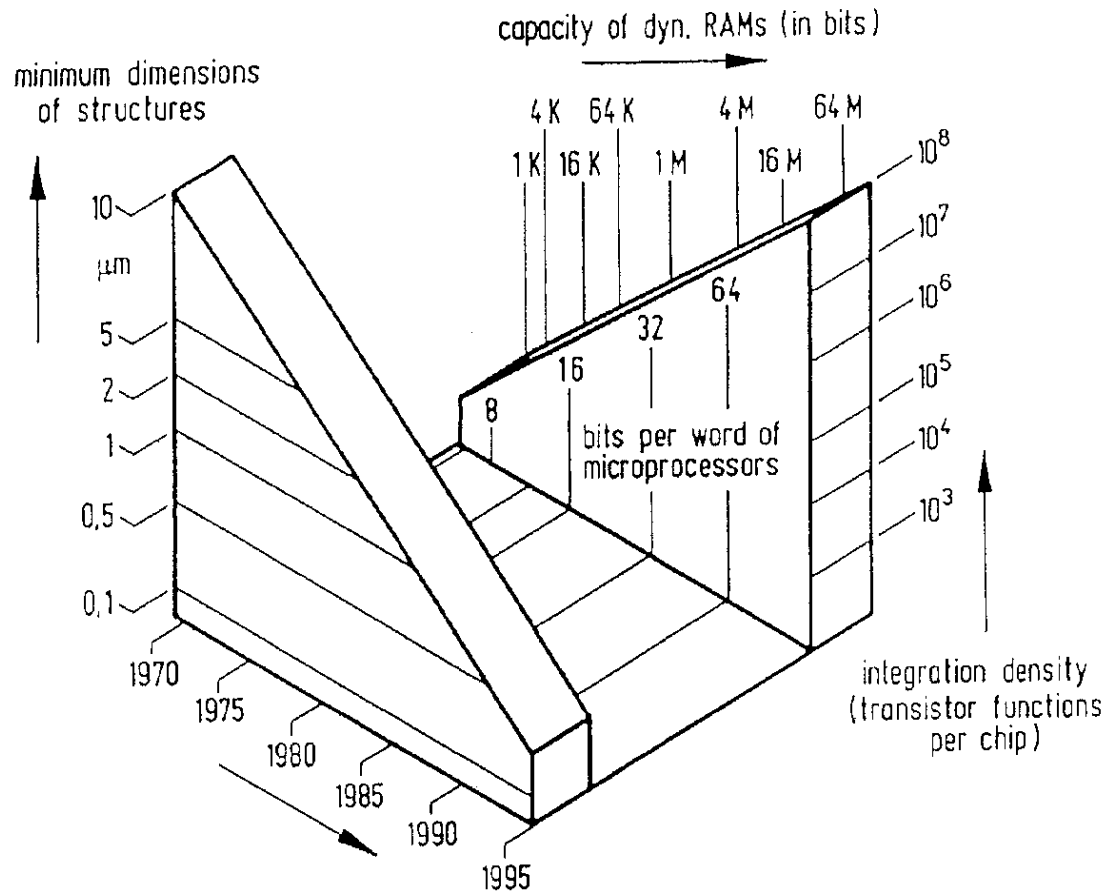
– "Resource efficient Europe" to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency.

– "An industrial policy for the globalisation era" to improve the business environment, notably for SMEs, and to support the development of a strong and sustainable industrial base able to compete globally.

**EUROPE 2020**

A European strategy for smart, sustainable and inclusive growth

# Nanometrology: Challenges



Miniaturization of integrated circuits.  
( source: Siemens, 1991 )

# Nanometrology: Challenges

Year of Production	2009	2010	2011	2012	2013	2014	2015	2016
<i>Microscopy</i>								
In-line, nondestructive microscopy process resolution (nm) for P/T=0.1	0,18	0,16	0,14	0,13	0,12	0,1	0,09	0,08
Microscopy capable of measurement of patterned wafers having maximum aspect ratio/diameter (nm) (DRAM contacts) [A]	17	>20	>20	>20	>20	>20	>20	>20
	60	50	40	35	30	28	25	23
<i>Materials and Contamination Characterization</i>								
Real particle detection limit (nm) [B]	20	18	16	14	13	11	10	9
Minimum particle size for compositional analysis (dense lines on patterned wafers) (nm)	17	15	13	12	11	9	8	7
Specification limit of total surface contamination for critical GOI surface materials (atoms/cm <sup>2</sup> ) [C]	5,00E+09	5,00E+09	5,00E+09	5,00E+09	5,00E+09	5,00E+09	5,00E+09	5,00E+09
Surface detection limits for individual elements for critical GOI elements (atoms/cm <sup>2</sup> ) with signal-to-noise ratio of 3:1 for each element	5,00E+08	5,00E+08	5,00E+08	5,00E+08	5,00E+08	5,00E+08	5,00E+08	5,00E+08

INTERNATIONAL  
TECHNOLOGY ROADMAP  
FOR  
SEMICONDUCTORS

2009 EDITION

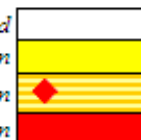
METROLOGY

*Manufacturable solutions exist, and are being optimized*

*Manufacturable solutions are known*

*Interim solutions are known*

*Manufacturable solutions are NOT known*

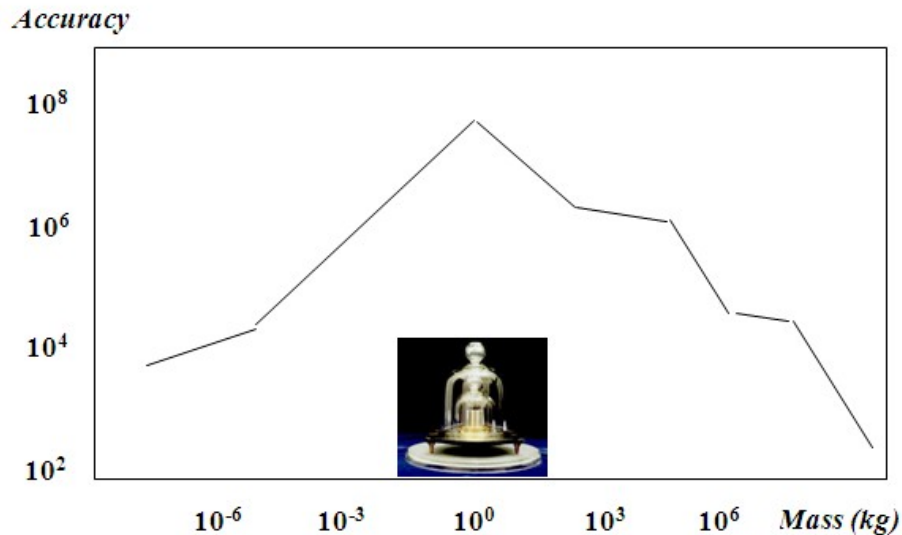


[http://www.itrs.net/Links/2009ITRS/2009Chapters\\_2009Tables/2009\\_Metrology.pdf](http://www.itrs.net/Links/2009ITRS/2009Chapters_2009Tables/2009_Metrology.pdf)

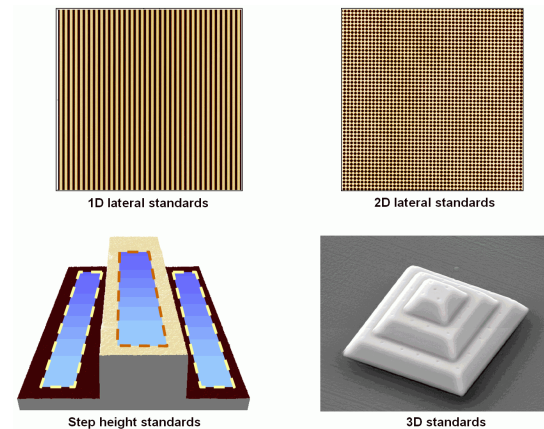
# Nanometrology: Challenges

- Longer chains of metrological traceability
- New nanoscale reference materials and standards
- Need for new measurement instrumentation and test methods working in the nanoscale
- New characteristics unique to the nanoscale need to be measured
- Measurements in challenging environments, e.g. ultra-high vacuum

## *Metrology over extended ranges*



Thorsten Dziomba, Hans U. Danzebrink PTB (DE)



M. Ritter and M. Hemmleb,  
m2c calibration, Potsdam (DE)

# Strategy for European national (nano)metrology 2020

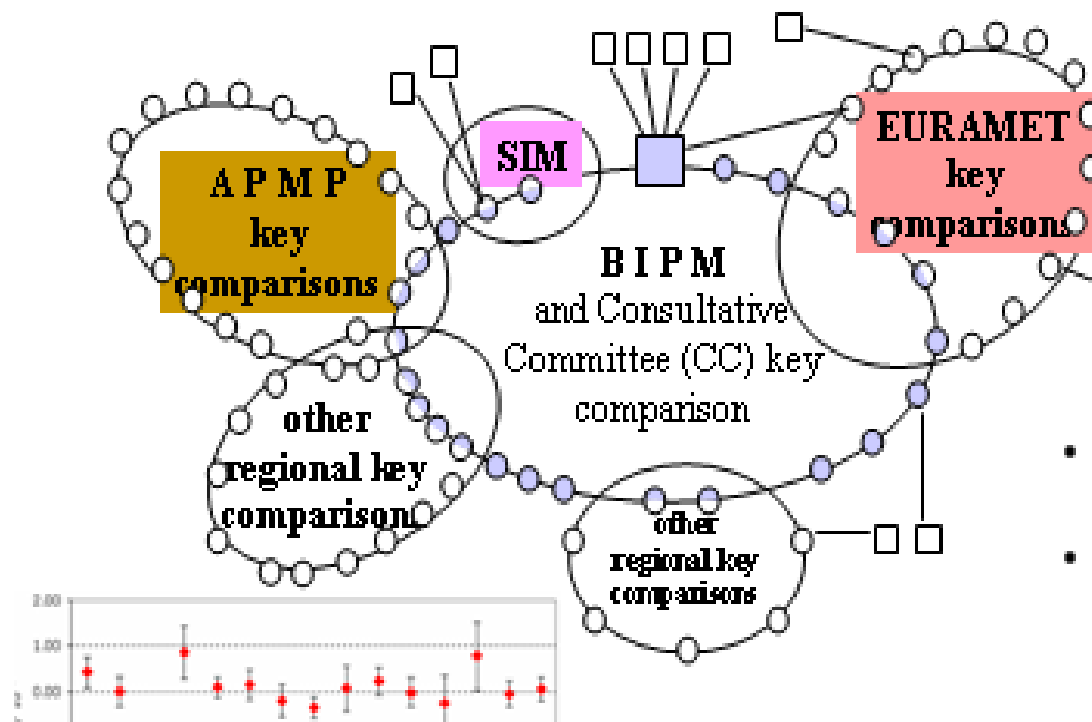
- "An industrial policy for the globalisation era" to improve the business environment, notably for SMEs, and to support the development of a strong and sustainable industrial base able to compete globally.

Traceability and metrology  
in industry

**Co-Nanomet**  
*Co-ordination of Nanometrology in Europe*

To bring nanotechnology through to successful business:

- relevant metrology tools
- suitably skilled human resources able to implement appropriately such tools



International recognition of national measurement standards and calibration & measurement capabilities (CMC)

Quality/management systems for EURAMET eV and its 100+ members and associate organisations

# Strategy for European national (nano)metrology 2020

## Traceability and metrology in industry

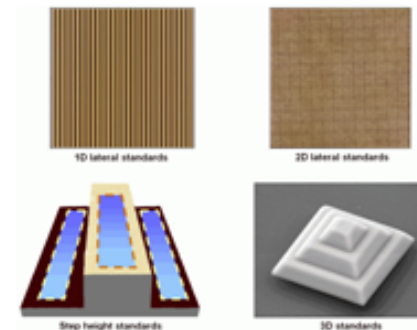
**Co-Nanomet**  
Co-ordination of Nanometrology in Europe

C Future needs & challenges, Metrology:

ENAG Critical Dimension and Scanning Probe Techniques

Comparison	Measurand	NMI	Status/Report
Euramet L-S15.a (Euromet 925)	Step height, 1D pitch	INRIM, MIKES, PTB, NMC/A*STAR, CMI	Draft B

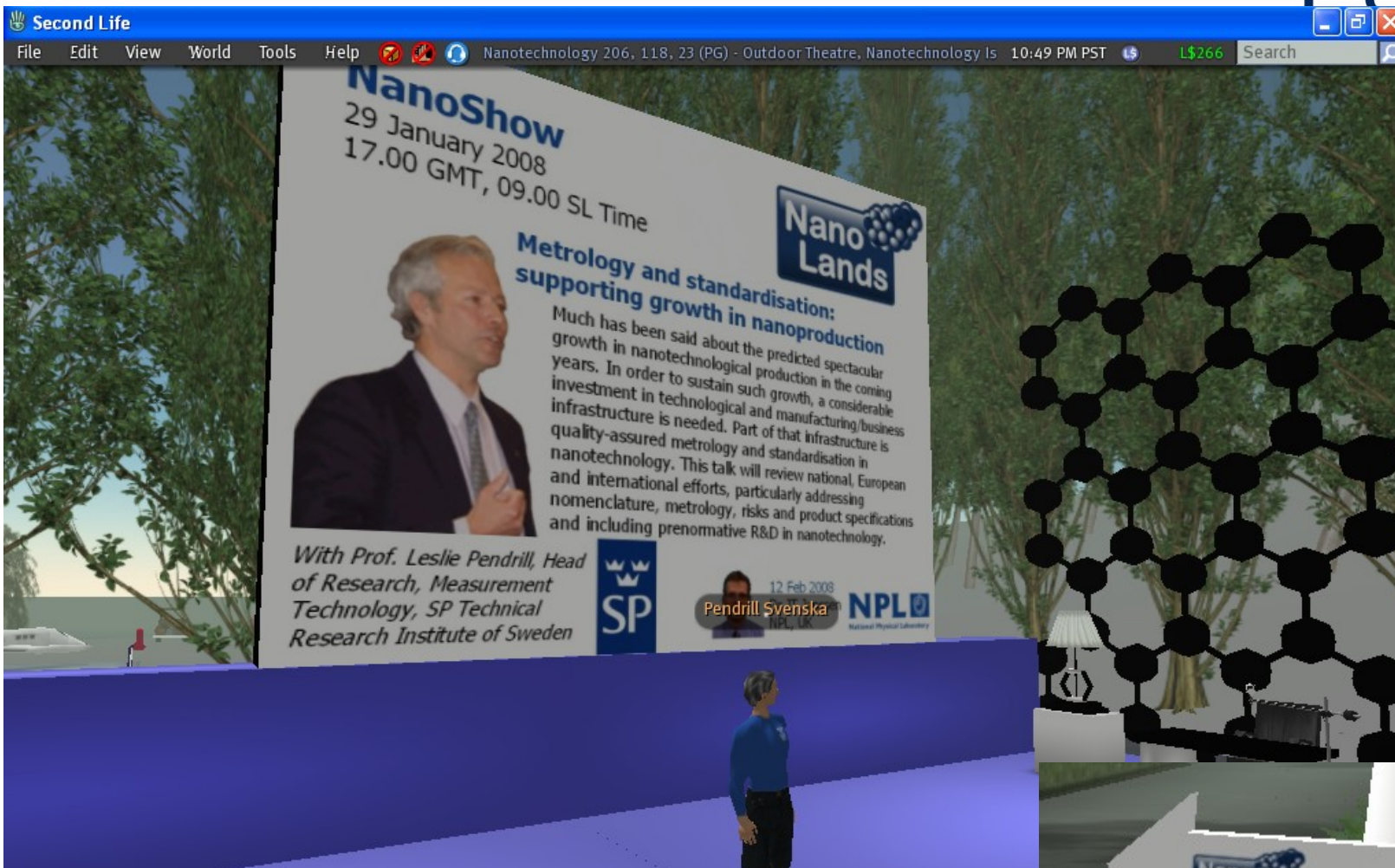
Thorsten Dziomba, Hans U. Danzebrink PTB (DE)



M. Ritter and M. Hemmleb, m2c calibration, Potsdam (DE)

Future intercomparisons:  
3D aspect of nanometrology  
(e.g. measuring shape and form of nano objects)

# "Sustaining growth in nanoproduction", SecondLife



# Strategy for European national (nano)metrology 2020

*Future needs & challenges, Standardisation:*

*Mandate:*

- Classification, terminology and nomenclature;
- Metrology and instrumentation, including specifications for reference materials;
- Test methodologies;
- Science-based health, safety and environmental practices;
- Nanotechnology products and processes.

[CEN TC/352 Nanotechnologies]



CEN/TC352 "Nanotechnologies"

<http://www.cen.eu/cen/Sectors/Sectors/Nanotechnologies/Pages/default.aspx>

# Strategy for European national (nano)metrology 2020



## COOPERATION AGREEMENT

Between

The EUROPEAN ASSOCIATION OF NATIONAL METROLOGY INSTITUTES

and

The EUROPEAN COMMITTEE FOR STANDARDIZATION

together with

The EUROPEAN COMMITTEE FOR ELECTROTECHNICAL STANDARDIZATION



Mrs Elena Santiago (Director General CEN-CENELEC) and Prof. Leslie Pendrill (Chairperson, EURAMET)

**New!** CEN-CENELEC/EURAMET CA Signed June 29th 2010 Brussels

*Strategic goals and projects of common interest:*

- in fields of metrology and standardization
- in support of scientific advancement and technological innovation
- to meet societal challenges with a significant impact on the economy and the quality of lives within Europe

# Strategy for European national (nano)metrology 2020

- "An industrial policy for the globalisation era" to improve the business environment, notably for SMEs, and to support the development of a strong and sustainable industrial base able to compete globally.

## *Policy support, regulation and written standards*

Quality-assured measurement => development of both generic standards and sector-specific standards:

- Sometimes unrealistic and ambiguous measurement specifications and unclear requirements.

## *Pre-normative R&D in context of conformity assessment*

Industry and society place increasingly exacting demands:

- Meeting 'grand challenges' such as in energy & the environment, health & safety
- Emergence of new technologies such as nano- and biotechnology.
- New science

A *Future needs & challenges, Standardisation:*

ENAG Engineered Nanoparticles

Methods to assess:

- **parameters describing aggregates/agglomerates**, e.g.  $X_{Gyr}$ ,  $N_{agg}$
- **shape parameters** from morphology data, e.g. sphericity, aspect ratio, fractal dimension for  $X_{Gyr}$
- **surface area** of a dispersed phase in a liquid phase (for example via SAXS or via titration experiments )
- **concentration** of particles in liquid or solid matrices
- **solubility and dissolution kinetics** of engineered nanoparticles (ENP)
- **wettability** of ENPs
- particle **structure** (porosity, fractal dimension)
- **composition** of different parts in nanostructured ENPs at the nanoscale (core-shell, hybrid,...)
- **density and optical properties** of nanoparticles



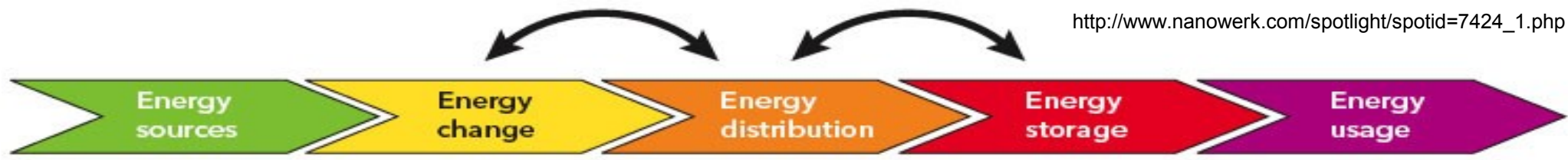
**NMP Theme**

CO-NANOMET

Co-ordination of NANOMETrology in Europe

Michael Stintz, Gert Roebben (contribution from ENAG1)

CO-NANOMET EU FP7 CSA-GA 218764



**Regenerative**

**Photovoltaics:** Nano-optimized cells (polymeric, dye, quantum dot, thin film, multiple junction), antireflective coatings

**Wind Energy:** Nano-composites for lighter and stronger rotor blades, wear and corrosion protection nano-coatings for bearings and power trains etc.

**Geothermal:** Nano-coatings and -composites for wear resistant drilling equipment

**Hydro-/Tidal Power:** Nano-coatings for corrosion protection

**Biomass Energy:** Yield optimization by nano-based precision farming (nanosensors, controlled release and storage of pesticides and nutrients)

**Fossil Fuels**

Wear and corrosion protection of oil and gas equipment, nanoparticulated oil yields

**Nuclear**

Nano-composites for radiation shielding and protection (personal equipment, container etc.), long term option for nuclear fusion reactors

**Gas Turbines**

Heat and corrosion protection of turbine blades (e.g. ceramic or intermetallic nano-coatings) for more efficient turbine power plants

**Thermoelectrics**

Nanostructured compounds (interface design, nanorods) for efficient thermoelectrical power generation (e.g. usage of waste heat in automobiles or body heat for personal electronics (long term))

**Fuel Cells**

Nano-optimized membranes and electrodes for efficient fuel cells (PEM) for applications in automobiles/mobile electronics

**Hydrogen Generation**

Nano-catalysts and new processes for more efficient hydrogen generation (e.g. photoelectrical, electrolysis, biophotonic)

**Combustion Engines**

**Electrical Motors**

Nano-composites for superconducting components in electro motors (e.g. in ship engines)

**Power Transmission**

**High-Voltage Transmission:** Nanofillers for electrical isolation systems, soft magnetic nano-materials for efficient current transformation

**Super Conductors:** Optimized high temperature SC's based on nanoscale interface design for loss-less power transmission

**CNT Power Lines:** Super conducting cables based on carbon nanotubes (long term)

**Wireless Power Transmission:** Power transmission by laser, microwaves or electromagnetic resonance based on nano-optimized components (long term)

**Smart Grids**

Nanosensors (e.g. magneto-resistive) for intelligent and

**Efficient heat in- and outflow** based on nano-optimized heat exchangers and conductors (e.g. based on CNT-composites) in industries and building

**Electrical Energy**

**Batteries:** Optimized Li-ion-batteries by nanostructured electrodes and flexible, ceramic separator-foils, application in mobile electronics, automobile, flexible load management in power grids (mid term)

**Supercapacitors:** Nanomaterials for electrodes (carbon-aerogels, CNT, metall(-oxides) and elektrolytes for higher energy densities)

**Chemical Energy**

**Hydrogen:** Nanoporous materials (organometals, metal hydrides) for application in micro fuel cells for mobile electronics or in automobiles (long term)

**Fuel Reforming/Refining:** Nano-catalysts for optimized fuel production (oil refining, desulphurization, coal liquefaction)

**Fuel Tanks:** Gas tight fuel tanks based on nano-composites for reduction of hydrocarbon emissions

**Adsorptive Storage:** Nano-porous materials (e.g.

**Thermal Insulation**

Nanoporous foams and gels (aerogels, polymer foams) for thermal insulation of buildings or in industrial processes

**Air Conditioning**

Intelligent management of light and heat flux in buildings by electrochromic windows, micro mirror arrays or IR-reflectors

**Lightweight Construction**

Lightweight construction materials using nano-composites (carbon nanotubes, metal-matrix-composites, nano-coated light metals, ultra performance concrete, polymer-composites)

**Industrial Processes**

Substitution of energy intensive operations (e.g. etc.)

**Lighting**

– "Resource efficient Europe" to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency.

# European Metrology Research (EMRP)

## Grand Challenges

- Health
- Energy
- Environment
- New technologies for nanosciences and security

## R&D for fundamental and applied metrology

- Fundamental metrology
- Focused single discipline and Applied metrology

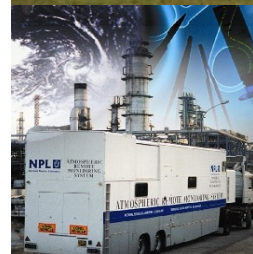
Mobility, Capacity Building, KE

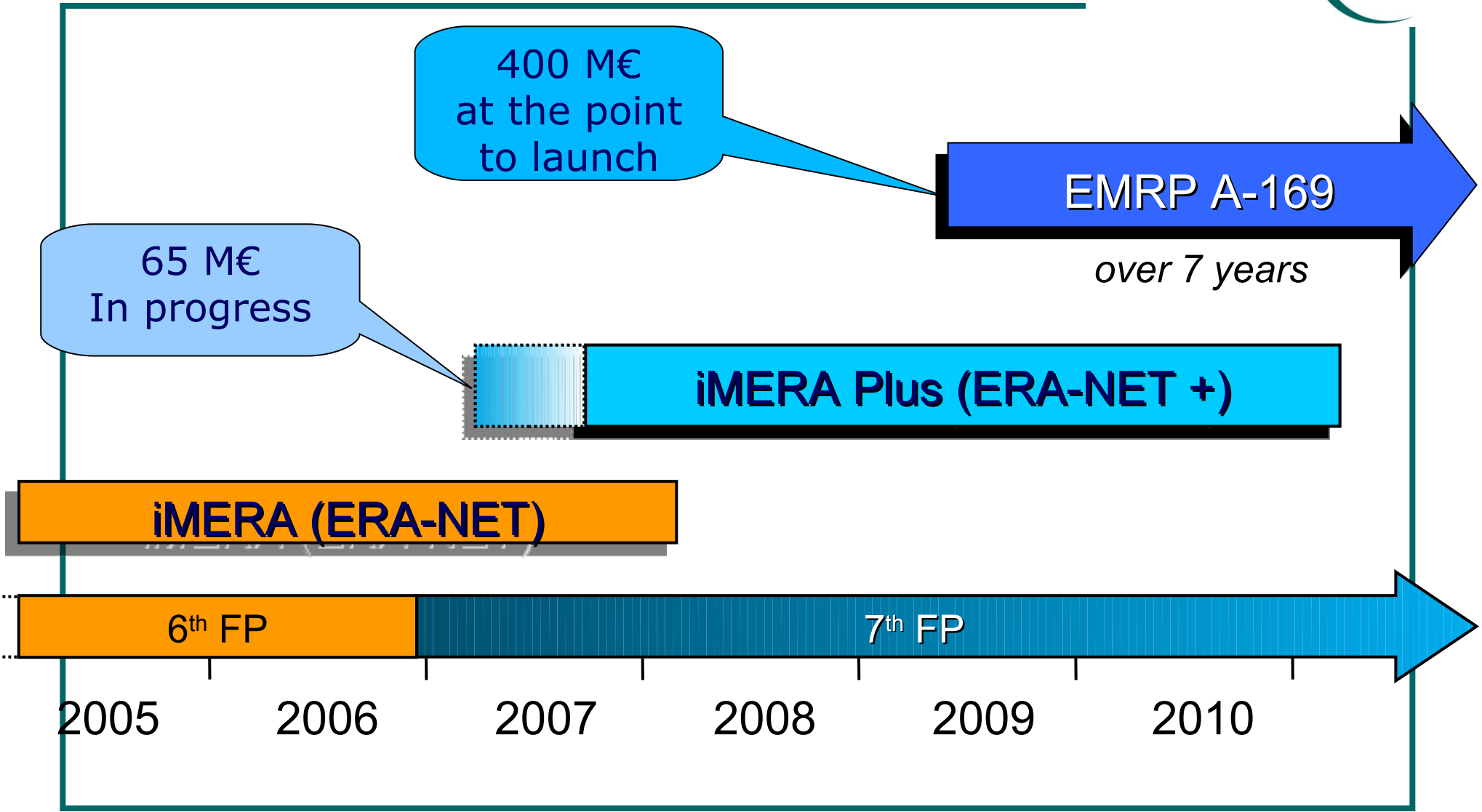
[www.euramet.org](http://www.euramet.org)



European Metrology Research Programme

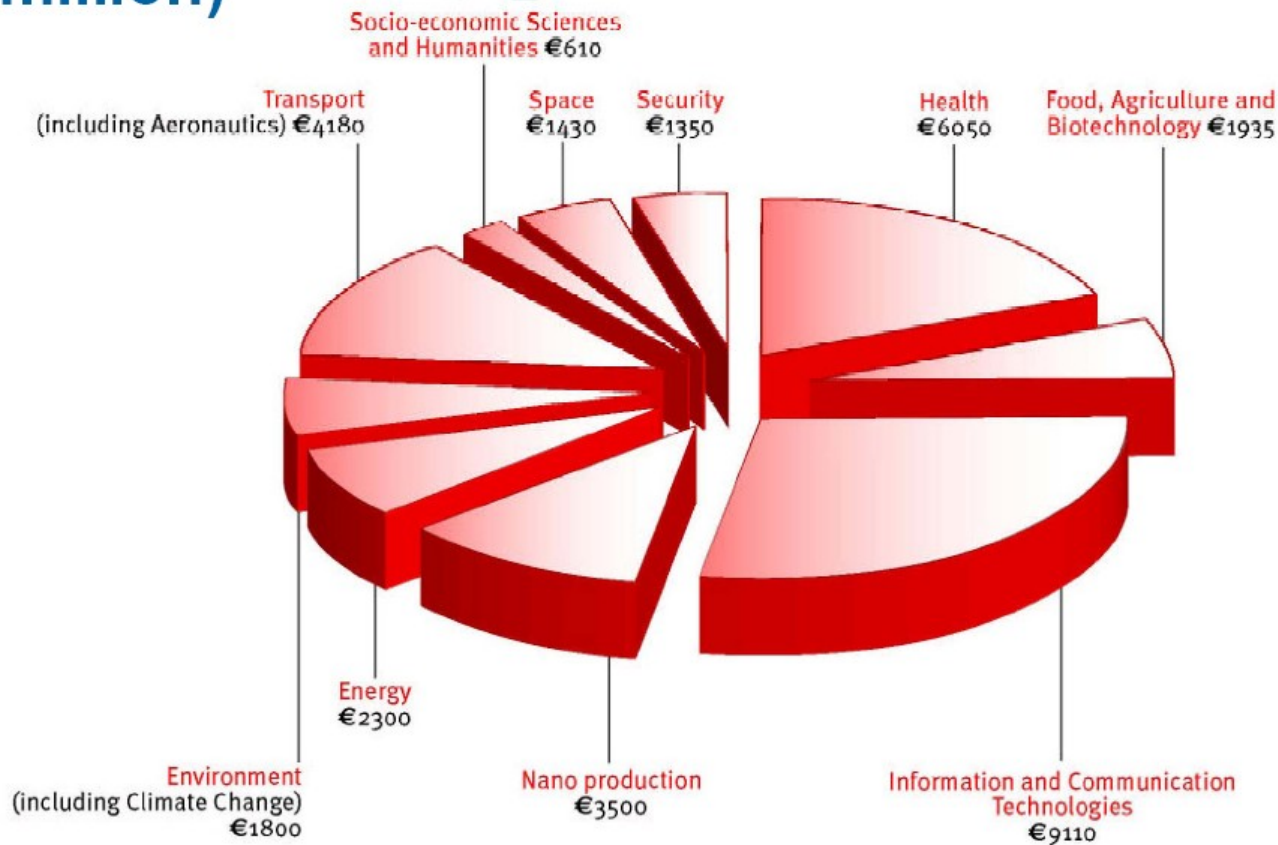
Outline 2008





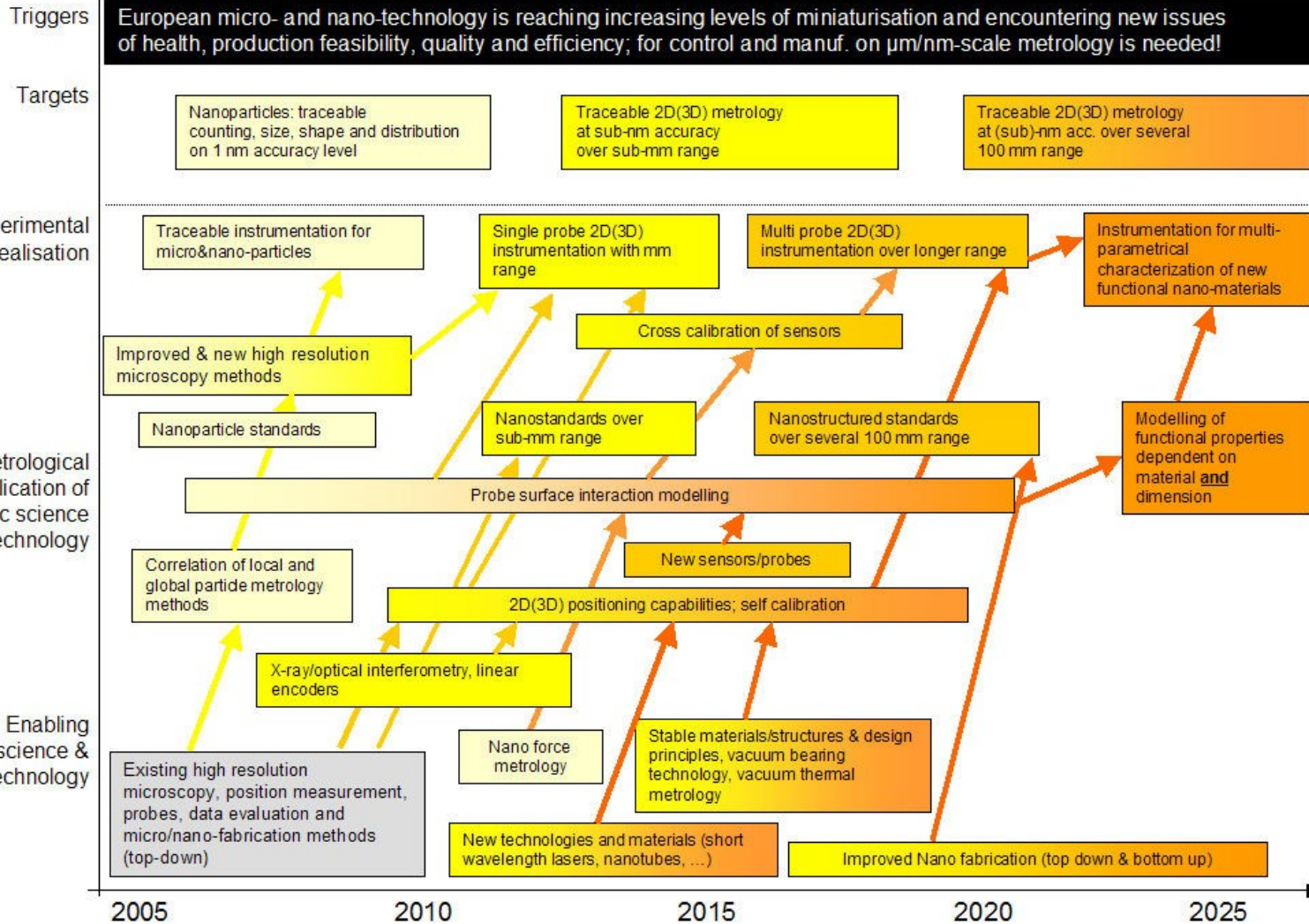


## Cooperation programme - thematic areas (€ million)



EMRP  
€220 million COM

**Dimensional metrology for micro-nano technology – DRAFT B**



**Theme 2: Health**

T2.J02	Breath analysis	Breath analysis as a diagnostic tool for early disease detection
T2.J04	Regenmed	Metrology on a cellular scale for regenerative medicine
T2.J06	Brachytherapy	Increasing cancer treatment efficacy using 3D brachytherapy
T2.J07	EBCT	External Beam Cancer Therapy

**ERA-NET+**  
*iMERApplus* 64.6M€

T2.J10 TRACEBIOACTIV

**Theme 3: Length**

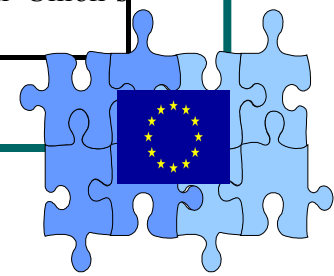
		T3.J1.1	Nanoparticles	Traceable Characterization of Nanoparticles
T2.J.11	CLINBIOTRACE	T3.J1.4	NANOTRACE	New Traceability Routes for Nanometrology
		T3.J2.2	NIMTech	Metrology for New Industrial Measurement

**Theme 4: Electricity and Magnetism**

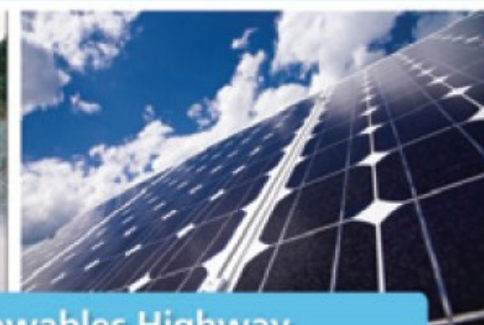
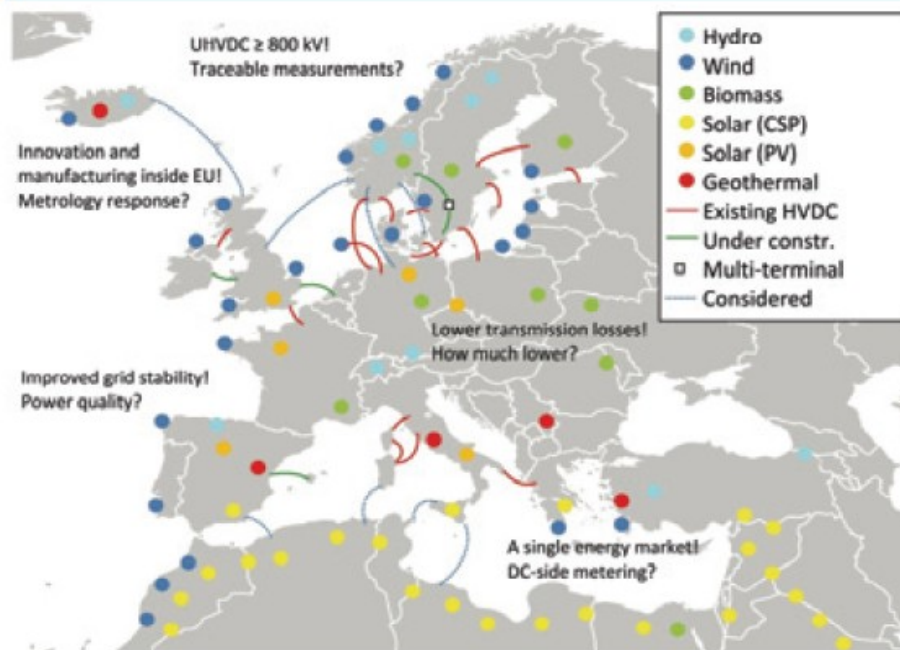
T4.J01	Power & Energy	Next generation of power and energy measuring techniques
T4.J02	NanoSpin	Nanomagnetism and Spintronics
T4.J03	JOSY	Next generation of quantum voltage systems for wide range applications
T4.J04	ULQHE	Enabling ultimate metrological Quantum Hall Effect (QHE) devices

Characterization of energy gases	Enable users of different gaseous fuel types to make informed commercial, environmental and safety decisions based on comparable measurements of the energy content, carbon content, moisture content and physical/chemical properties of the fuels.
Energy harvesting	Develop metrological methods for the assessment and improvement of integrated micro-/nano-generator systems.
Liquefied Natural Gas	Develop new and improved measurement techniques for Liquefied Natural Gas transfer, to support a more diversified and secure energy supply for Europe, and fair and open trade in natural gas.
Smart electrical grids	Develop a metrological capability and infrastructure to support successful implementation of a Smart Grid in Europe, enabling low losses, security of electricity supply, grid stability and fair trade between commercial parties using the grid.
Solid-state lighting	Improve metrology for novel light sources (including optical, thermal, electrical and visual perception measurements) to support a consumer-led market increasing the uptake of these energy efficient light sources and meeting EU targets.
Improved power plant efficiency	Improve power plant efficiency through the development of reliable and accurate in-situ temperature, thermophysical, mechanical properties, flow rate measurements and electrical power output of generating plants.
High-voltage DC	Provide metrology support to ensure accurate loss measurement in HVDC stations, and fair trade between commercial parties employing the electricity grid.
New generation of nuclear power plants	Advance measurement capability to enable improved nuclear power plants including temperature, thermal properties, interaction cross sections, half-life of nuclides, absolute activation, thermo-chemical data and modelling and radiochemical analysis.
Biofuels	Develop the metrological capability and infrastructure to determine the physical and chemical characteristics, and the geographical and biological origin of biofuels to enable compliance with the European Union's Renewable Energy Directive.

Art 185 2009 34 M€



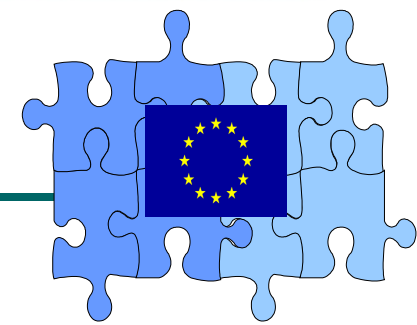
## ENG07: Metrology for HVDC



### HVDC – Renewables Highway



EMRP A169 ENG07 HVDC, Co-ordinator: SP (Sweden)



## EMRP A185 (169)

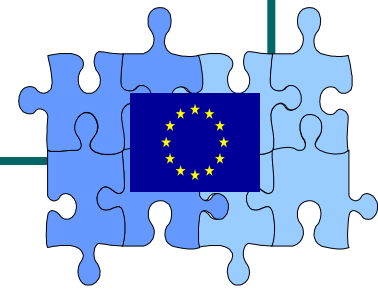
EURAMET EMRP Targeted Programme

“Metrology & the Environment” 2010 - 2013

### *Aim*

- improve quality of data for policy making and regulation
- underpin other environmental research initiatives through collaborative metrological research and development
- stimulate technological innovation

Art 185 2010 42.8 M€



# EMRP A185 (169)

## EURAMET EMRP Targeted Programme

### “Metrology for Industry” 2010 – 2013

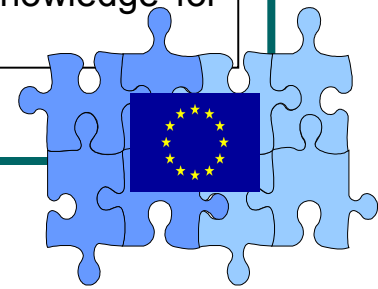
#### *Aim*

- Develop metrological methods to improve the metrological infrastructure with industry
- Industrial exploitation of quality-assured measurements in terms of traceability and measurement uncertainty.

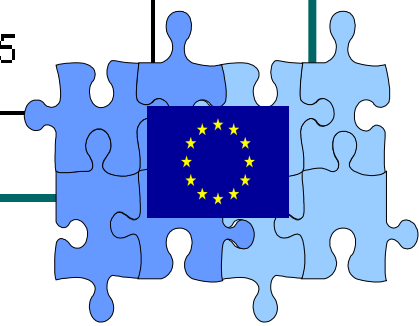
#### *Metrological research which:*

- improves competitiveness of European industry
- generates knowledge to ensure industry's transformation from resource-intensive to knowledge-intensive base,
- optimization and enhancement of efficiency and effectiveness by 'smarter' application of existing technologies
- innovations and possibly step changes through research and implementing decisive knowledge for new applications at crossroads between different technologies and disciplines

Art 185 2010 49.3 M€

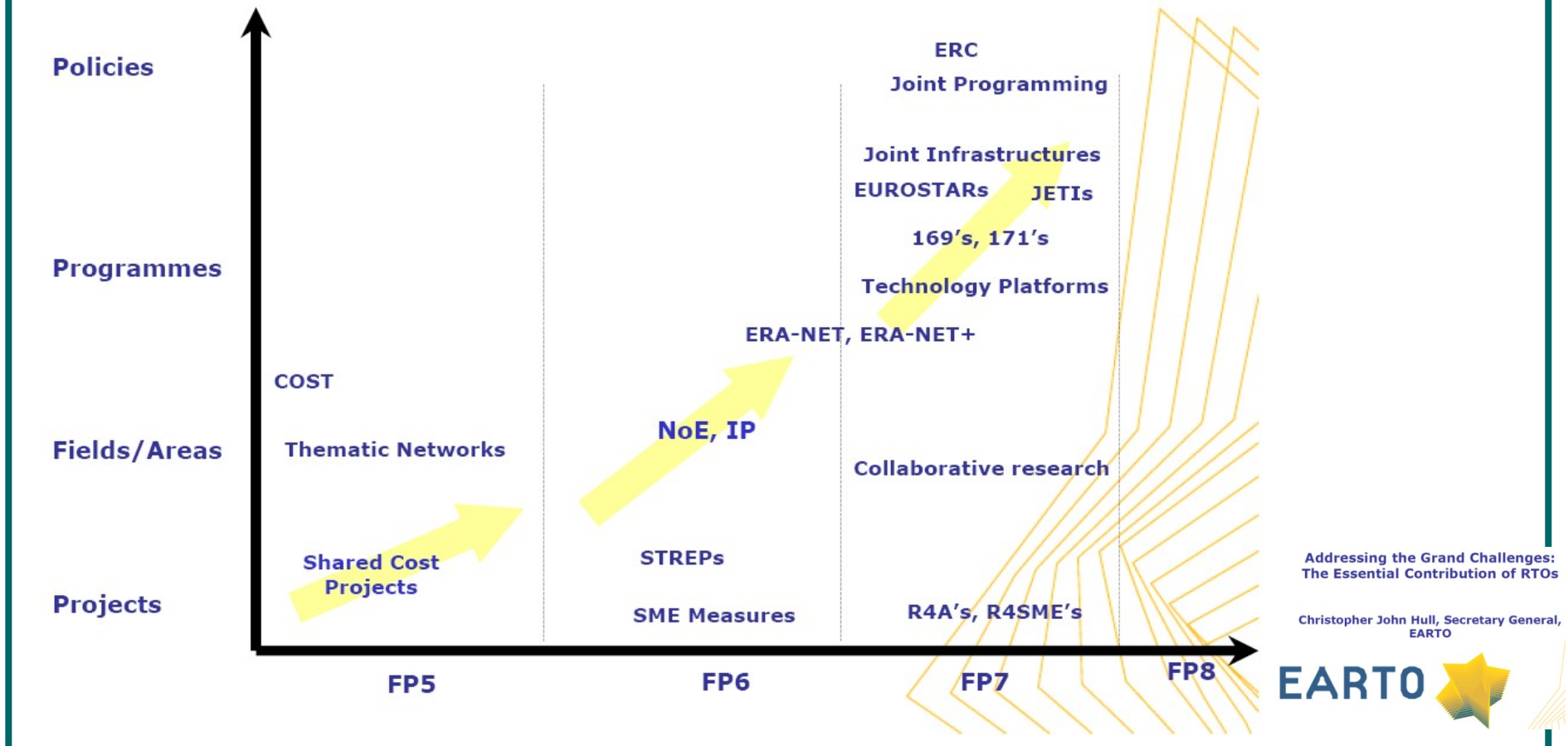


			Targeted Programme (TP)	total budget of TP (mio €)	COM budget appropriations (mio €)
call 1	2009	a)	Energy (1 <sup>st</sup> )	34	17
call 2	2010	b)	Environment (1 <sup>st</sup> )	48	48
		c)	Metrology for Industry (1 <sup>st</sup> )	48	
call 3	2011	d)	Health (2 <sup>nd</sup> )	30	45
		e)	SI broader scope (1 <sup>st</sup> )	30	
		f)	New Technologies	30	
call 4	2012	g)	Metrology for Industry (2 <sup>nd</sup> )	40	45
		h)	SI broader scope (2 <sup>nd</sup> )	40	
		i)	Open excellence call	10	
call 5	2013	j)	Energy (2 <sup>nd</sup> )	55	45
		k)	Environment (2 <sup>nd</sup> )	35	



# Joint programming

## Changing Architecture of EU R&D Policy



# Strategy for European national (nano)metrology 2020

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– "Resource efficient Europe" to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency.

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**EUROPE 2020**

A European strategy for smart, sustainable and inclusive growth