Laboratoire national de métrologie et d'essais

Dr Jean-Rémy FILTZ



LNE
Sharing a passion for progress

Thermal and Optical Metrology

A panorama of Key recent developments at LNE

Metrology for Health, Environment and Energy

Outline

1 - Main actions for sustaining the Industry

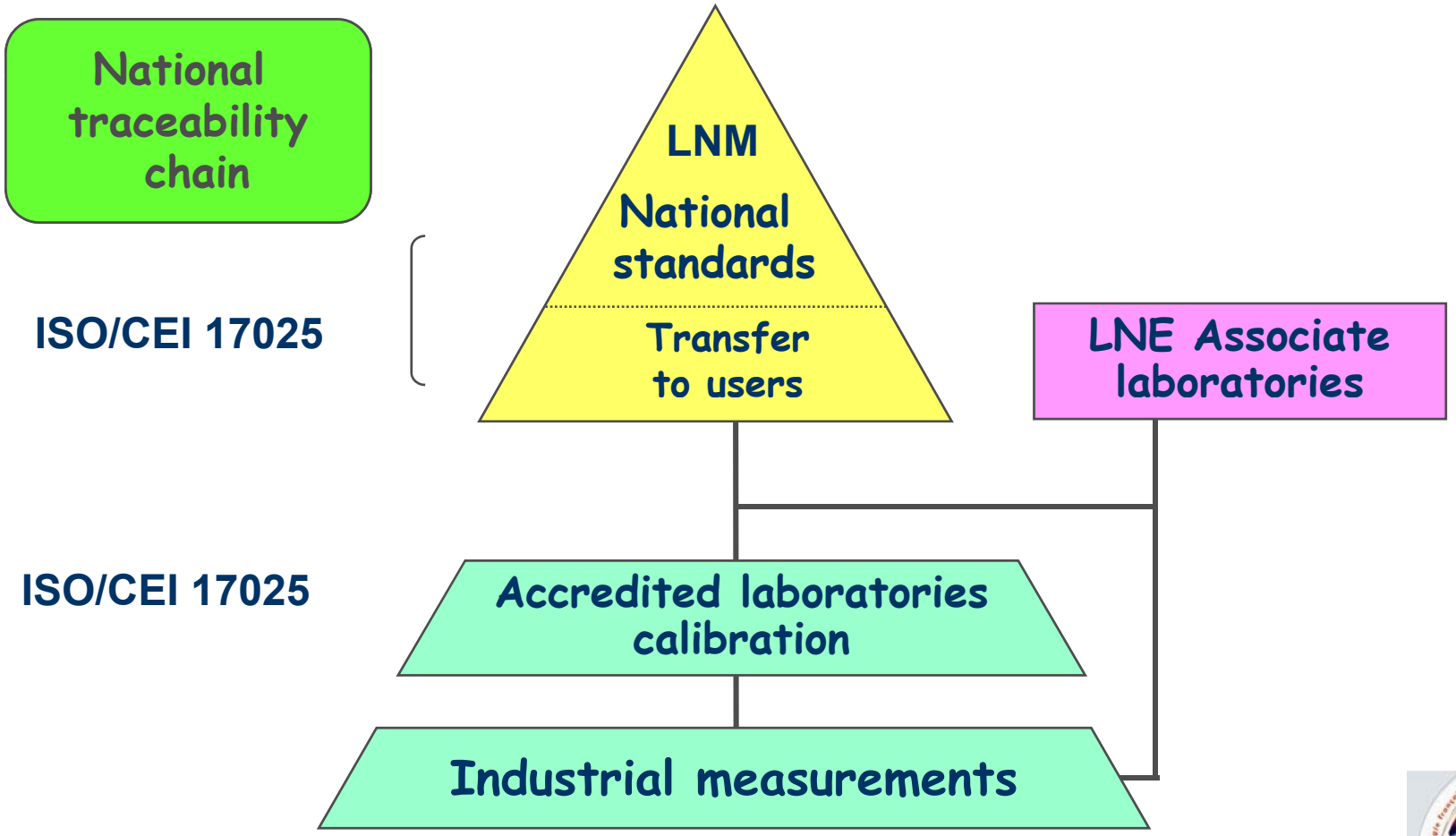
2 - New triggers driving developments in metrology

3 - 4 examples in 3 domains

4 - Conclusions

Main actions for sustaining the Industry

Traceability



Main actions for sustaining the Industry

- Perform missions devoted to National Metrology Institute
  - Develop National Standards for basic units
  - Maintain National standards and develop sub units
  - Guaranty traceability to industry
  - Provide technical assistance to industry in supporting and developing Metrology

Based on the experience acquired for constructing the future…

Applied Research

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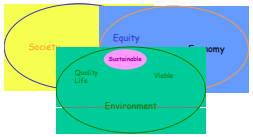
- Development of **standards** and **specifications**
- Studies for **innovative technical solutions**

- Design, **development and fine adjustment of test** and **calibration facilities**
- **Experiments** and **statistical analysis programmes**

Based on the experience acquired for constructing the future…

New triggers driving developments in metrology

Sustainable development



Global warming

Kyoto Protocol

International Issues

European Directives, Regulation,…

Grenelle de l'environnement

Agenda 21…

National or European Issues

Based on the experience acquired for constructing the future…

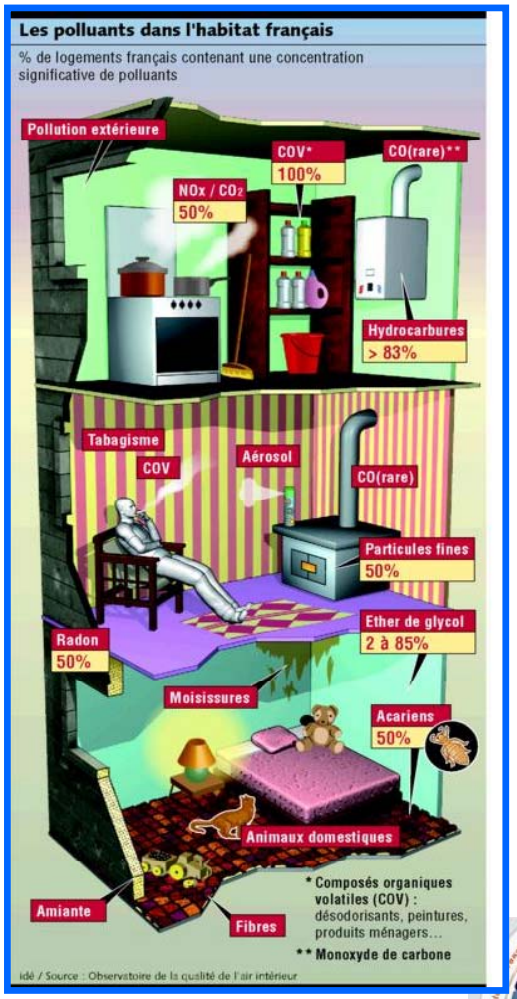
New triggers driving developments in metrology

- Help governmental agencies to prevent Society from risks
- Support policies related to public health
- Support French and European industry…
- Act for constructing a European Metrology infrastructure
- Support and take part in advanced metrology
- Disseminate Metrology and Knowledge Transfer

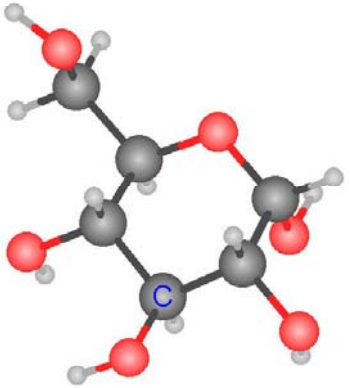
Based on the experience acquired for constructing the future…

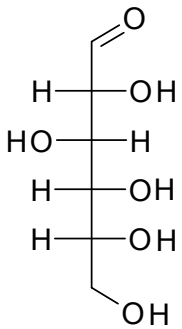
Environment : developments at LNE

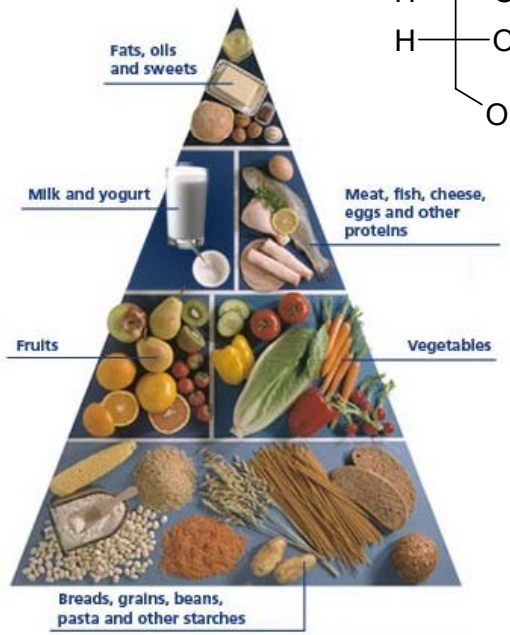
- Indoor air quality
- NO_2, VOCs
- Aldehydes
- GhG
- Heavy metals,
- HAP, PCB,
- Endocrine disruptors
- Speciation
- Pesticides, OCP



Health: developments at LNE

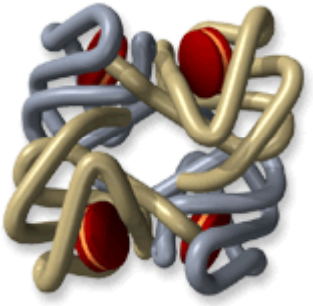


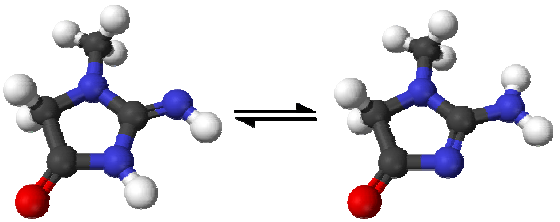




Diabetes food pyramid

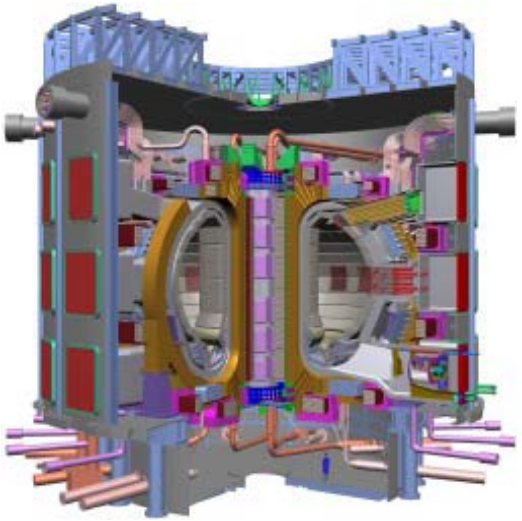
- Traceability of bio-medical analysis
- Glycosylated hemoglobin - Diabetes
- Measuring out Glucose concentration
- Blood pressure metrology
- Ethylometry
- Creatinine
- Tonometry, Spirometry
- UV radiometry
- Metrology to prepare for a potential pandemic influenza
- Metrology supporting Nano-particles developments





Energy: developments at LNE

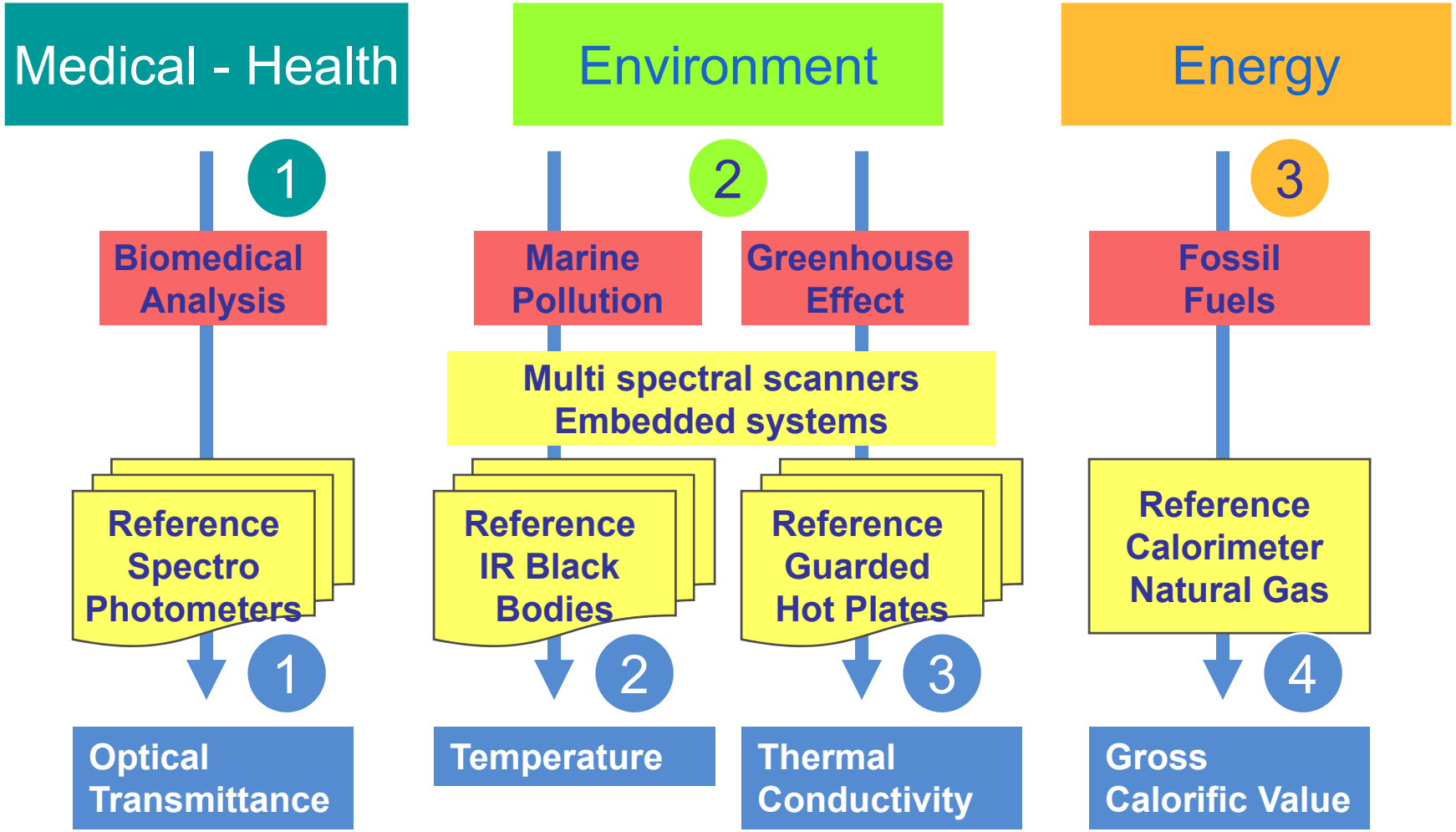
Help saving energy
Power and Energy,
Energy conversion and
Metrology;
LEDs highlighting
Solar
Biofuels…



Iter : International thermonuclear experimental reactor

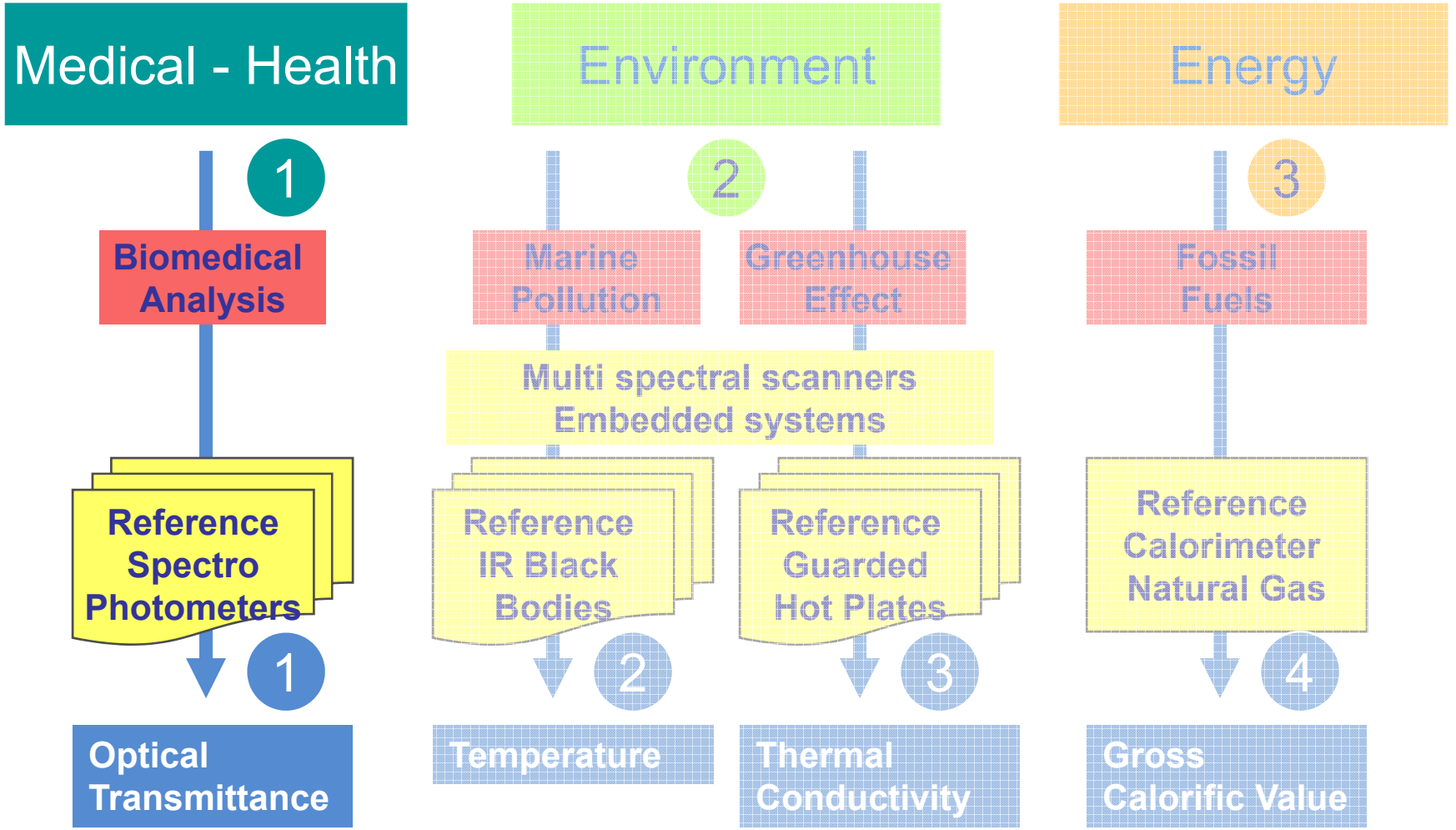
Developments : 4 examples in 3 domains

In the field of Thermal and Optical Metrology

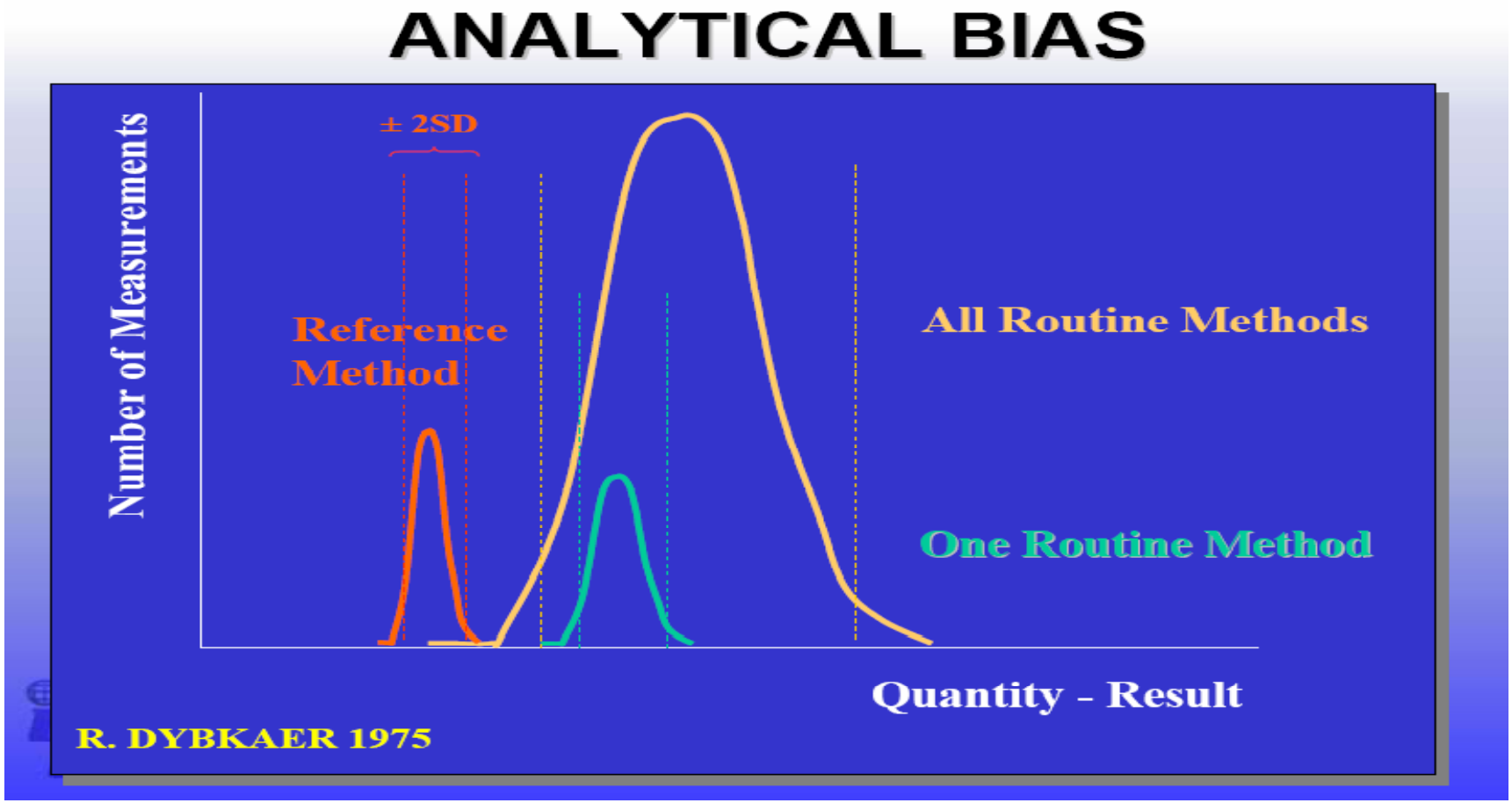


Medical - Health

In the field of Thermal and Optical Metrology



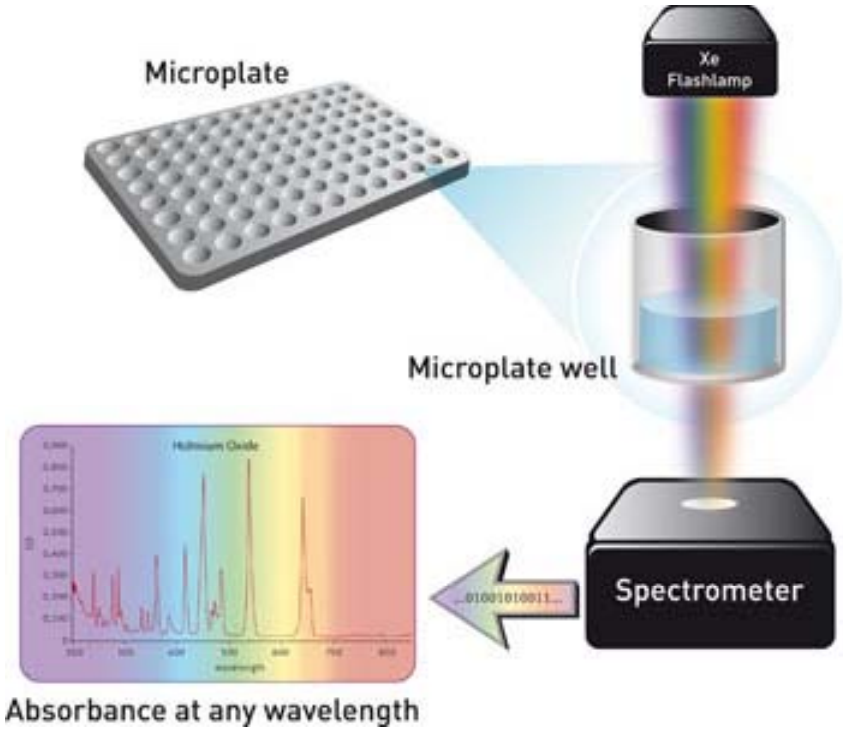
Biomedical analysis and Traceability



Traceability to references : a common requirement
Directive 98/79 DIV, ISO 17511, ISO 15195

Biomedical laboratory and Optical properties of liquids

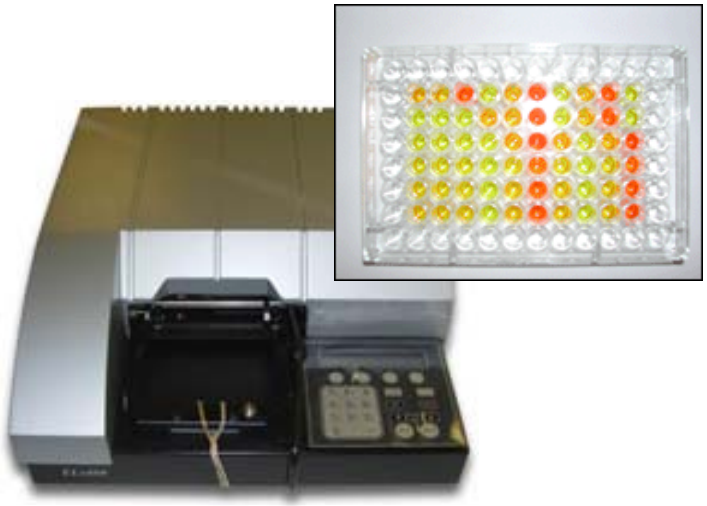
Testing laboratories using optical instruments such as **microplates readers** for making biological and bacteriological analyses in the field of health, food or the environment **need to be traceable to SI**



Source :www.bmglabtech.com

Biomedical laboratory and Optical properties of liquids

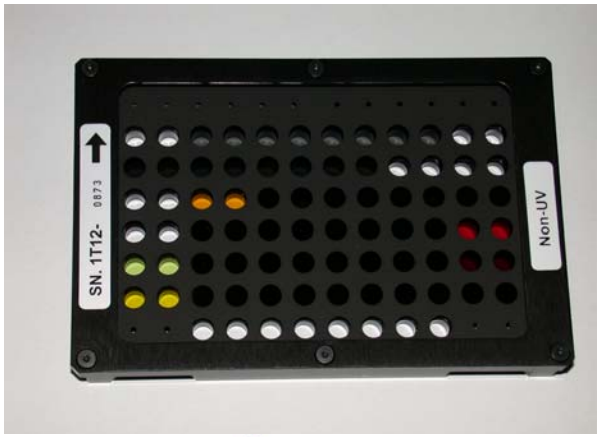
For quality assurance, the sets of filters fitted into quality control plates, used to check the accuracy of microplates readers, require

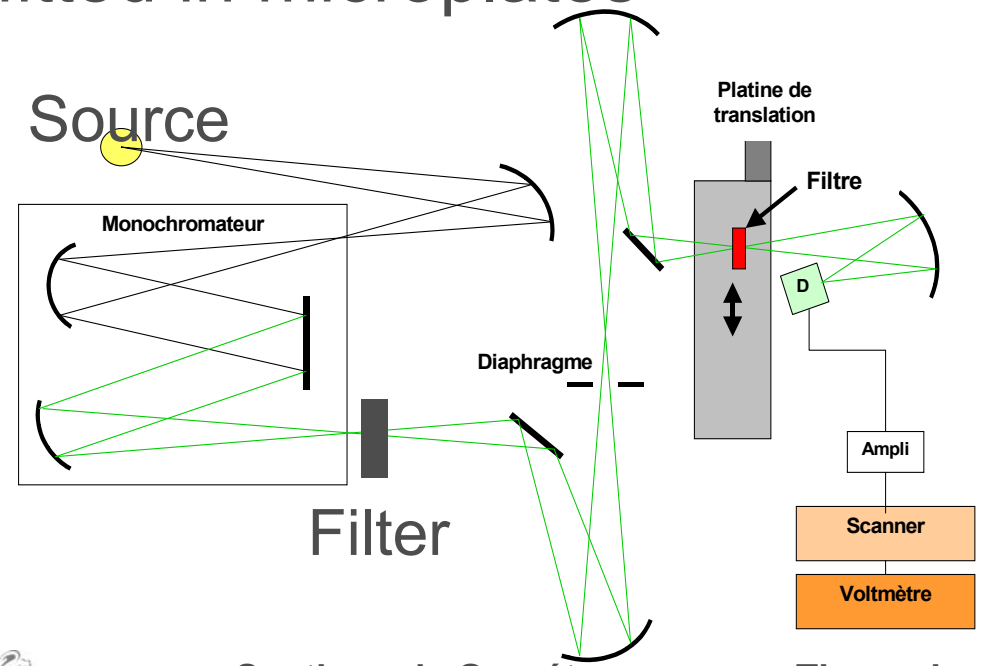


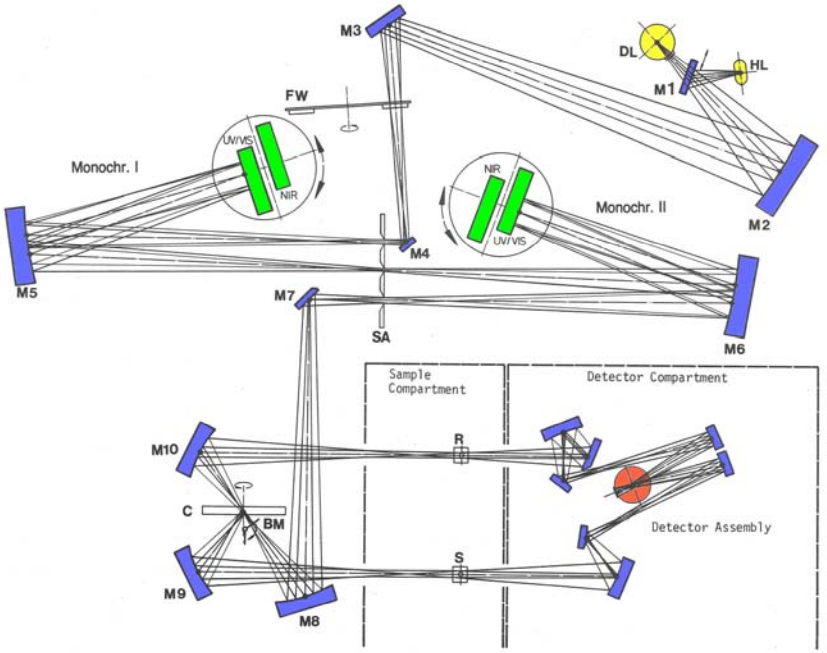
calibration in spectral optical density

Biomedical laboratory and Optical properties of liquids

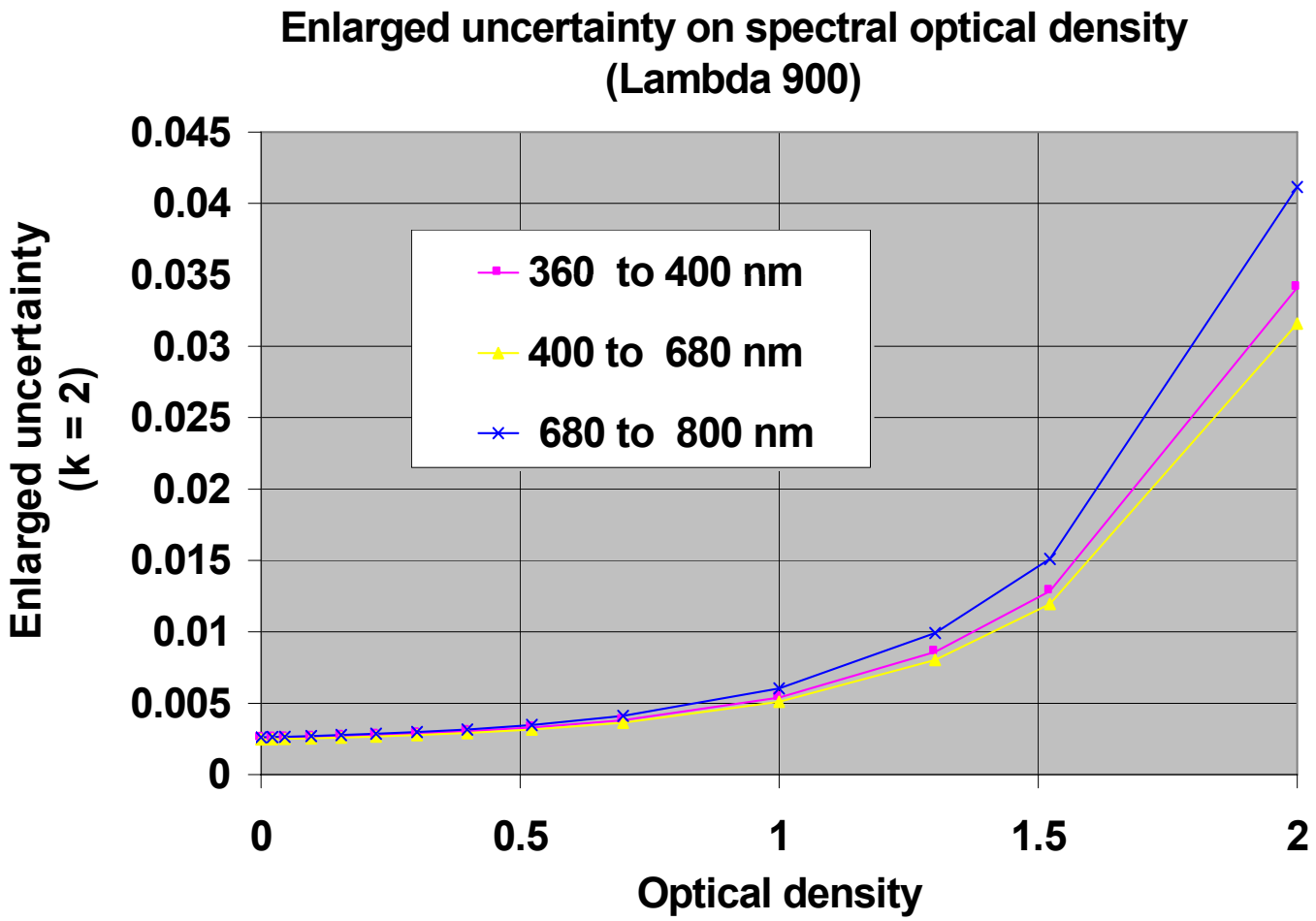
LNE has developed specific ways to calibrate in regular spectral transmittance the very **small reference filters** fitted in microplates





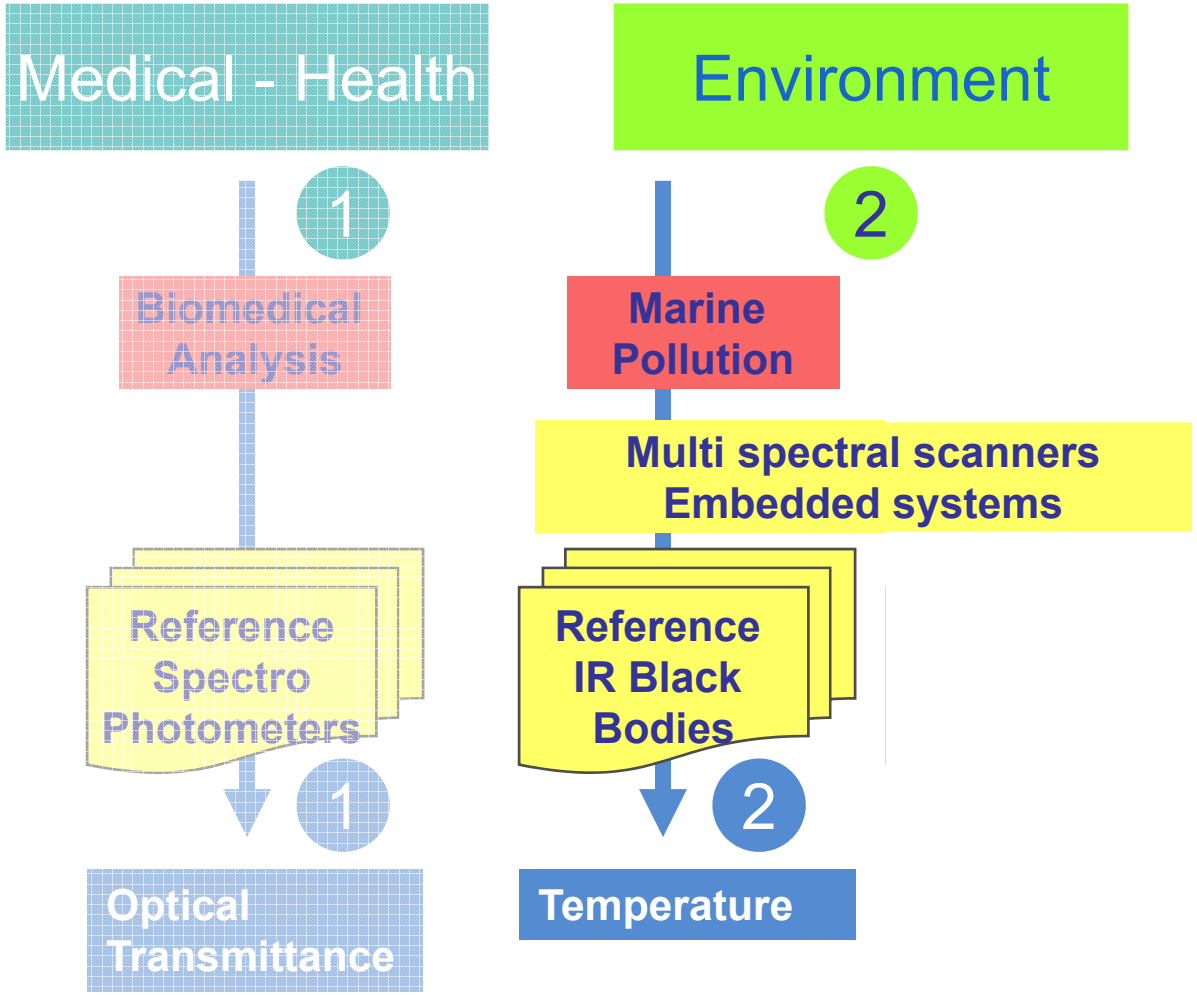


Biomedical laboratory and Optical properties of liquids



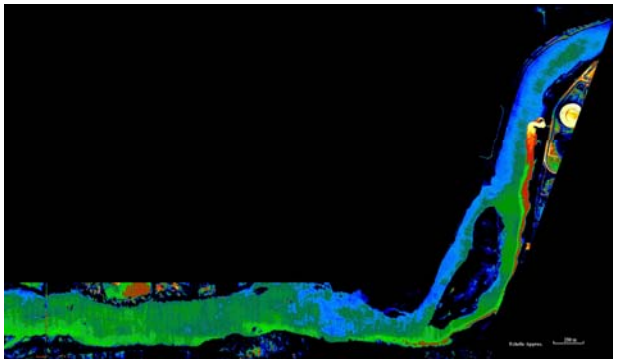
Environment

In the field of Thermal and Optical Metrology



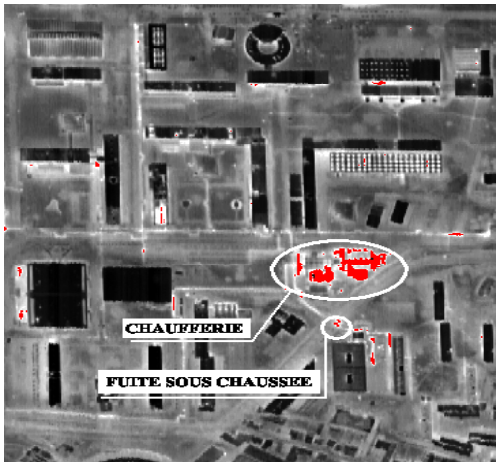
Help public agencies and local communities to take decision

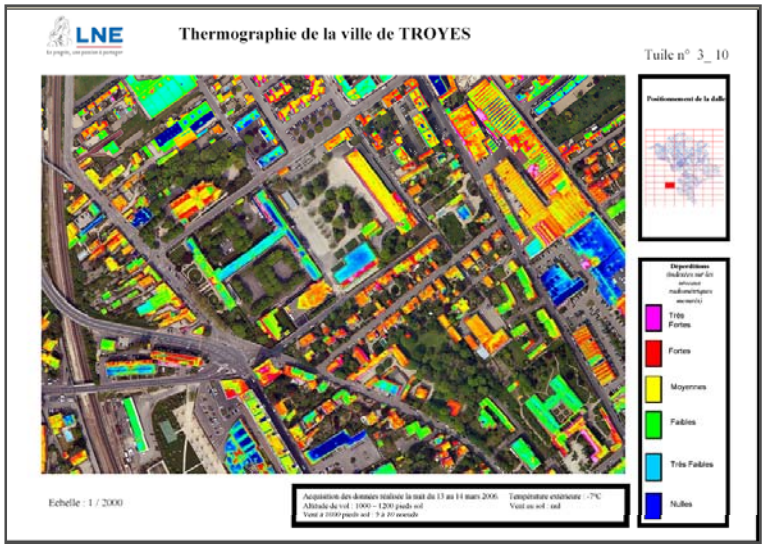
Design and set up of multi-spectral embedded systems for french coast guards (Polmar)



Monitoring water cooling of electrical power plants

Diagnosis of heating network and leak detection (Lyon)





Airborne thermography of many towns (Marseille, Troyes,…)

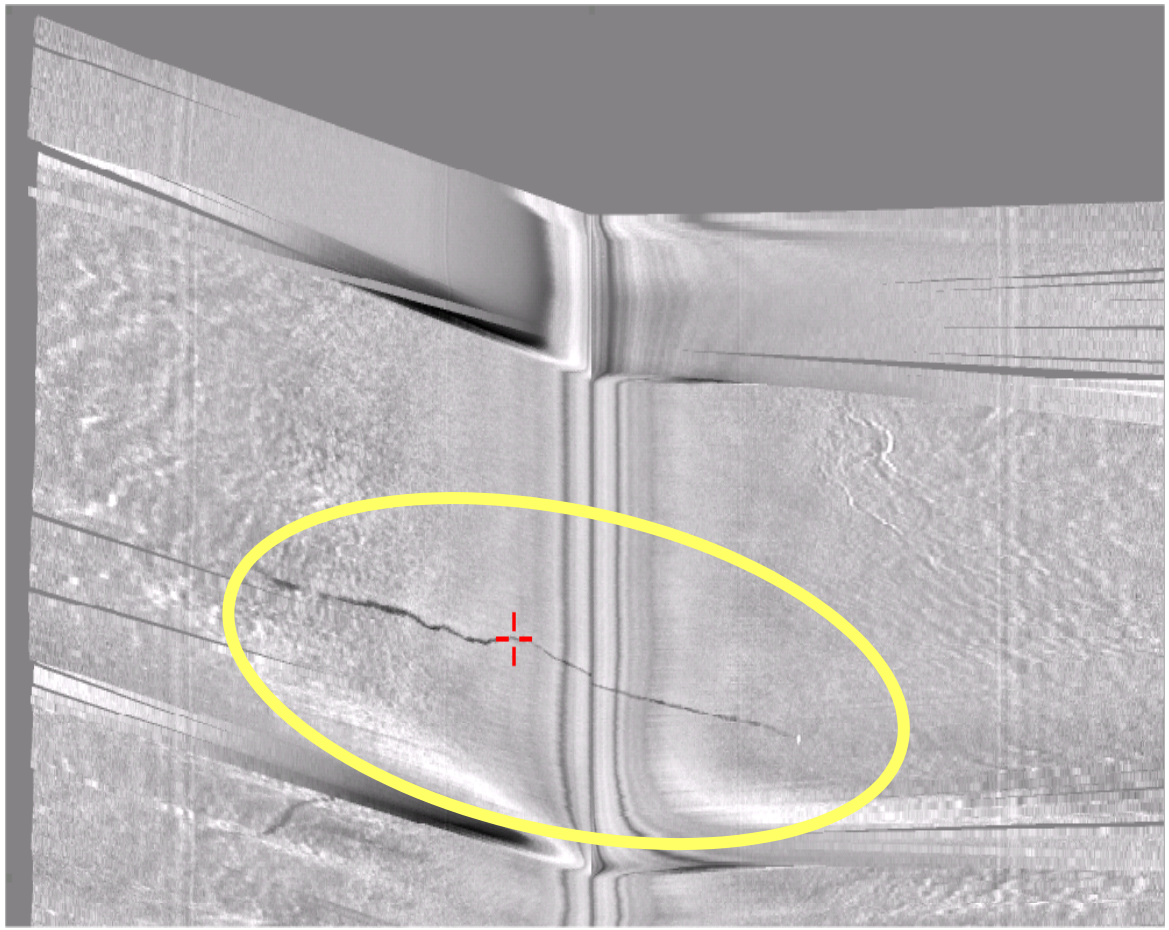
Marine Pollution

After the sinking of cargo Prestige

Prestige infrared image of split spills

Name: Prestige
Date : 13/11/2002
Place: Spain
Pavilion : Bahamas
Product: crude oil
Quantity : 77 000 t
Oil spill : Spain, France, Portugal

Marine Pollution



DETECT : SLAR Image

Polluted wake (black line) is detected.

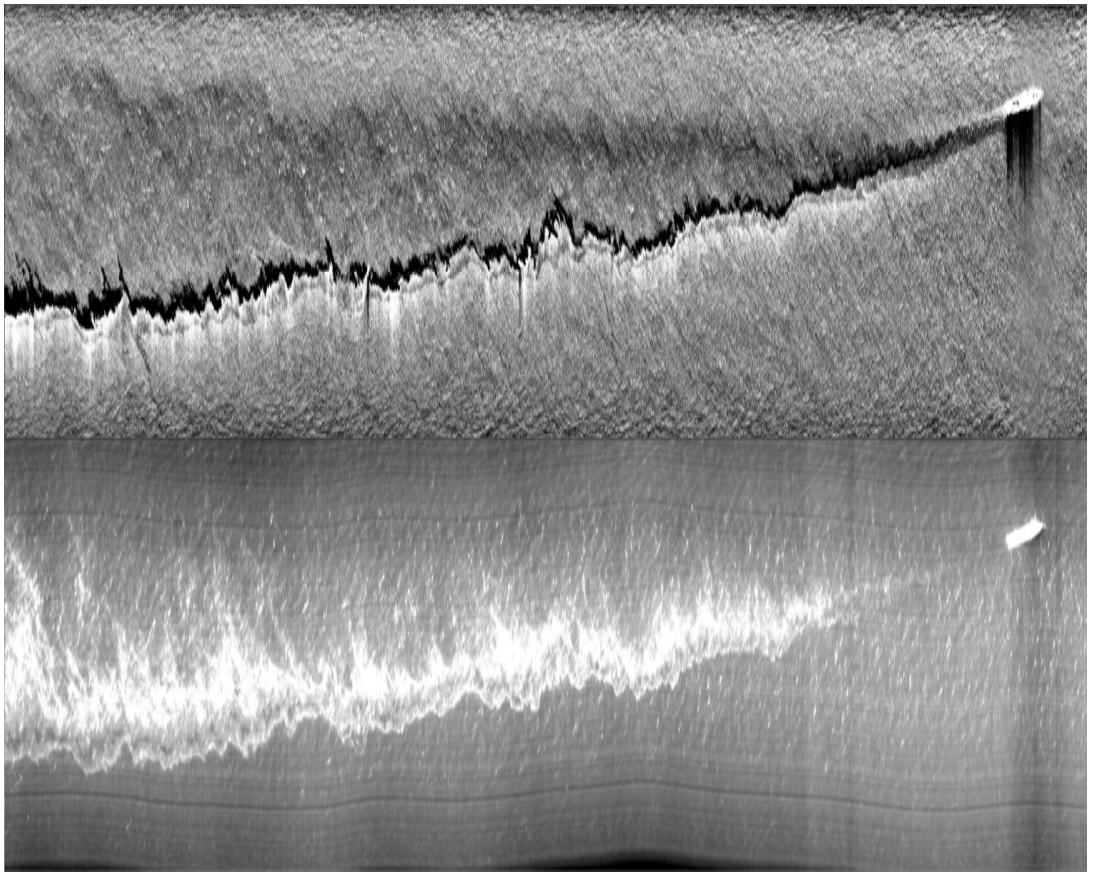
It is 20 nautical miles long.

This image and all data are recorded in the data base.

SLAR Electronic units head.

TYPICAL Pollution Detection System Functions Developed

Marine Pollution

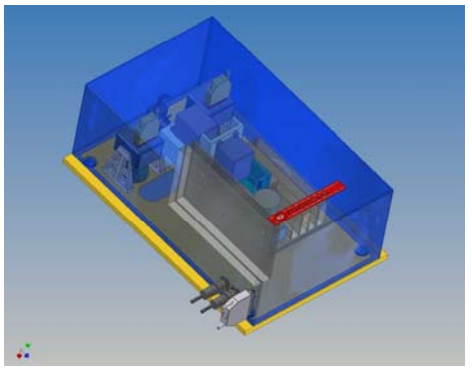


CONFIRM : SCANNER Image

The pollution is confirmed.

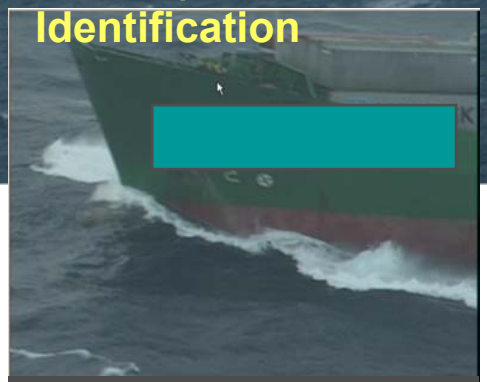
If necessary, the oil spill surface is measured and the volume is computed.

Scanner Head



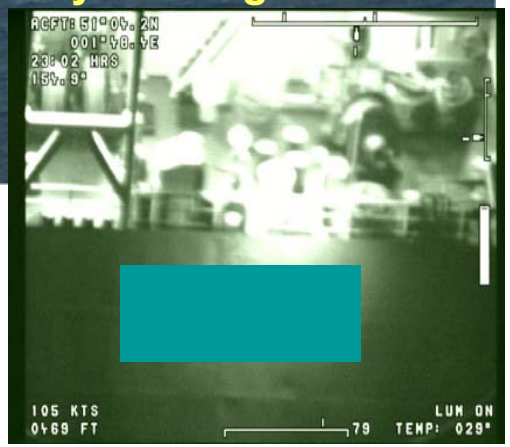
Marine Pollution

Day Identification



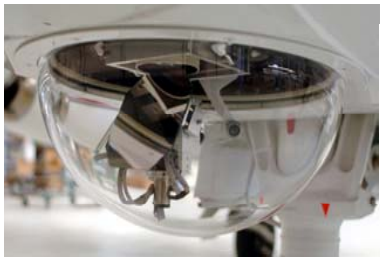
Long : xxxxx Lat : xxxxx

Night identification
Very Low Light Camera

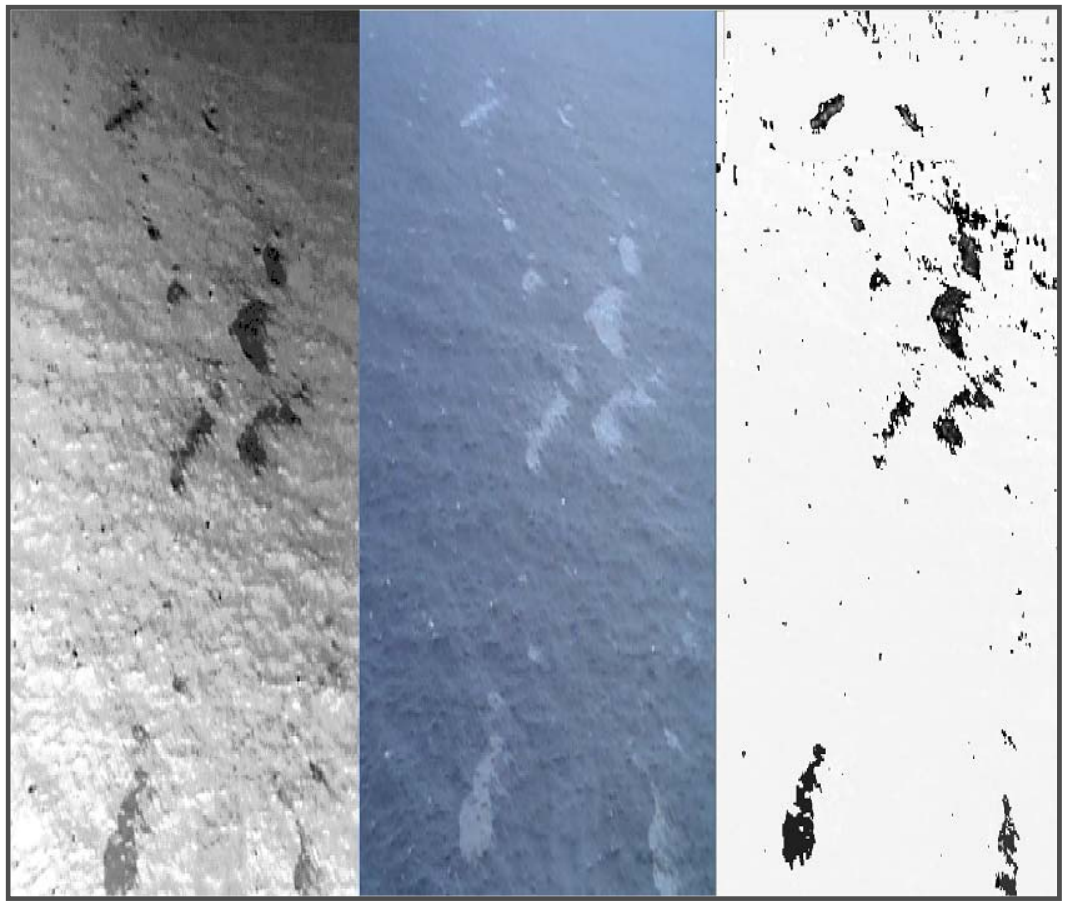


IDENTIFY : Photos or Camera Images

The ship is identified and all views are recorded in the data base .



Scanner integrated functions



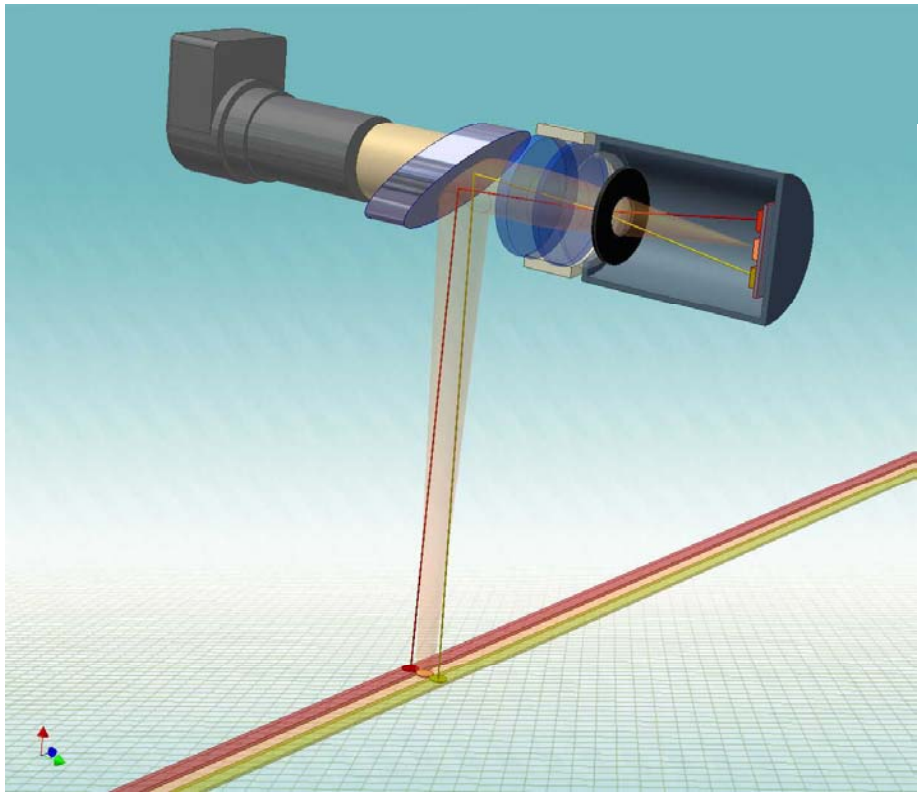
Multi channel Display and processing

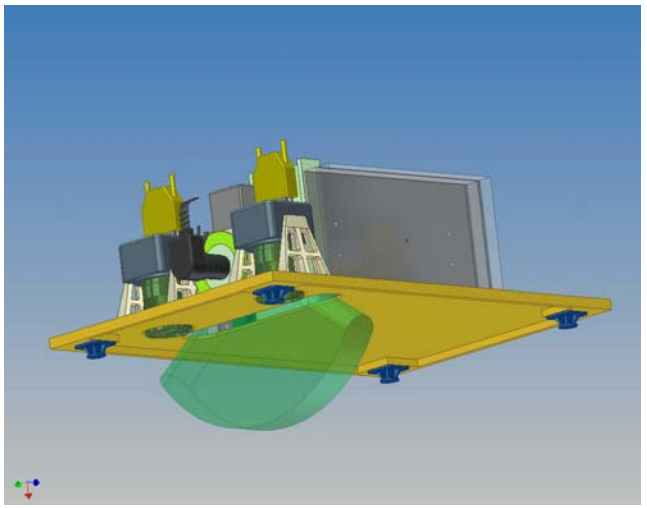
- Channel combinations

- Arithmetic operations

- Neural Network classification (development)

Marine Pollution

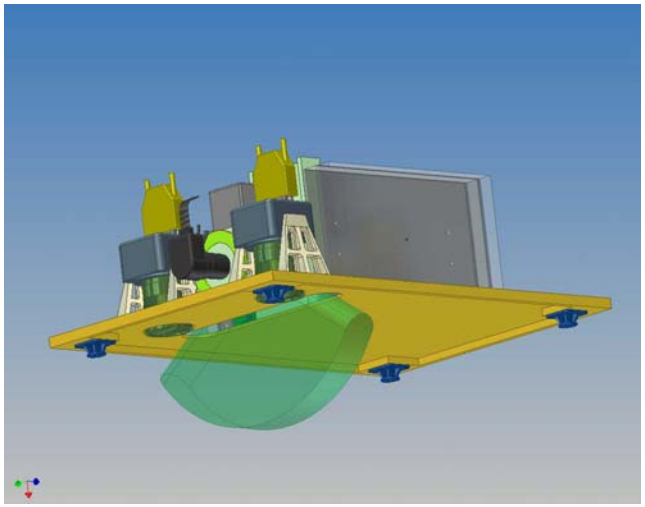


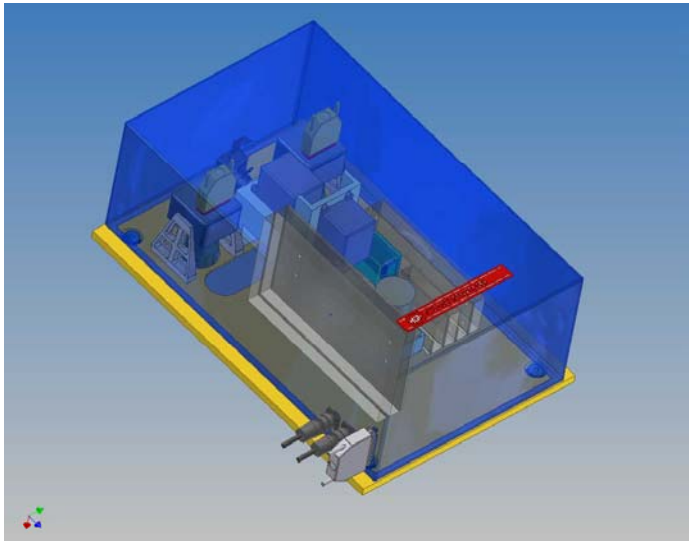


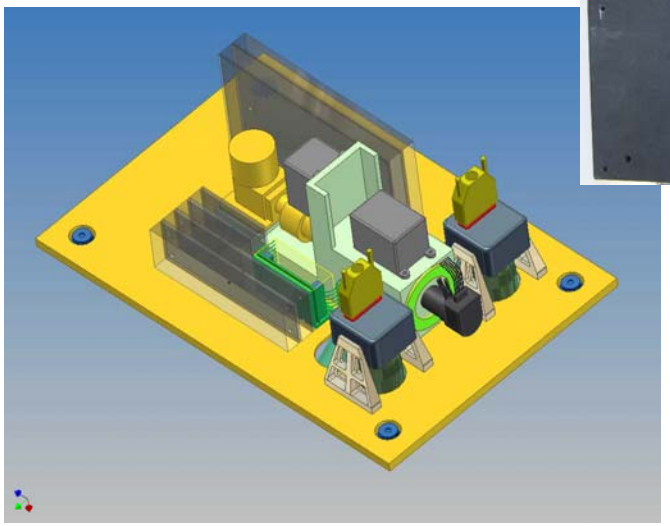
STORM Multispectral scanner

STORM Multispectral scanner

Scanner Head







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Metrology of the infrared systems based on Standard IR Black Body Cavities

Reference IR Black Bodies

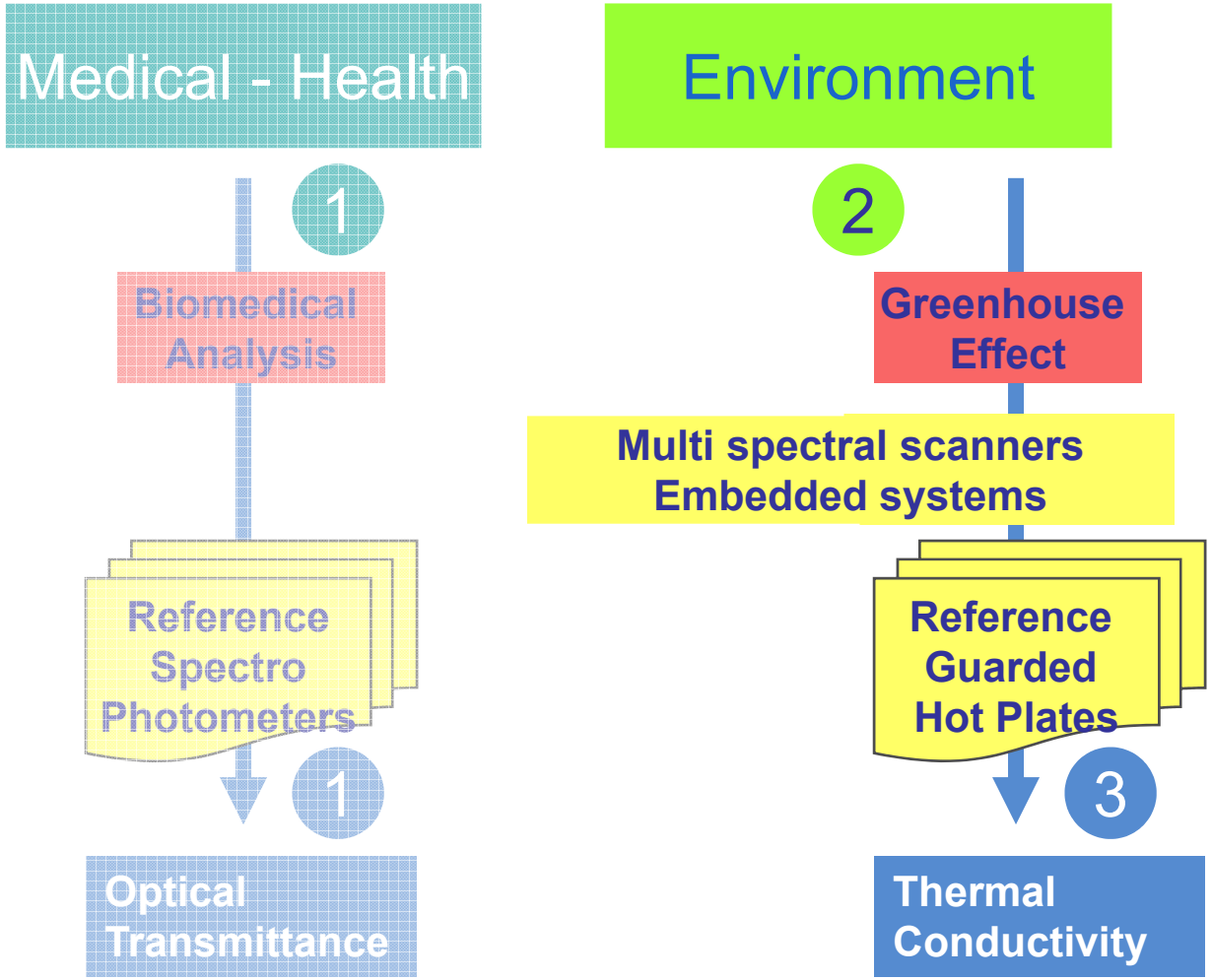
2

Temperature

Radiation Thermometry Laboratory

Environment

In the field of Thermal and Optical Metrology



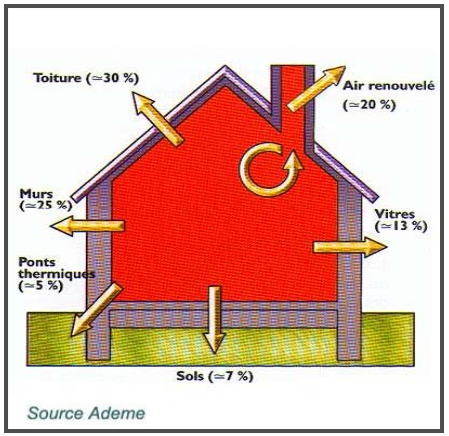
SIMPOSIO Metrología 2008

Saving energy in existing houses

Kyoto protocol has been ratified in 2005 and is now applied.

One objective: increase energy efficiency

Construction = sector most energy consumer in France

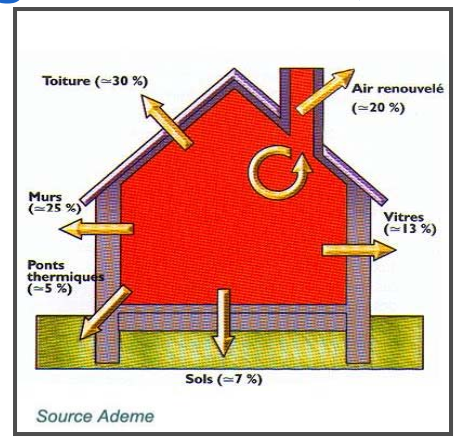


Saving energy in existing houses

The LNE's answer : airborne infrared thermography

Convince citizen to renovate houses and to improve thermal insulation

For instance, the proportion of heat loss through the roof is around 25-30 % , 30-35% through the walls, 10% through the windows…



Environment : Greenhouse Effect

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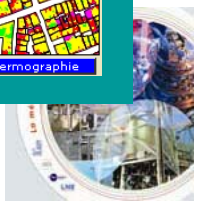
One cost-effective way to save energy and reduce GHG emission

Service to Local Communities or Public Authorities

Mapping of heat losses

Marseille, Troyes, Blois, Epernay…

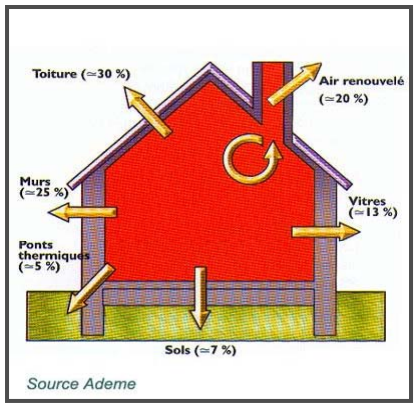


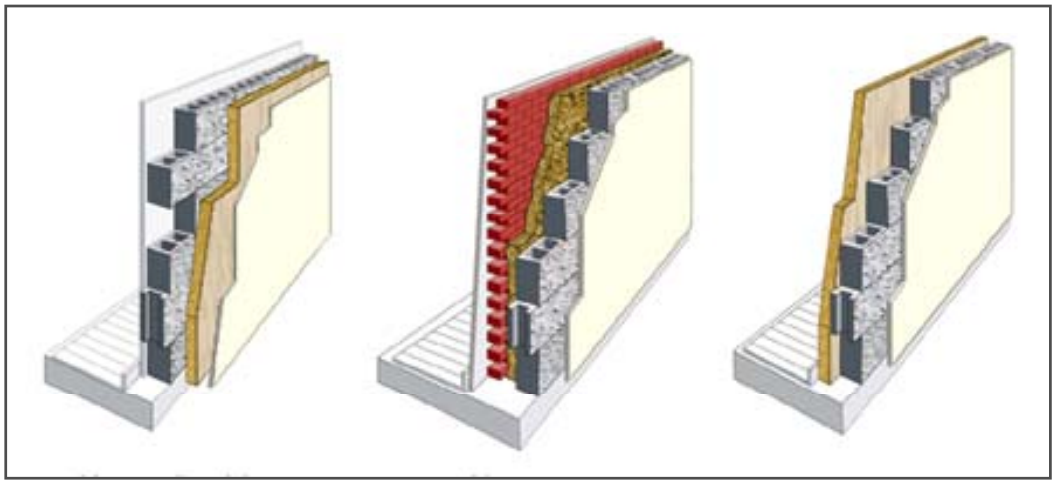
Context

The thermal properties of materials are studied at LNE for a long time…

Main concerned industrial sectors

- Automotive industries
- Aeronautics / Defence
- Energy / Nuclear
- **Building**

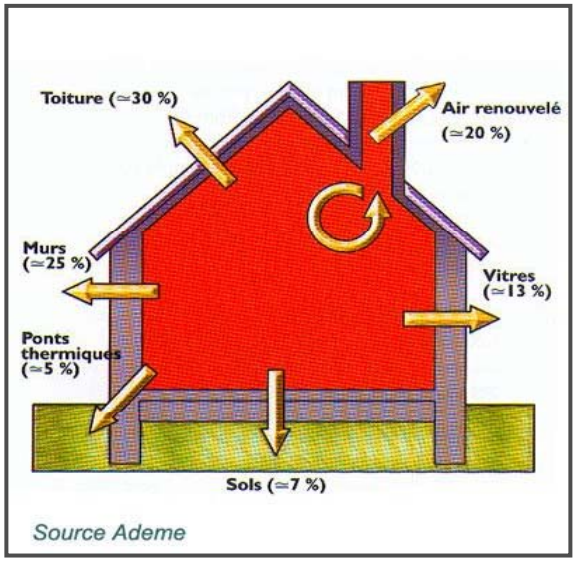




Thermal Properties of Materials

LNE has been developing several facilities to study :

- **Thermal conductivity and thermal diffusivity**
- **Specific heat and enthalpy**
- **Thermal Expansion**
- **Emissivity, Reflectance, Transmittance**



Thermal Properties of Materials – Range and Methods

Direct Method

Guarded Hot Plate

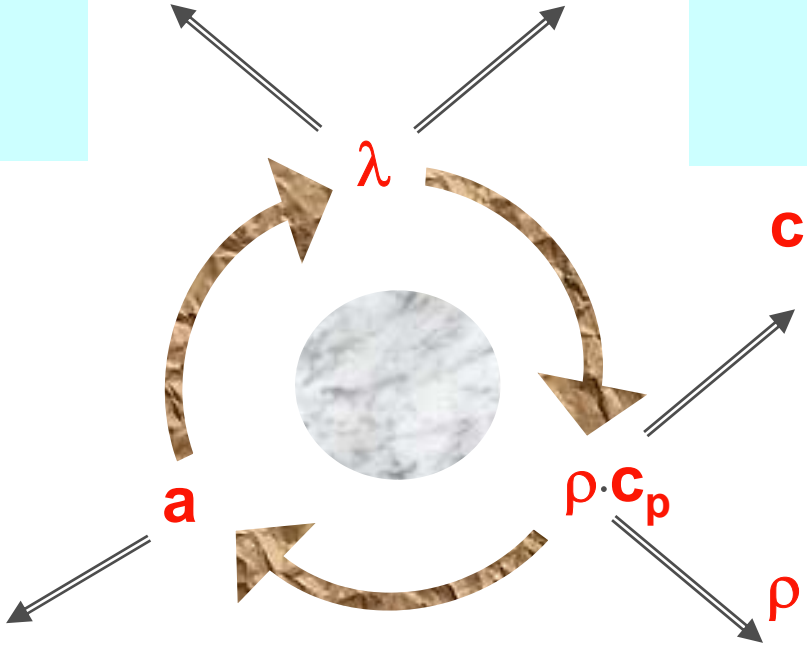
- 10 °C / 60 °C

23 °C / 200 °C

Indirect Method

$\lambda = a \cdot \rho \cdot c_p$

23 °C / 800 °C



Drop Calorimetry

23 °C / 1000 °C

DSC

- 100 °C / 800 °C

a **Laser pulse Method**

23 °C / 1500 °C

\+

α **Dilatometry**

- 100 °C / 1000 °C

ε **Emissivity**

- 20 °C / 800 °C

Immersion Method

23 °C

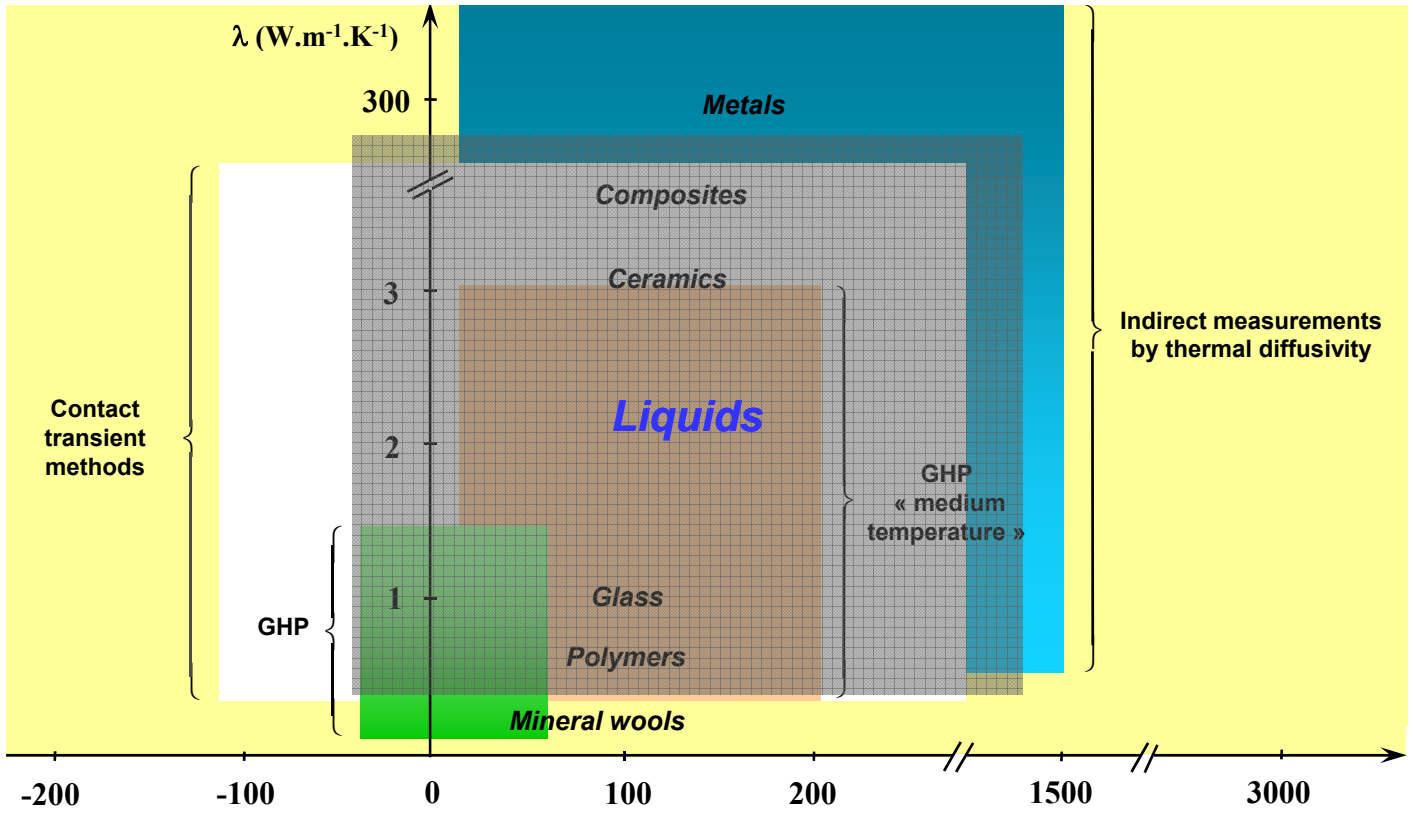
\+

α **Dilatometry**

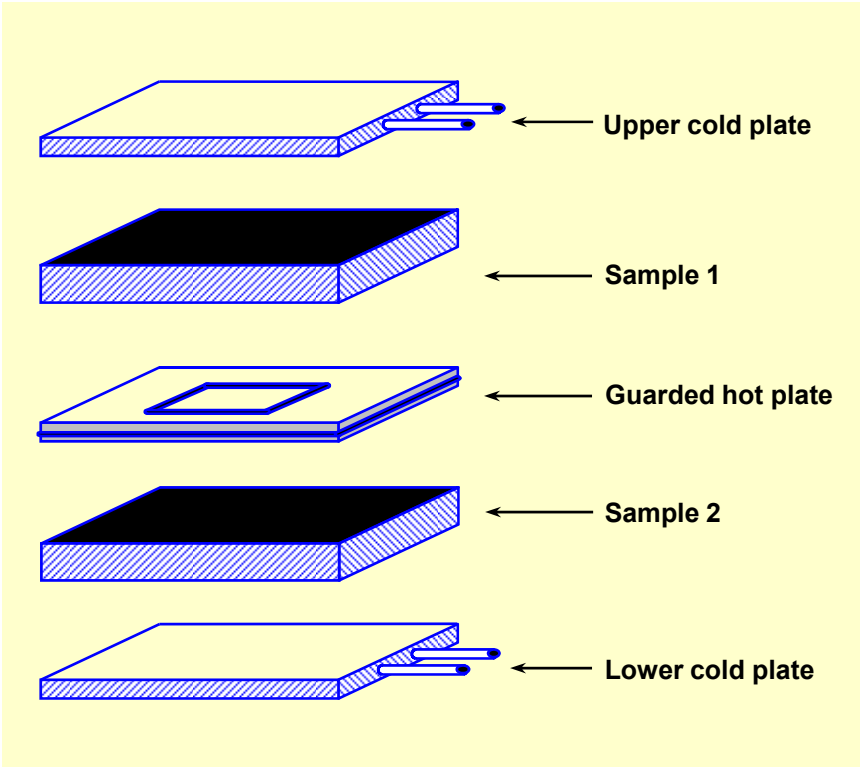
- 100 °C / 1000 °C

Thermal Conductivity - Materials and Means

Measurement means of LNE cover a large temperature range

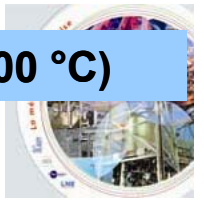


Thermal Conductivity - Guarded Hot Plate (GHP)



- Measurement by guarded hot plate (ISO 8302)
- Temperature range from - 5 °C to + 50°C
- Low conductive materials (λ<0.5 w/m.K)
- Uncertainty (k=2) : from $\pm$ 0.5% to $\pm$ 2 %

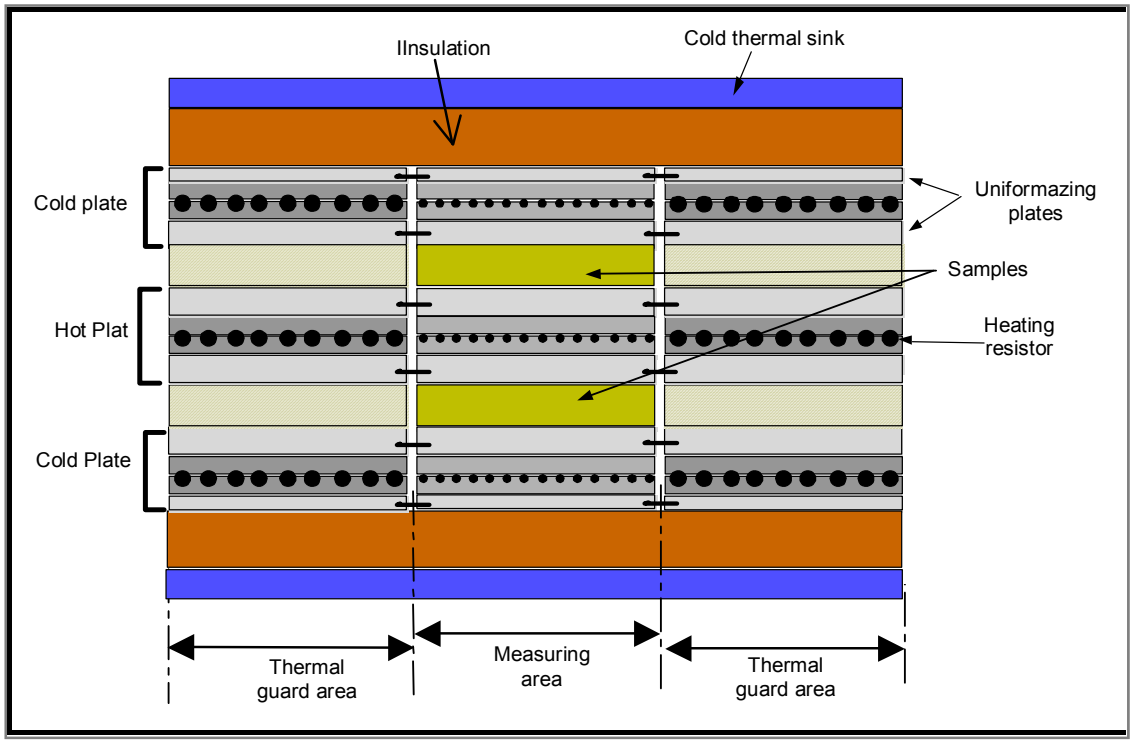
Development of a new GHP for medium temperatures (up to 500 °C)



Insulation Materials – a new GHP

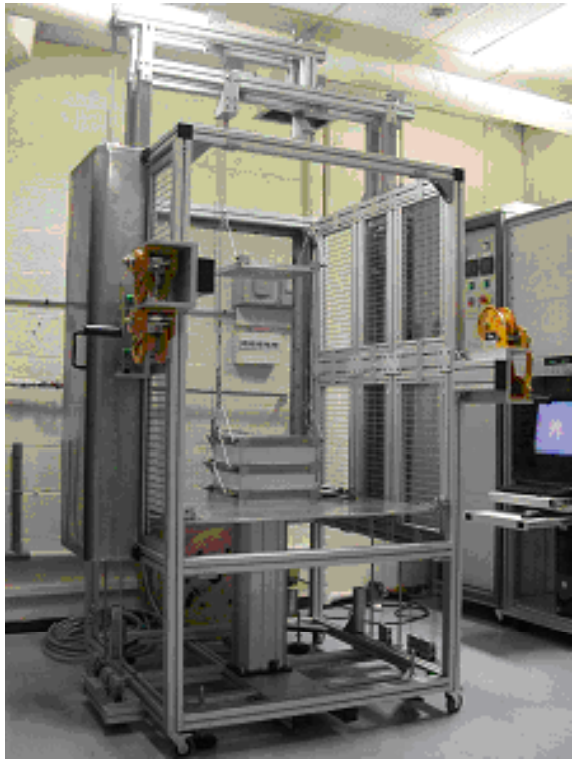
Thermal conductivity range: 0.1 to 10 $W.m^{-1}.K^{-1}$
Temperature range : 23 to 500 °C

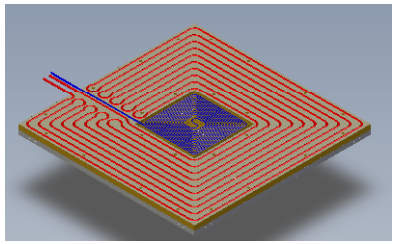
The goal is to measure thermal conductivity with a relative uncertainty from 1to 5%.



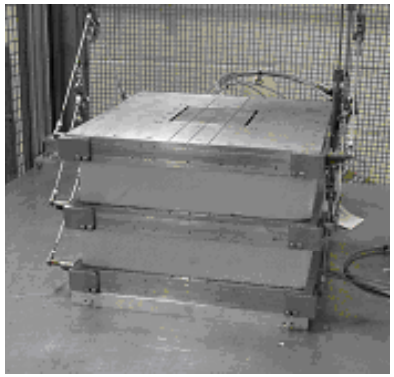
Cross section view of the "stacking"

GHP Reference set-up





Patterns of the heating resistors of the measuring area and the thermal guard ring

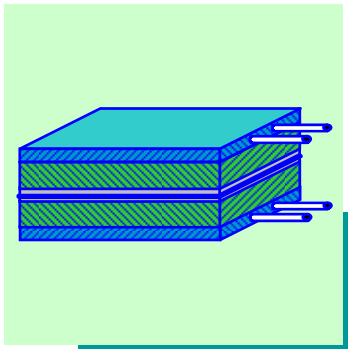


General views of the LNE set-up and of the heating plates.

GHP Reference set-up

Material	Specimen thickness	Temperature (°C)	Thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	Uncertainty (k=2) ($W \cdot m^{-1} \cdot K^{-1}$)
Rubber	20 mm	20	0.2822	0.0068
		70	0.3168	0.0074
Silicone	10 mm	20	0.2211	0.0037
		70	0.2156	0.0035
PVC	20 mm	20	0.1403	0.0068
		70	0.1815	0.0074

Materials used for checking



Pilot study for limited comparison on thermal conductivity measurement by Guarded Hot Plate

Jean-Rémy FILTZ - Bruno HAY – Benoît DOUCET
Jacques HAMEURY
Thermal and Optical Division

Thermal conductivity pilot study

The main characteristics of the measurement protocol are the following:

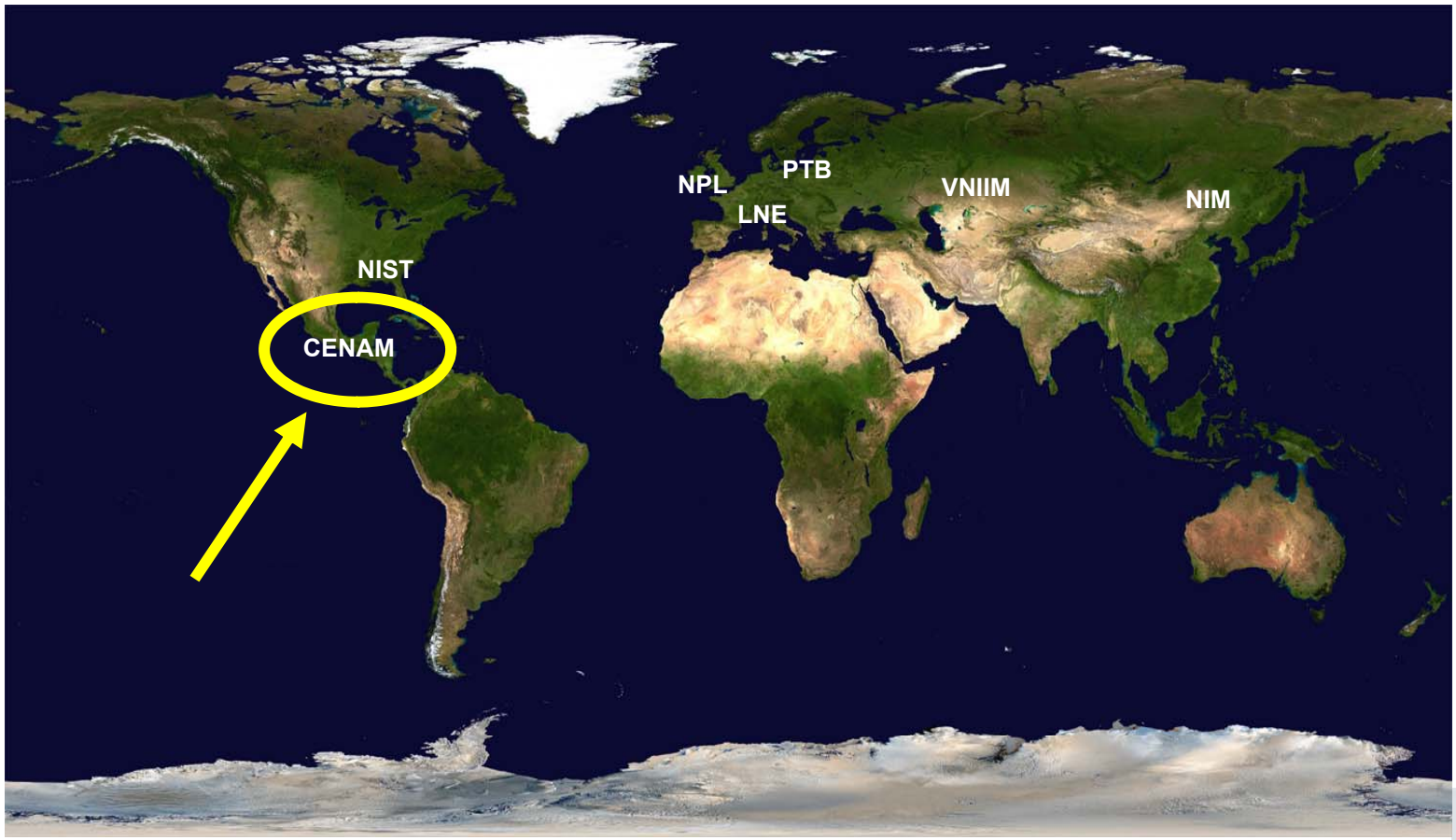
- ***Method:*** *ISO 8302*
- ***Materials:***
  - *Resin-bonded glass fibre board - IRMM440 thickness = 35 mm*
  - *Expanded polystyrene board (specific batch produced by Lafarge - France) - thickness = 35 and 70 mm*
- ***Programme of measurements:***

1 measurement	at 10 °C	with ΔT = 20 K	MW - thickness = 35 mm
4 measurements	at 23 °C		EPS - thickness = 35 mm
1 measurement	at 40 °C		EPS - thickness = 70 mm

Measurements performed successively by all the participants on the same specimens

Thermal conductivity pilot study

NMI's involved in this pilot study.



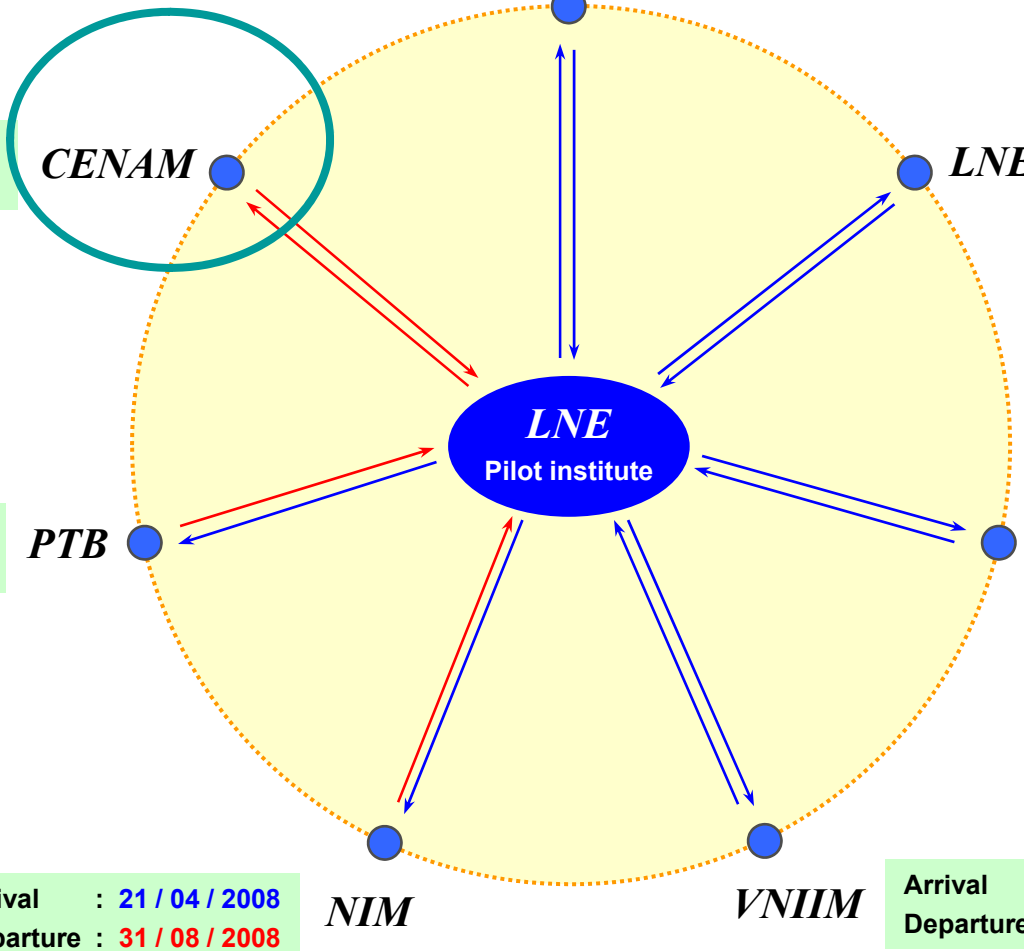
Thermal conductivity pilot study

Summary of the measurement program

Laboratory	GHP	Dimensions (mm)	Program of measurements	Materials and thicknesses (mm)
NIST (USA)	Double	ϕ 1016	10 °C (x1) 23 °C (x4) 40 °C (x1)	MW (35 mm) EPS (35 mm) EPS (70 mm)
LNE (FR)	Double	610 x 610		
NPL (UK)	Single	610 x 610		
VNIIM (RU)	Double	ϕ 330		MW (35 mm) EPS (35 mm)
NIM (CN)	Single	ϕ 330		MW (35 mm) EPS (35 mm) EPS (70 mm)
PTB (DE)	Single	ϕ 100	23 °C (x4) 40 °C (x1)	EPS (20 mm) EPS (25 mm)
	Transient Hot Bridge	*105 x 50*		*MW (35 mm)* *EPS (35 mm)* *EPS (70 mm)*

Thermal conductivity pilot study

Up to date schedule



NIST
Arrival : 04 / 01 / 2007
Departure : 09 / 03 / 2007
Measurements performed

CENAM
Arrival :
Departure : *2008*

LNE
Arrival : 20 / 03 / 2007
Departure : 17 / 07 / 2007
Measurements performed

PTB
Arrival : 23 / 04 / 2007
Departure : / /
Measurements performed

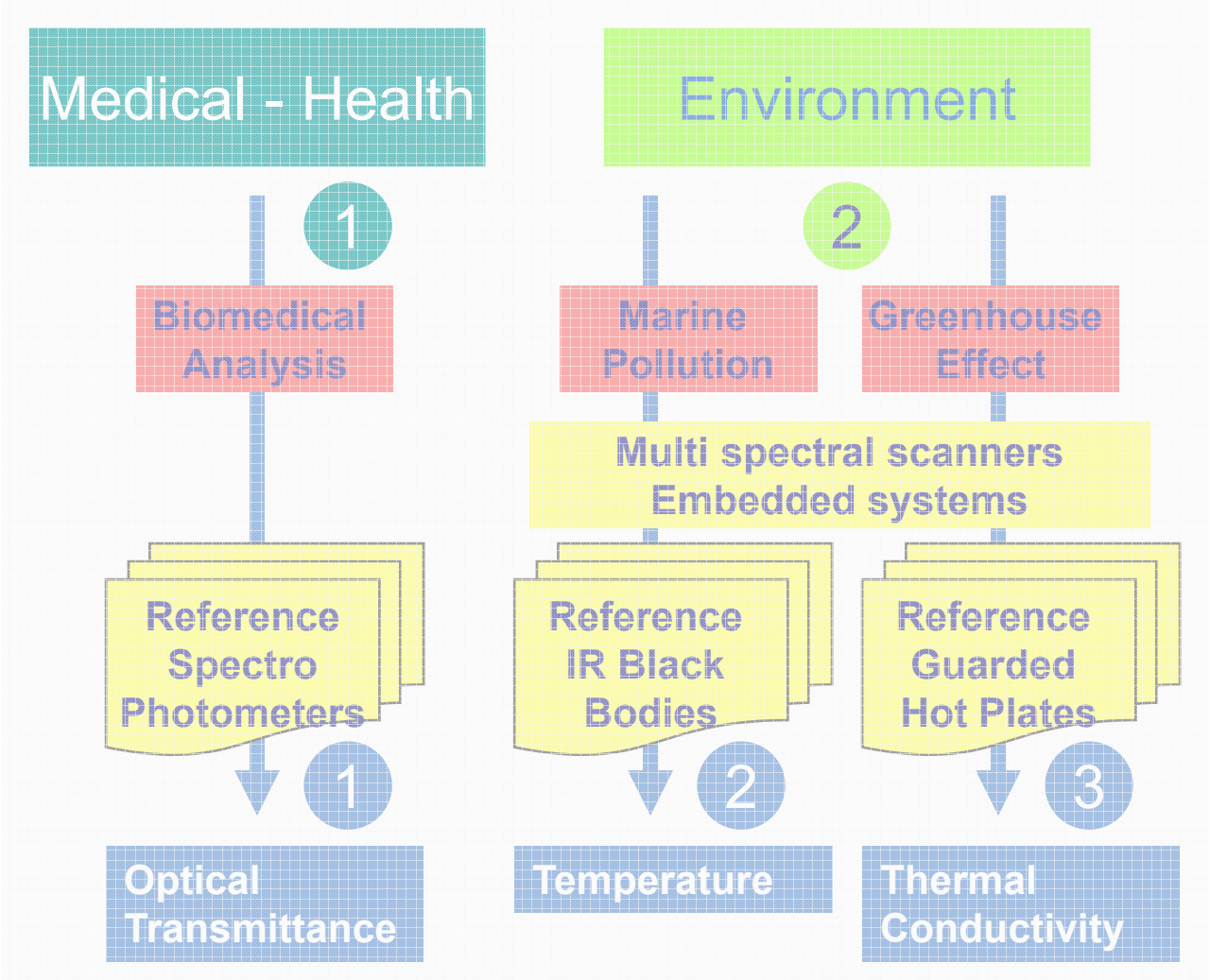
NPL
Arrival : 20 / 07 / 2007
Departure : 05 / 11 / 2007
Measurements performed

NIM
Measurements performed
Arrival : 21 / 04 / 2008
Departure : 31 / 08 / 2008

VNIIM
Arrival : 09 / 01 / 2008
Departure : 18 / 02 / 2008
Measurements performed

Energy

In the field of Thermal and Optical Metrology



Background

Natural Gas Market; Key dates

Who can choose the provider ?

August 2000	August 2003	July 2004	July 2007
20%	37%	70%	100%
Industrials **Very High Consumers**	Industrials > 83 GWh	Professionals Enterprises Local Communities	**All**

Europe, France,
the market is now fully open

Background

SIMPOSIO Metrología 2008

GrDF
GAZ RÉSEAU DISTRIBUTION FRANCE

ALTERGAZ
Naturellement économique

Today

2008

eRDF
ÉLECTRICITÉ RÉSEAU DISTRIBUTION FRANCE

POWEO

Background

Metrology & Natural Gas:

What does it mean in Europe and in France ?

- Opening of the natural gas market in Europe
  - Non constant natural gas composition flowing in the pipes
  - Accurate energy measurements * needed

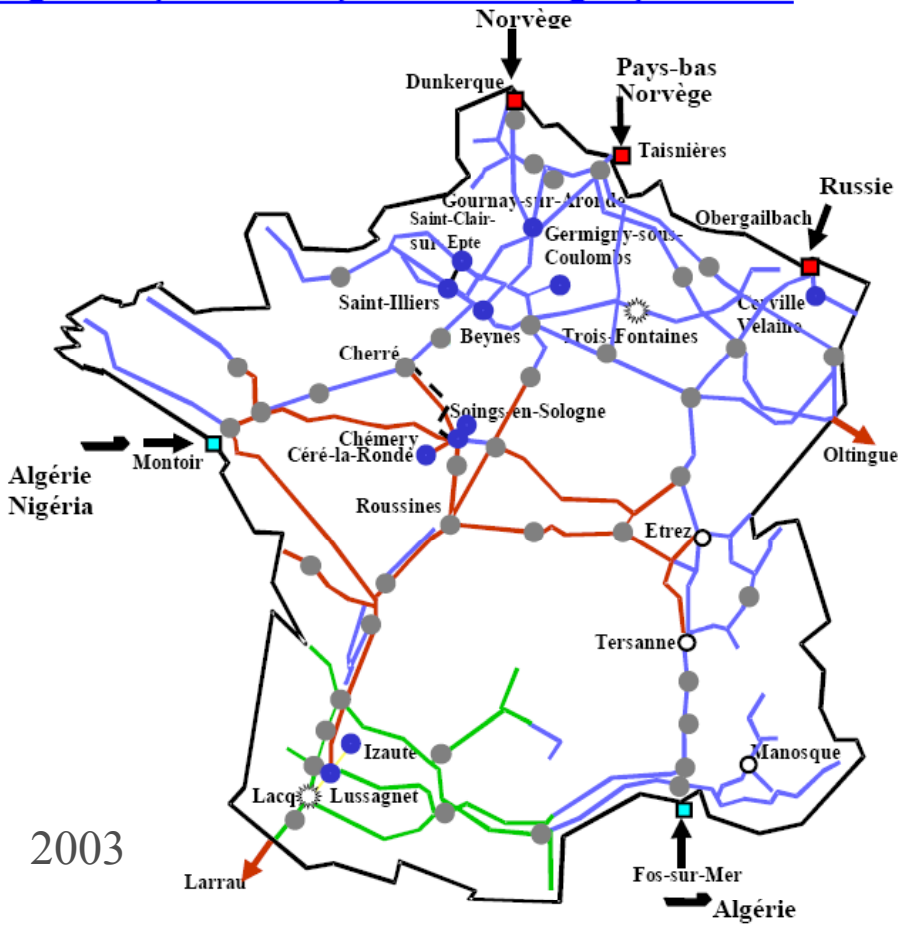
Improvement of the transported and distributed gas transactions by more accurate measurement of natural gas gross calorific value (GCV)

•GCV = Quantity of heat released by complete combustion of a specified gas quantity

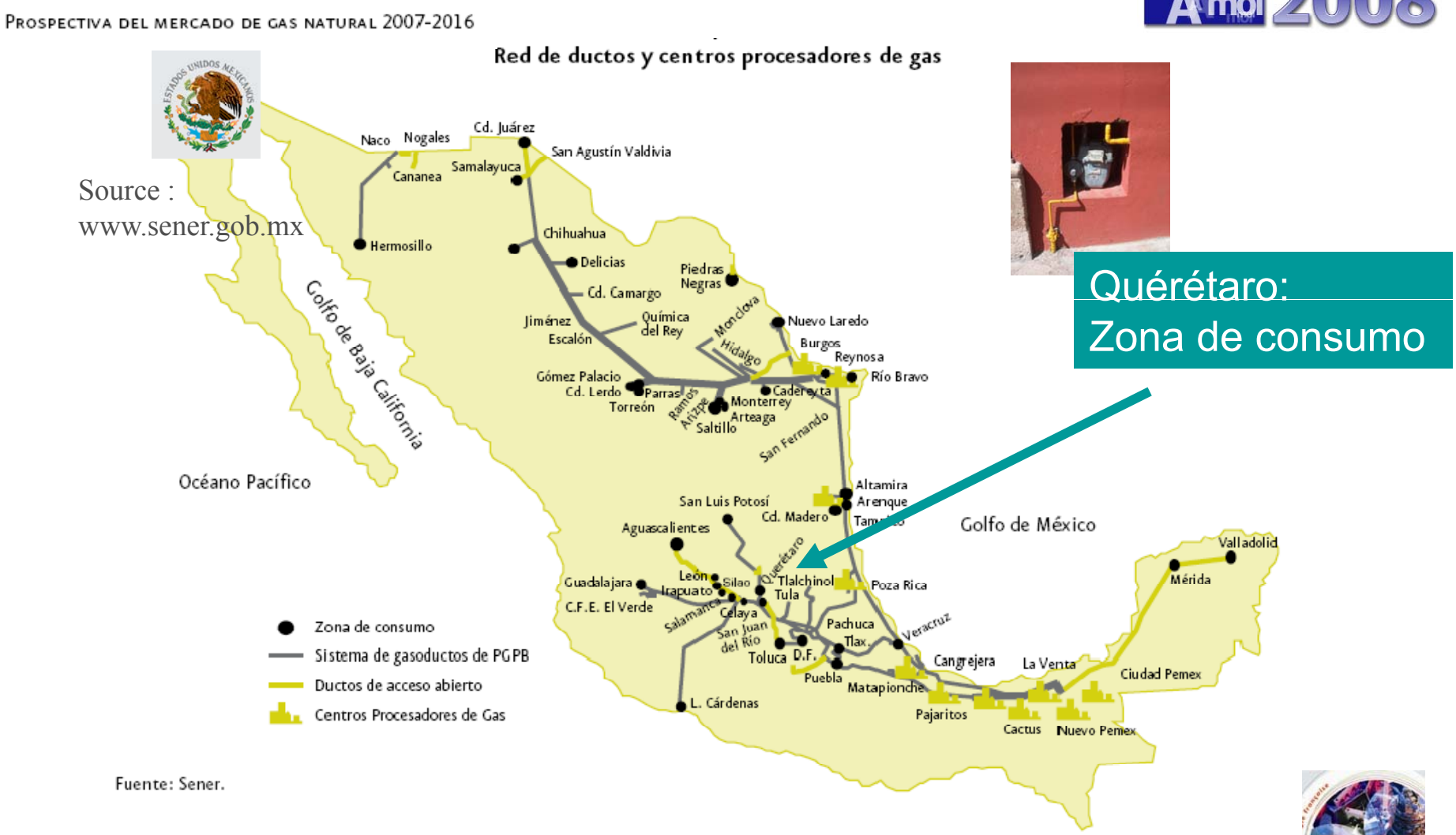
France : Natural Gas, Pipelines and Transportation

Réseaux de transport, stockage, compression et production de gaz par nature

- *Stockage en nappe aquifère*
- *Stockage en cavités salines*
- *Station de compression*
- *Gisement de gaz naturel*
- *Canalisation GDF*
- *Canalisation GSO*
- *Canalisation Total*
- *Canalisation CFM*
- *Canalisation en projet*
- *Arrivée de gaz naturel*
- *Méthanier*
- *Terminal méthanier*
- *Terminal de réception*



México : Natural Gas network

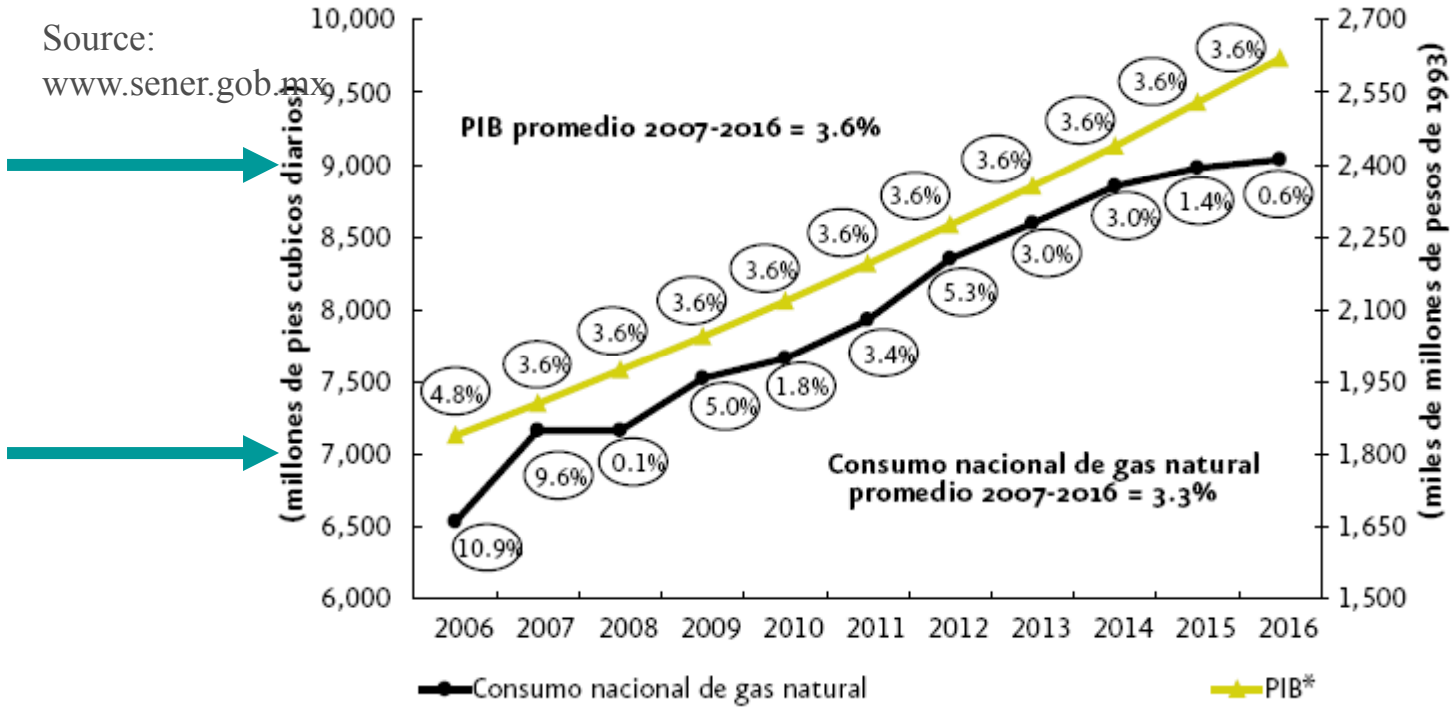


Quérétaro:
Zona de consumo

Gas Natural : Consumo nacional 2007-2016

PROSPECTIVA DEL MERCADO DE GAS NATURAL 2007-2016

Source:
www.sener.gob.mx



*Las cifras están referidas al año base de 1993.
Fuente: CAPEM e IMP.

Gas Natural : 2007-2016

PROSPECTIVA DEL MERCADO DE GAS NATURAL 2007-2016

www.sener.gob.mx

…Desagregación de tipos de combustible y transformación a unidades comunes (Btu´s, GWh, Joules, etc.)….

-> Breakdown of fuel rates and conversion to common units (Btu's, GWh, Joules, etc.)…

Gas Calorimetry

NG : GCV Determination

Direct Method
Calorimetry

Non-Direct Method
Gas Chromatography
+ GCV values (ISO 6976)

Reference Calorimeter

Reference Gas Mixtures

Gas Calorimetry – Non-Direct Method

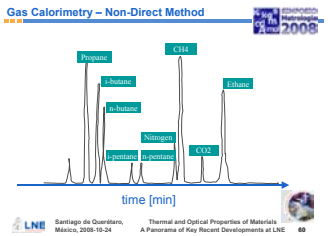
Natural Gas pipeline

Metrology

Temperature | Pressure | Chromatography | Flow

ISO 6976

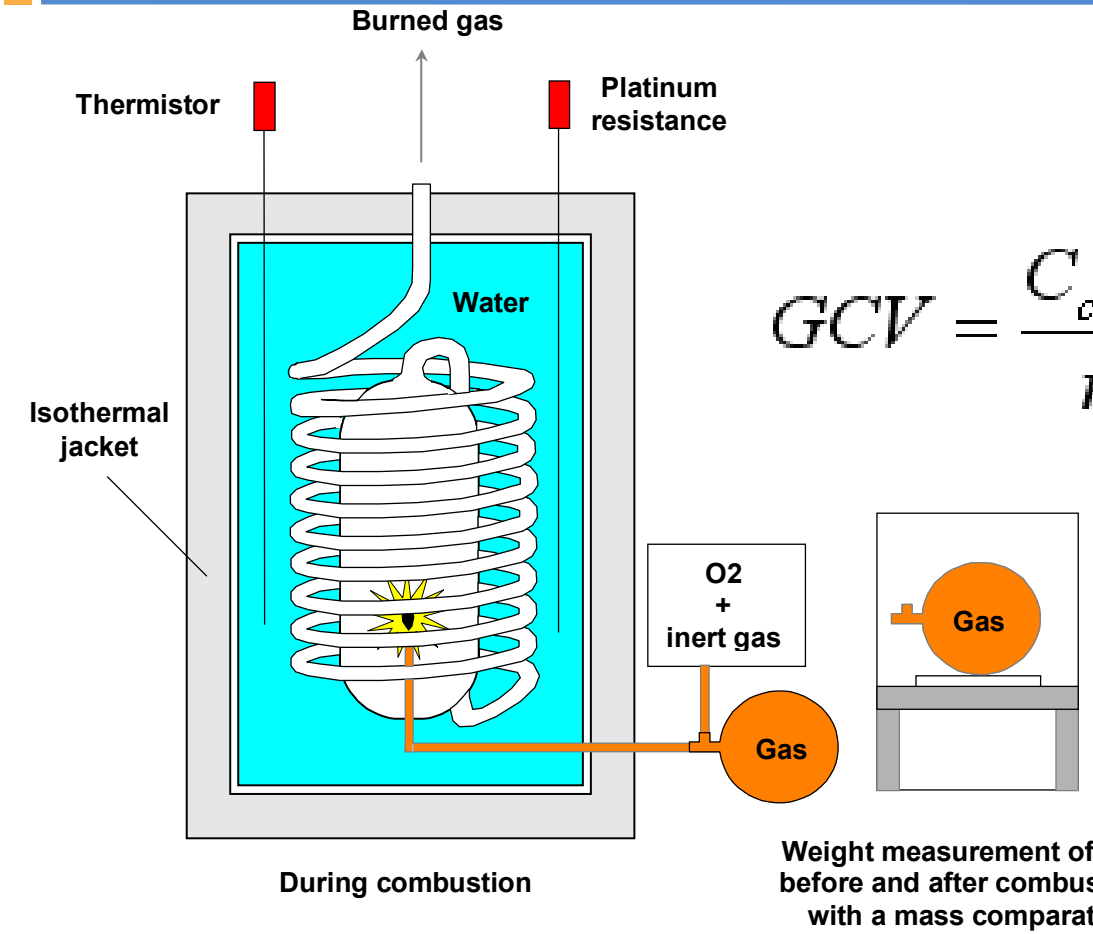
Calculation
Correction factors
Data: flow, t, p, GCV, Energy



Checking

Data exploitation

Gas Calorimetry - Reference Method



$$GCV = \frac{C_{cal} \cdot \Delta T}{m_{gas}}$$

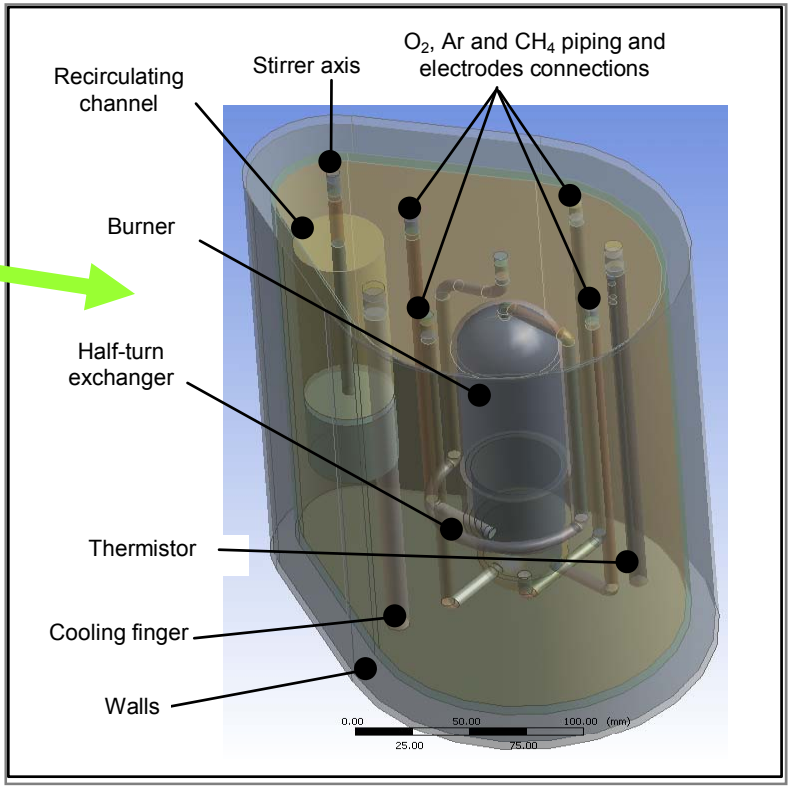
www.nap.edu

Frederick Dominic Rossini
1899 - 1990
1928 - 1950 (NBS)
1966 - 1970 (1st Pdt CODATA)

C_{cal} is the heat capacity of the calorimeter ($J.K^{-1}$)

m_{gas} is the mass of burned gas (kg)

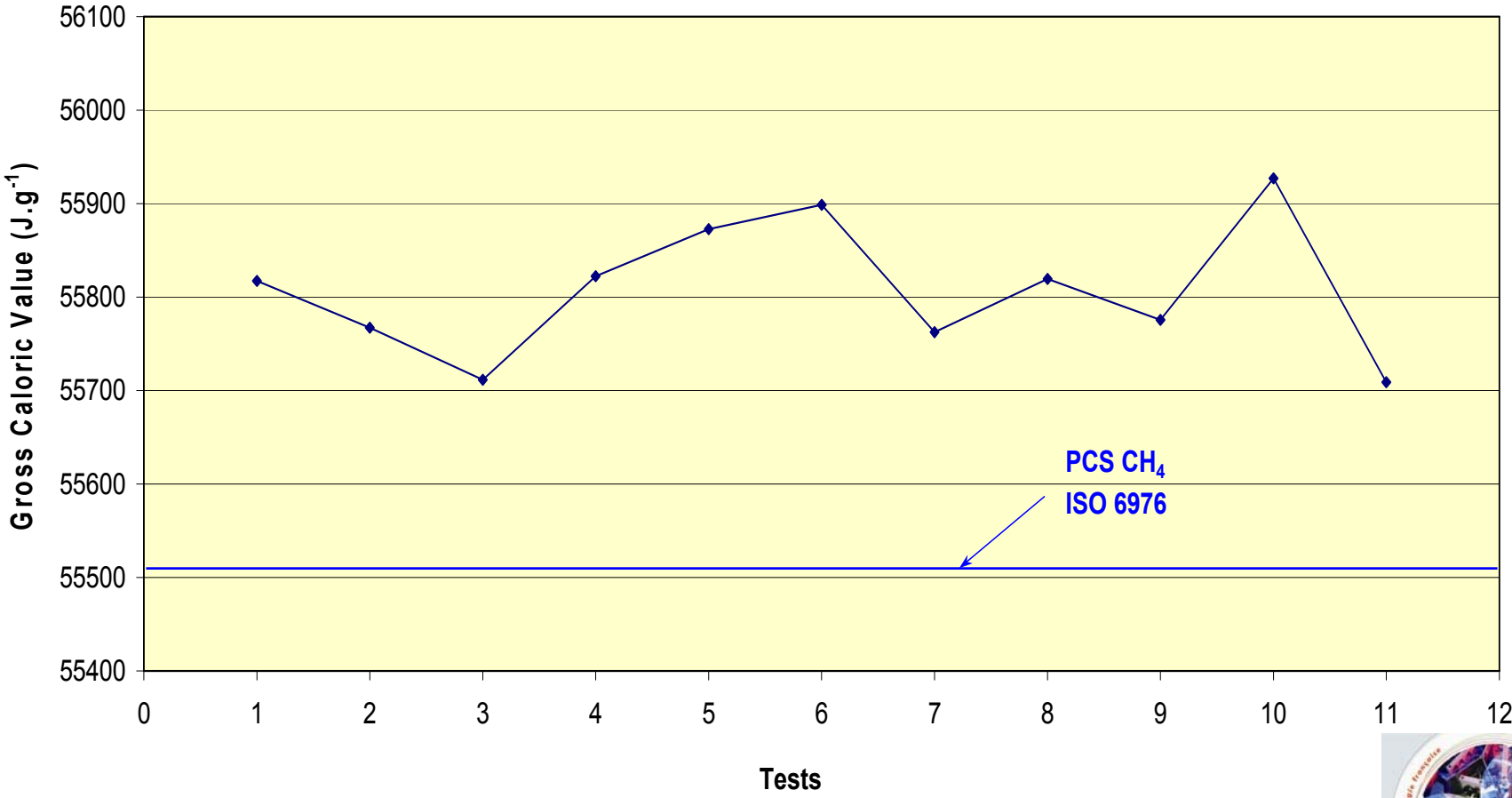
Gas Calorimetry - Reference Method



New design of the LNE Calorimeter

Gas Calorimetry - Reference Method

Preliminary results



Conclusions

Mainly with regards to the Metrology at the transfer level but not only…:

- On the basis of its regular missions, LNE as all NMIs can provide a useful support to the industry or relatively to the needs of the society. We do it !

- New triggers driving developments in metrology have recently arisen . They lead our institute to strengthen our links with the Industry, the society and the governmental agencies. We try to answer to these different challenges in a practical way. We do it !

- As you have seen through the different illustrations, there is no barrier for Metrology. Basic Competencies of NMIs are a real power to be exploited for constructing innovative solutions useful for meeting a sustainable development. We think it, we try to do it and we would like to share it with you!

LNE

Laboratoire national de métrologie et d'essais (LNE)

Organisme de référence pour la métrologie française avec le concours de :

3 autres laboratoires nationaux

- LNE-INM
Conservatoire National des Arts et Métiers
- LNE-LNHB
Commissariat à l'Energie Atomique
- LNE-SYRTE
Observatoire de Paris

et 6 laboratoires associés

- Centre Technique des Industries Aérauliques et Thermiques (CETIAT)
- Ecole Nationale Supérieure d'Arts et Métiers de Paris (ENSAM)
- Franche-Comté, Electronique, Mécanique, Thermique et Optique - Sciences et Technologies (FEMTO-ST)
- Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
- Laboratoire Associé de Débitmétrie Gazeuse (LADG)
- Observatoire de Besançon

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La métrologie française

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LNE

Thank you for your Attention

Gracias por su atención

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