



NMC Capability and Achievement in Supporting  
**Energy Efficiency Measurements  
& Climate Change**

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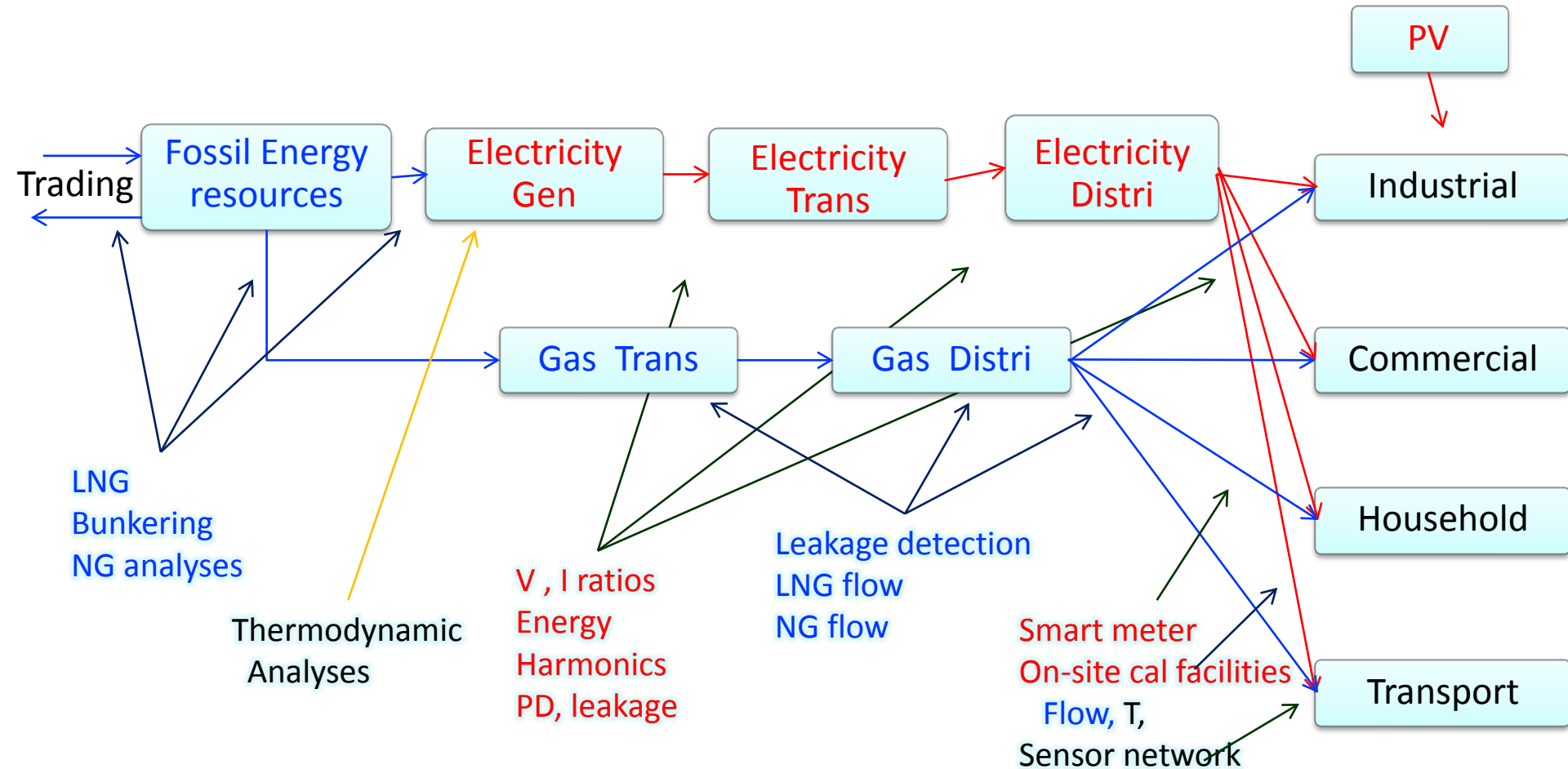
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APMP Midyear Symposium  
08 Jun 2016

# Contents

- Singapore energy flow and measurement needs
- NMC's capability in supporting such measurements, in
  - Energy trading and transmissions
  - Energy consumptions
- NMC's effort in supporting climate change

# Energy Flow and Measurement Demands



# NMC's capability in supporting energy trading and transmissions

- Liquid flow and gas flow measurements
- NG calorific value analyses
- Electrical measurement
- Photovoltaic cells characterization

# Capability in Liquid Flow Measurement



Range, kg/h

Capability

340 - 43,200

0.05%



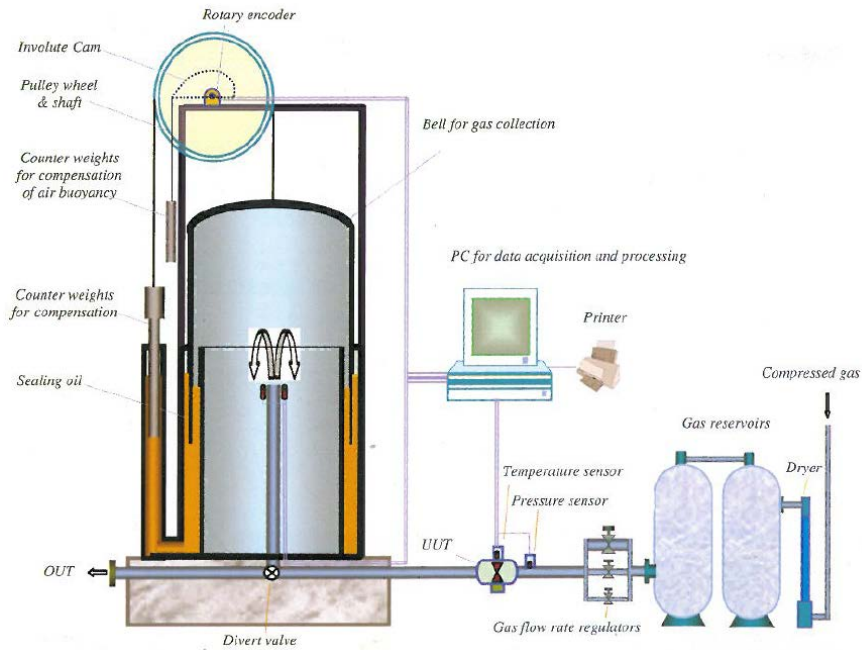
- Bunkering Ind
- Marine & Offshore Ind
- Water/wastewater treatment
- Chemical, beverage, pharmaceutical ...

# Achieving Mass Flow Meter (MFM) in Singapore



Item	Tank Gauging	MFM	NMC's Contributions
Standard	SS600:2008	SS600:2014 <b>TR48:2015</b>	<ol style="list-style-type: none"> <li>1. WG member &amp; main tech advisor, in dev'ing the TR.</li> <li>2. <b>Validated data for MFM acceptance on board.</b></li> <li>3. <b>Cappuccino study:</b> to clarify gauging issues.</li> <li>4. <b>Dev'ed course on TR48 and MFM technology for bunker surveyors and cargo officers, operators</b></li> </ol>
Manpower	At least 4 involved in a measurement	Automatically	
Productivity	Low. Measured manually	Save >3 hours per delivery	
Accuracy	Not ensured	Ensured with traceably MFM verification on board barges	

# Capability in Gas Flow Measurements



**Range**

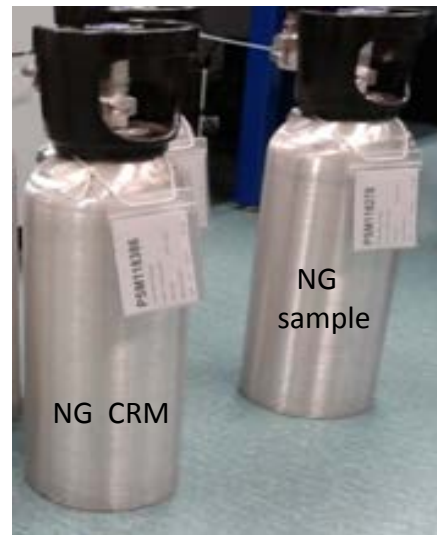
3 – 110 m<sup>3</sup>/h

**Capability**

0.5%

# Capability in Determining NG Calorific Values

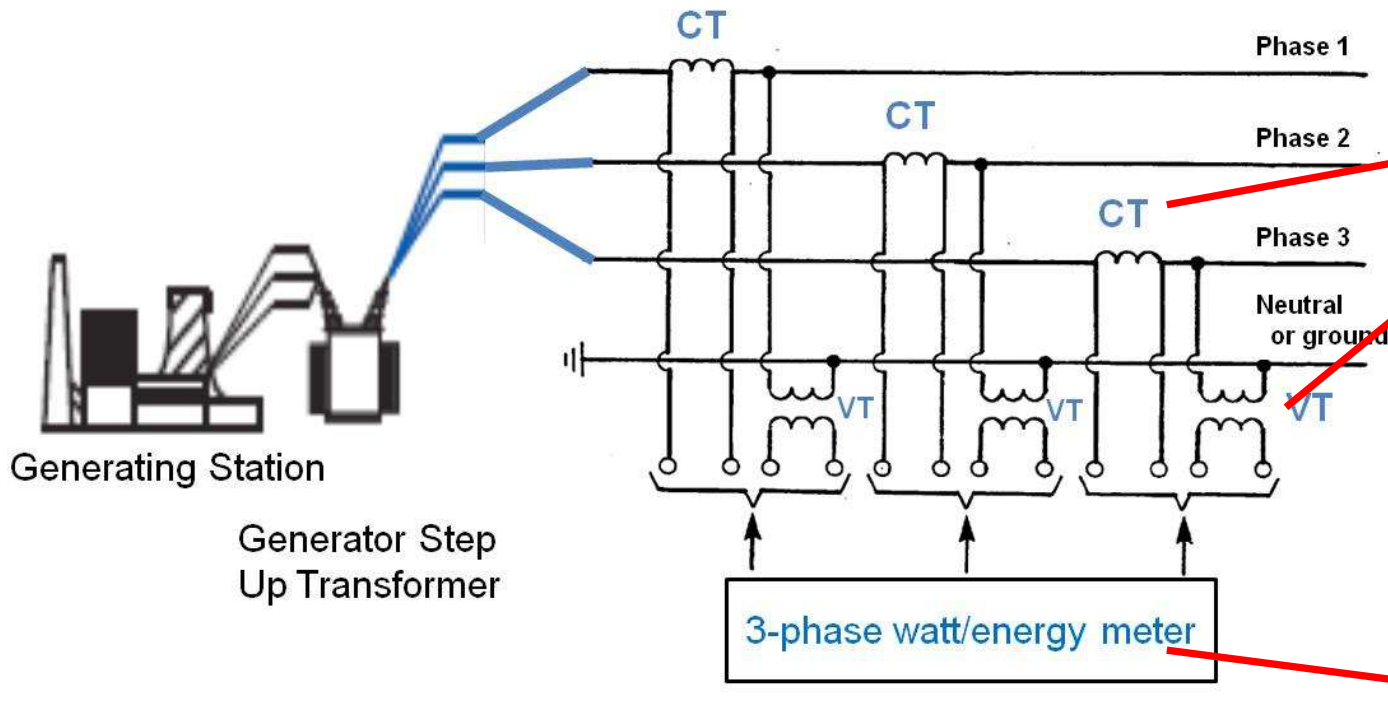
- Commutability of NG depends on its compositions, and determined by analyzing its calorific value
- Certified Reference Material (CRM) are needed for this purpose.



NG Mixture	
N2	n-C4
CH4	neo-C5
CO2	i-C5
C2H6	n-C5
C3	n-C6
i-C4	



# Electricity Measurements



- **CT**: Current transformer for current ratio
- **VT**: voltage transformer for voltage ratio
- **Watt/Energy meter**: metering readings/records

# Capability in Electricity Measurements

## ■ Voltage ratio

- AC 100 kV at 0.016 %
- DC 200 kV at 0.007 %

## ■ Current ratio

- AC 20 A at 0.02 %, 100 A at 0.1%

## ■ Watt meter

- 50/60 Hz, 0.01 %
- 400 Hz, 0.02 %

# Capability in Solar Cell Measurements

## ■ Primary calibration of reference solar cells

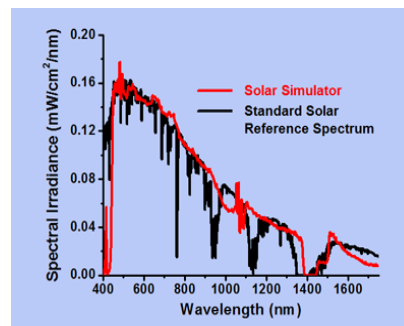
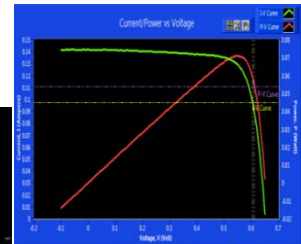
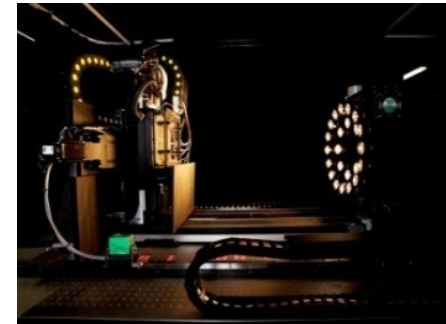
- Absolute / differential spectral irradiance responsivity (285 nm - 1195 nm) at irradiance levels from 0.1 – 1.1 Sun
- Short circuit current under IEC standard testing conditions with measurement uncertainty  $\sim 1\%$  ( $k = 2$ )

## ■ I-V characteristics of solar cells

- V at open circuit
- I at short circuit
- Evaluation of solar cell efficiency

## ■ Solar simulator

- Spectral power distributions
- Irradiance's non-uniformity and instability



# NMC's capability in supporting measurement of energy consumption

- Chilled water system energy efficiency
  - Green Mark requirement
  - Singapore standard SS 591
  - Temperature measurement & evaluation (M&V)
  - Consultancy in chiller plant survey and setting up M&V facilities
- Lighting efficiency determination
- Power quality analyses

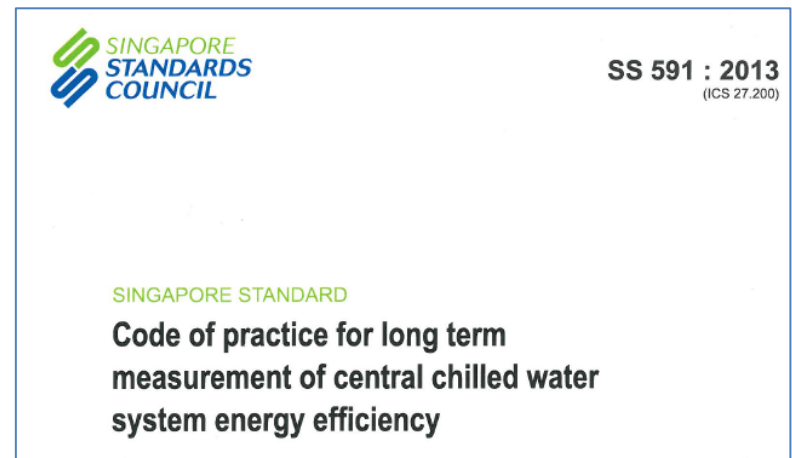
# Green Mark – building sustainability scheme, Building and Construction Authority (BCA), Singapore

- Since inception in 2005, Singapore has certified about 29 per cent of its buildings for sustainability under the Green Mark Scheme up to 2015
- Nation's vision of greening 80 per cent of the city-state's buildings by 2030
- More than 250 projects in 75 cities from 14 countries have adopted the Green Mark Scheme up to 2015
- Requirement of measurement & evaluation of temperature, flow and power for central chilled water system in the latest version GMV4.0 2010



# Singapore standard SS591 – Code of practice for long term measurement of central chilled water system energy efficiency

- Description of measurement and verification
- Measurement and instrumentation required
  - Temperature measurement system with measurement uncertainty within 0.05 °C
  - Flow measurement uncertainty within 1-2 %
  - Power measurement uncertainty within 2%
- Data collection, handling and presentation
- Testing and commissioning
- Long term monitoring



# NMC's contribution

- Key contributor for the development of SS591 in particular for setting up the criteria for temperature measurement instrumentations and uncertainty evaluations
- Public awareness in calibration of thermometers to fulfill the GM needs
- Cooperated with SINGLAS accredited laboratories in meeting temperature traceability requirement

### Calibration of Temperature Sensor for Chilled Water Plant

Type of Interpolation Equation

a) Steinhart and Hart - Thermistor Probe

$$\frac{1}{T} = a + b(\ln R) + c(\ln R)^3$$

R = Resistance in ohms  
T = Temperature in Kelvin (°C + 273.15)

b) Callendar-Van Dusen - PT100 / RTD Probe

$$\frac{R_t}{R_0} = 1 + at + bt^2$$

R<sub>t</sub> = Resistance of temperature sensor at temperature t(°C)  
R<sub>0</sub> = Resistance of temperature sensor at 0°C

The coefficients a, b and c from the above equations are calculated after calibration

Interpolation error of the fitting equation for thermistor

The table shows the calibration results of a Thermistor probe. The results are used to generate the Steinhart and Hart coefficients.

Reference Temperature (°C)	Thermistor Reading (Ω)
0.000	3269.37
15.030	16637.03
30.073	8012.79

Recheck the probe at 2 other temperature points to evaluate the error due to the fitting error of the equation.

Reference Temperature (°C)	Thermistor Reading (Ω)	Calculated temperature using the coefficients generated (°C)	Error between Reference and calculated temperature (°C)
0.000	3269.37	0.000	0.000
15.030	16637.03	15.030	0.000
30.073	8012.79	30.073	0.000
6.581	23004.92	6.566	-0.025
22.000	11374.12	22.022	-0.008

Fitting errors

The typical value for the interpolation error of the fitting equation for PT100 is 0.01 °C or better.

National Metrology Centre

### Calibration of Temperature Sensor for Chilled Water Plant

#### Uncertainty Evaluation

Figure 1 shows the setup for the calibration of Temperature Sensor by comparison method.

Expanded measurement uncertainty with approximately 95% confidence level is 0.03 °C

Figure 1: Comparison calibration

Calibration bath set at 15 °C

SPRT connected to Resistance Bridge

Water Triple Point Cell

Galium Cell

Figure 1: Fixed Point calibration

Insert the temperature sensor into the Fixed Point Cell.

Figure 2: Comparison calibration

At 15°C, the temperature sensor is calibrated by comparison method using calibration bath.

The bath temperature is measured by a Reference Thermometer (Standard Platinum Resistance Thermometer, SPRT) connected to resistance bridge.

The resistance of the temperature sensor is measured using either NMC's or the user's resistance meter. User's resistance meter needs separate evaluation if NMC's meter is used.

The best uncertainties of reference temperature for fixed point and comparison calibrations are approximately 0.001 °C and 0.007 °C respectively.

Figure 2: Expanded measurement uncertainty on site with approximately 95% confidence level is 0.05 °C

When the calibrated sensor is used on site, the site condition affect the measurement uncertainty. The measurement instrument used on site, if not calibrated together with the temperature sensor, shall be evaluated separately and meet certain accuracy requirements.

Figure 2: Expanded measurement uncertainty on site with approximately 95% confidence level is 0.05 °C

Uncertainties for Figure 1 and 2: Standard Uncertainty

- GREEN MARK prerequisite requirement: Uncertainty of temperature measurement system shall be less than 0.05 °C.
- For a chiller with designed ΔT of 5.5 °C, 0.05 °C contributes uncertainty of 1.3% of overall COP at full load.

$$\frac{0.05 \text{ °C}}{5.5 \text{ °C}} \times 100\% = 0.91\%$$

$$\frac{0.05 \text{ °C}}{8.8 \text{ °C}} \times 100\% = 0.57\%$$

- For a 1 000 ton chiller, 0.05 °C results in uncertainty of annual power consumption of \$5 24K

Cooling ton	Elect power (kW)	Annual hrs	U in COP	Thref rate	U in \$/year
1,000	780	8,760	1.3	0.27	24,000

National Metrology Centre

### Calibration of Temperature Sensor for Chilled Water Plant

#### Method of Calibration

##### A) Fixed Point + Comparison Method

Calibration of temperature sensor using:

1. Water Triple point Cell (0.01 °C)
2. Calibration Bath (15 °C)
3. Galium Fixed point Cell (29.7646 °C)

SPRT connected to Resistance Bridge

Water Triple Point Cell

Galium Cell

Figure 1: Fixed Point calibration

Figure 2: Comparison calibration

Insert the temperature sensor into the Fixed Point Cell.

At 15°C, the temperature sensor is calibrated by comparison method using calibration bath.

The bath temperature is measured by a Reference Thermometer (Standard Platinum Resistance Thermometer, SPRT) connected to resistance bridge.

The resistance of the temperature sensor is measured using either NMC's or the user's resistance meter. User's resistance meter needs separate evaluation if NMC's meter is used.

The best uncertainties of reference temperature for fixed point and comparison calibrations are approximately 0.001 °C and 0.007 °C respectively.

##### B) Comparison Method using calibration bath

The temperature sensor and Standard Platinum Resistance Thermometer (SPRT) are inserted into a calibration bath as shown in Figure 2. The temperature of the bath is monitored using an SPRT connected to a Resistance Bridge with a best measurement uncertainty of 0.007 °C. Temperature of the bath can be set from 0 °C to 30 °C.

National Metrology Centre

SINGAPORE STANDARDS COUNCIL

### Launch of SS 591 : 2013 – Long Term Measurement of Central Chilled Water System Energy Efficiency

Date : 22 November 2013 (Friday)  
Time : 1.30pm to 5.30pm  
Venue : 2 Bukit Merah Central (Formerly SPRING Building) Auditorium, Podium Block Level 3 Singapore 159835



# NMC's contribution

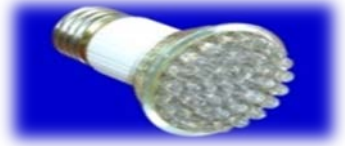
- Provided training for on-site temperature measurement and evaluation
- Provided consultancy in setting up temperature calibration laboratories
- Provided measurement solutions from selection of measurement systems to calibration and installation of the system



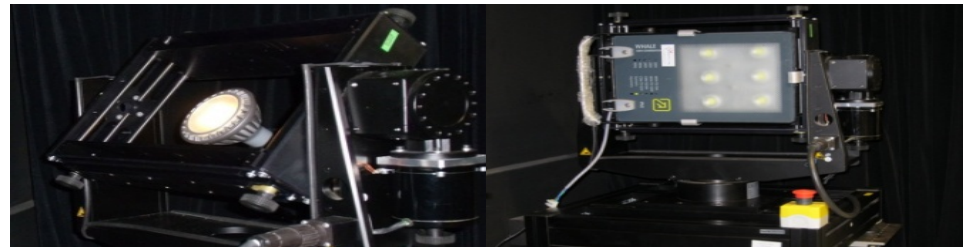


# Capability in LED Lighting Tests

- Luminous flux 20-2000 lumen at 2.5 %
- Luminous efficacy
- Correlated Colour Temperature 2000-7000 K at 30 K)
- Colour Rendering Index 50-100 at 2
- Chromaticity co-ordinate values 0-1 at 0.0015
- Input power, Power factor



1 meter integrating sphere



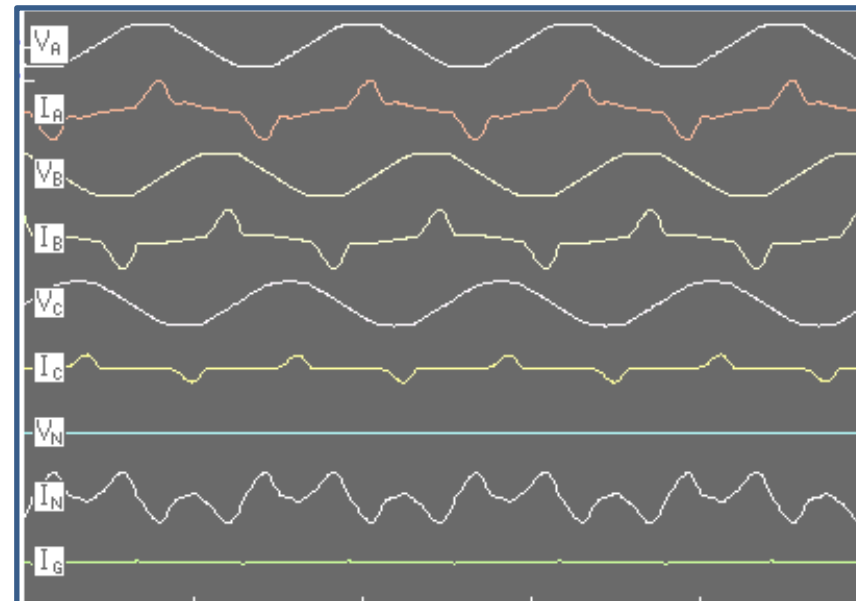
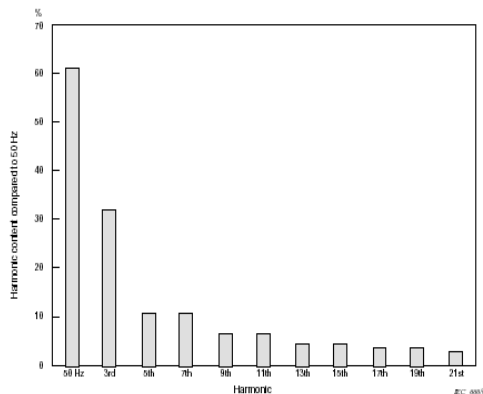
2-axis goniometer

# Capability in Power Analyses

- Voltage: 0.01 %
- Current: 0.01 %
- Power: 0.02 %
- Phase:
  - V to I: 0.003 deg
  - V to V: 0.005 deg



**For sinusoidal and non-sinusoidal signals**



# New technologies are needed for Environmental Sensing

## Traditional Approaches:



- Expensive, complex, stationary equipment
- Limited mostly to governments, industry and researchers
- Data are collected for compliance monitoring, enforcement, trends and research
- Accessed by government websites, permits records and research databases

## New Paradigm:

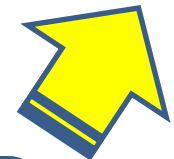
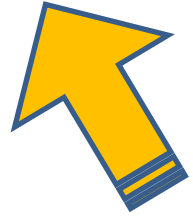


- Lower-cost, easy-to-use, portable pollution monitors (Sensors)
- Provides high resolution data in near real-time
- Enhance a range of existing pollution monitoring capabilities
- Provide avenues to new monitoring applications
- Enhanced availability and accessibility of pollution monitoring data

# Metrology for Environmental Sensing

Urban Solutions & Sustainability

Smart Nation Programme

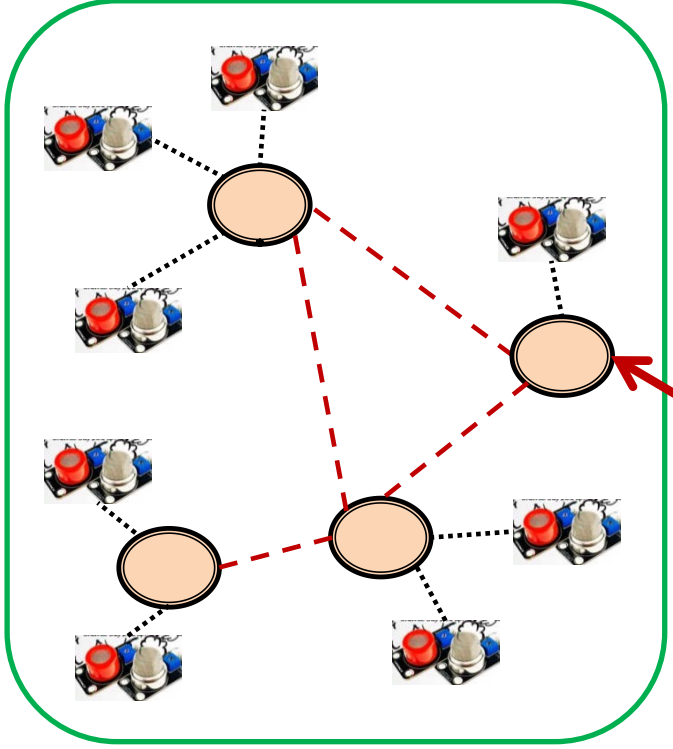


Reliable and Traceable Data



Calibration & Validation

Ref. Standard



 Sensor Node  
 Sensor

CREATING GROWTH, ENHANCING LIVES

# 2016 APMP TCI project: Research on low-cost sensors

- ✓ Review commercial sensors.
- ✓ Effects of temperature and humidity on sensing methods.

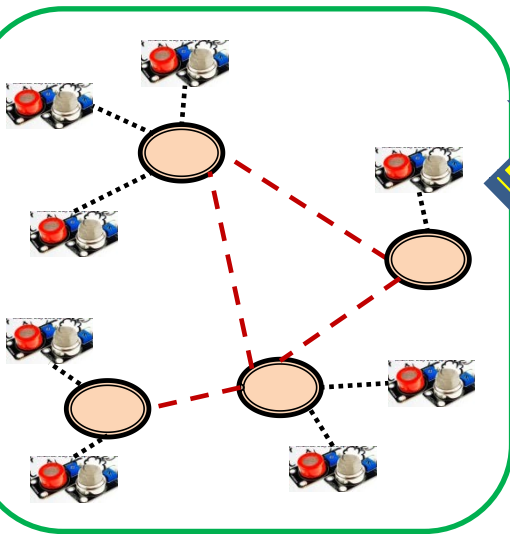
- ✓ Current metrological assessment methods.
- ✓ Relevant regulations in Asia Pacific regions.



APMP Team Discussion

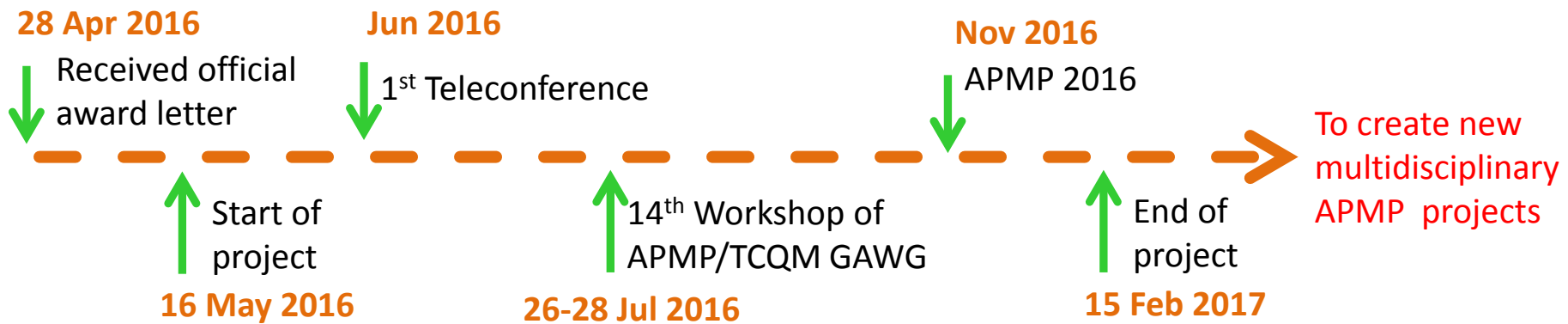
## Outcome

New information of metrology capabilities required to support urban air quality measurements



 Sensor     Sensor Node

# TCI Project Latest Development and Plans:



## Main project team members:

10 researchers from 6 NMIs (NMC; NIM; NMISA; ITRI/CMS; LIPI; SIRIM)

- NMC, Singapore: Dr KAI Fuu Ming, Dr Wendy LIU, Dr FAN Yan, Dr CUI Shan
- NIM, China: Dr ZHOU Zeyi
- NMISA, South Africa: Dr James TSHILONGO
- ITRI/CMS, Chinese Taipei: Dr LIN Tsai-Yin
- LIPI, Indonesia: Dr Oman ZUAS
- SIRIM, Malaysia: Mr Fauzi bin Ahmad, Mr Arshad bin Selamat, Mrs Faridah Hussain

**Thank you!**