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NATIONAL PRODUCT TESTING LABORATORIES DRIVE ECO-EFFICIENCY: CAPACITY BUILDING STUDY TOUR IN THAILAND

INTRODUCTION

In line with Pakistan´s Nationally Determined Contribution commitments to reduce its emissions by 20%, the National Energy Efficiency and Conservation Bill was approved by the National Assembly in February 2016 to strengthen Pakistan's institutions and accelerate the procedures and mechanisms for the effective conservation and efficient use of energy in the country. In support of the national decarbonization plans and sustainable economic development for over 230 million people in Pakistan, the Global Environment Facility supported project "Delivering the Transition to Energy Efficient Lighting in Residential, Commercial, Industrial, and Outdoor Sectors" was formally launched in February 2019. The project, jointly implemented by Pakistan's National Energy Efficiency and Conservation Authority (NEECA) as the federal focal authority and the United Nations Environment Programme United for Efficiency (U4E) initiative, aims to secure significant global climate change and environmental emissions reductions benefits by instituting high quality and energy-efficient lighting as the norm across Pakistan.

Fundamental to the successful implementation of any regulatory programme which aims to fully transform a national market to eco-efficient lighting products is the country´s competent photometry test laboratories as a key part of the national monitoring, verification and enforcement (MVE) system. Having local facilities with the capacity to meet the testing demands of manufacturers, suppliers and government enforcement agencies will enhance the compliance rate and underpin confidence in the market. Pakistan's Minimum Energy Performance Standards and Labelling Regulations for Lighting Products in the Domestic and Street Lighting Sectors became mandatory from December 2020. Nonetheless, recent assessments of the testing facilities in Pakistan have concluded that there are still limited capabilities in the provision of the full range of testing requirements for these recently implemented standards, as well as a lack of sufficient experience with some equipment including the new calibration and test methods required.

Against this background, a testing laboratory capacity building programme for Pakistan was deemed vital in preparation for the onset of a full national market MVE system for safeguarding the application of the new lighting regulations. Pakistan´s Energy Efficiency Lighting Project therefore included the design and delivery of a Photometric Laboratory Study Tour Training Programme at an internationally accredited testing facility within an existing energy efficient regulatory regime as preparation for the new regulations. The aim of the training was to develop competent national laboratories capable of undertaking the testing required to underpin the regulation of energy efficiency for lighting products in Pakistan. The training week was carried out at the national laboratory of Thailand in August 2022 for relevant staff from both Pakistan, along with a small delegation from the Sudanese Standards and Metrology Organization (SSMO) representing the *Energy Efficient Appliances and Lighting in Sudan* project, with the aim of sharing experiences and practices with the relevant technical equipment, terminology, calibration and test methods related to lighting market quality regulation.

Specific objectives of the lighting technical study tour programme included:

- In-house calibration of reference items and laboratory equipment.
- Conducting various test methods for measurement of lamps and luminaires, including inter-laboratory comparison of test results from visiting international laboratories.
- Investigation of measurement uncertainties.
- In-house operational maintenance, monitoring, and undertaking remedial actions.

THE PREPARATION STAGE FOR THE LIGHTING STUDY TOUR TO THAILAND

In coordination with the National Energy Efficiency and Conservation Authority (NEECA), the International Institute for Energy Conservation (IIEC) and United Nations Environment Programme United for Efficiency (U4E) initiative, the study tour took place between 8 and 11 August 2022 at the Electrical and Electronics Institute (EEI) in Bangkok, Thailand. The EEI is an industry specific institute under the supervision of the Ministry of Industry in Thailand founded in July 1998. The services provided by its Operation and Standards Center include electrical and electronic product testing, measuring instrument calibration and factory quality inspection. All services are accredited by the Thailand Industrial Standards Institute (TISI) and the National Accreditation Council (NAC).

Picture 1. The Electrical and Electronics Institute (EEI) in Bangkok, Thailand

The travelling delegation included participants from several key government agencies and test facilities from Pakistan, including the Ministry of Science and Technology, the Pakistan Council of Scientific and Industrial Research (PCSIR) and the Centre for Energy Research and Development (CERAD). The eight attendees were:

- **Mr Ghulam Muhammad Memon**, Federal Secretary, Ministry of Science and Technology, Government of Pakistan
- **Dr Sardar Mohazzam**, Managing Director, National Energy Efficiency and Conservation Authority
- **Mr Ahmed Hassnain**, National Project Manager
- **Mr Feroz Baig**, Director (Industry), NEECA
- **Mr Imran Ali Shah**, Senior Manager Research, Centre for Energy Research and Development
- **Mr Waqas Khalid**, Assistant Manager, Centre for Energy Research and Development
- **Mr Khurram Javed**, Experimental Officer, Electric Measurement Test Laboratory, Pakistan Council of Scientific and Industrial Research
- **Mr Touqeer Hussain Shah**, Research Officer, National Institute of Electronics

They were joined by a small delegation from the Sudanese Standards and Metrology Organization (SSMO) as special guests:

- **Mr Mohamed Widaa Ali Mohamed**, Head of Household Appliances Testing Laboratory
- **Ms Intisar Abdallah Sid Ahmed Abuswar**, Household Appliances Testing Engineer

The delegates were joined by U4E´s International Lighting Expert, **Steven Coyne**, and IIEC personnel.

Picture 2. Pakistani delegation at EEI, Thailand

The study tour consisted of a four-day training framework, 6 hours per day, and involved:

- Touring laboratory facilities, inspecting measurement equipment relevant to testing requirements for energy efficient lighting regulation.
- Observing testing being carried out on lighting artefacts.
- Participation in seminars presenting materials on theory and practice in photometric testing.

The detailed agenda is given below.

Time		Activities
Day 1 **08/08/2022**	09.00-12.00	**Opening session** **Laboratory tours** • Integrating sphere with spectroradiometer • Far-field gonio-spectroradiometer (Cγ) • Test product ageing room (Luminous flux maintenance) • Photobiological hazard measurement facility • Q&A
	13.00-16.00	**Laboratory tours (Cont.)** • Electrical test facility • Temporal light modulation (flicker) measurement equipment • Electromagnetic compatibility (EMC) test facilities • Q&A
Day 2 **09/08/2022**	09.00-16.00	**Observing the testing of Pakistan artifacts** • Far-field gonio-spectroradiometer (directional LED lamp) • Integrating sphere with spectroradiometer (non-directional LED lamp) • Far-field gonio-spectroradiometer (small LED streetlight) • Q&A
Day 3 **10/08/2022**	09.00-12.00	**Traceability and calibration method** • Traceability of photometric and radiometric quantities • Integrating sphere system and gonio-spectroradiometers system • Calibration of luminous flux standards • Q&A
	13.00-16.00	**Traceability and calibration method (Cont.)** • Calibration of luminous intensity standards • Calibration of illuminance and luminance meters • Q&A
Day 4 **11/08/2022**	09.00-12.00	**Laboratory housekeeping** • Record keeping system • Test item identification and storage conditions • Accreditation maintenance • Monitoring laboratory conditions • Q&A
	13.00-16.00	**Analysis of inter-laboratory test results** • Correlation of results • Uncertainty considerations • Identifying inconsistencies in test results • Investigating flaws in testing procedures and equipment faults/inadequacies • Lessons learned • Q&A

STUDY TOUR DAY 1

The morning of the first day of training, participants were welcomed at EEI by Mr Witee Srimongkol, Vice President from the Testing and Calibration Department.

This was followed by inspections of the photometric measurement facilities, were the attendees gained an appreciation for the type and scale of equipment required for conducting the testing, and testing laboratory conditions.

Where testing is conducted in an open room, stray light reflected from walls/objects or infiltrating the room from outside must be minimised, so walls are painted black and curtains are used to block any of this unwanted light from being measured, as illustrated in Pictures 3 and 4. Where an enclosed measurement vessel such as an integrating sphere is used such precautions are not required.

Internal calibration and traceability to external calibration bodies for the reference light sources and meters used in a laboratory is critical to its accurate determination of measured quantities. Picture 3 illustrates the optical bench and alignment systems used for internal calibrations.

These two equipment types, goniophotometers and integrating spheres, provide the fundamental measurement means for light output and colour of a lighting source.

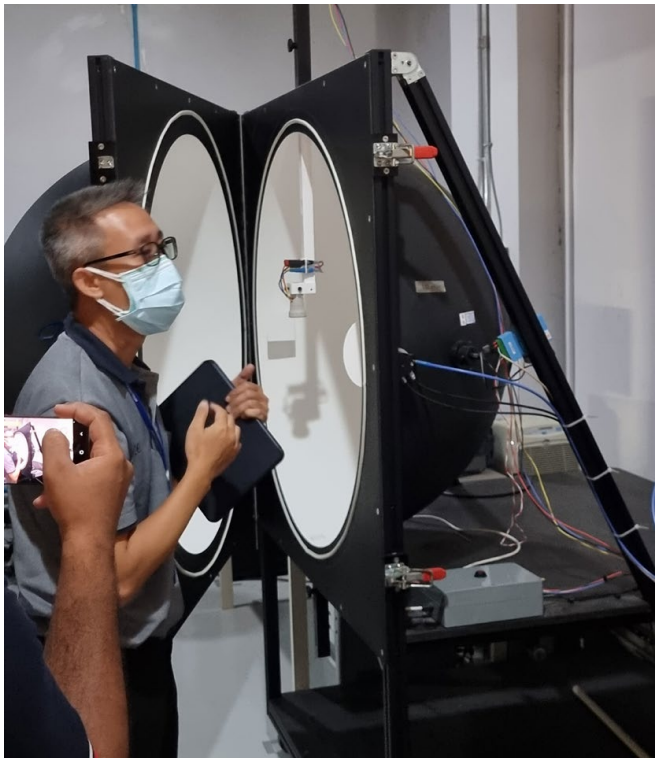
In order to measure the light intensity distribution emitted by a light source, a large goniophotometer is required which uses a mirror to redirect the light to be measured from around the light source towards a measurement sensor. Picture 4 shows a mirror type goniophotometer at EEI.

Picture 4. Inspection of mirror type goniophotometer with C,γ coordinate system, used for measuring luminous intensity distribution and total luminous flux of light sources

If only the total amount of light and average colour of light emitted by the light source is to be determined, an alternate system known as an integrating sphere can be used, where the light source is enclosed within the sphere. In this situation, the light emitted in all directions by the light source is internally reflected and ultimately reaches a measurement sensor that is situated in the side of the sphere. Picture 5 and 6 show two integrating spheres in situ at EEI.

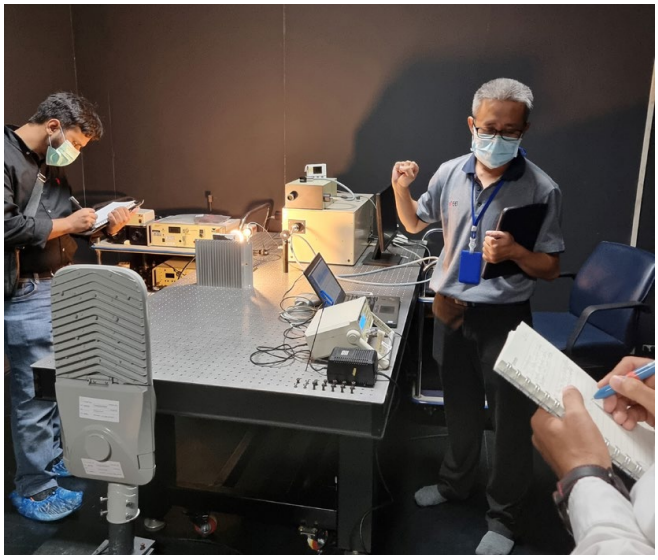
Picture 3. Inspection of optical bench used for calibration of reference light sources (for luminous intensity) as well as calibration of illuminance and luminance meters

Picture 5. Inspection of 3 metre diameter integrating sphere, used for measuring total luminous flux and colour quantities of light sources ranging from small lamps to large luminaires

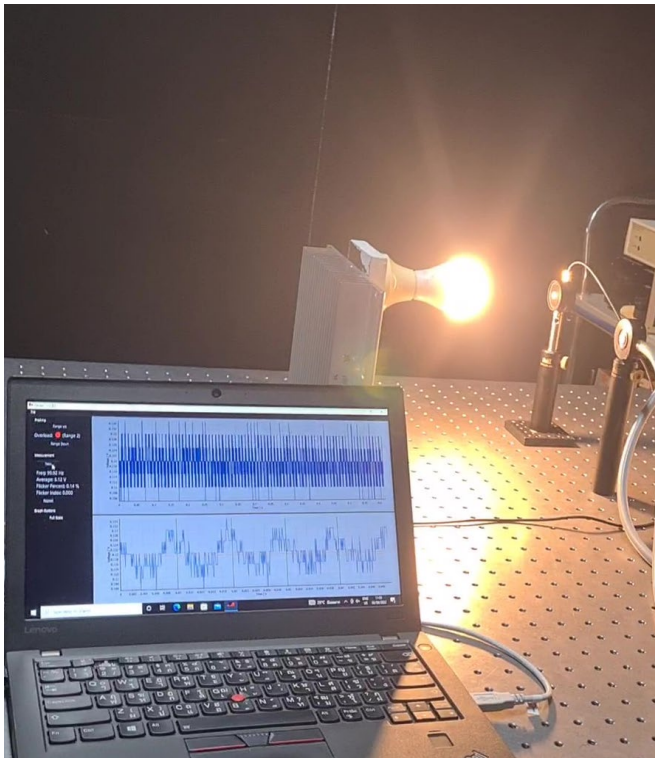


Picture 6. Inspection of 0.5 metre diameter integrating sphere, used for measurement of luminous flux and colour quantities of small lamps

Lighting matters relating to a person's health also require measurement of a product to determine the level of risk it presents. Measurement of blue light hazard (retinal health) and UV hazard (eye lens and skin health) are particularly important for LED and discharge lamps respectively. The equipment used to measure these is shown in Picture 7. Systems for measurements of flicker and stroboscopic effects are very important for LED light sources. The equipment used to measure these is shown in Picture 8.



Picture 7. Inspection of spectroradiometer used to measure photobiological safety (blue light hazard, UV hazard)



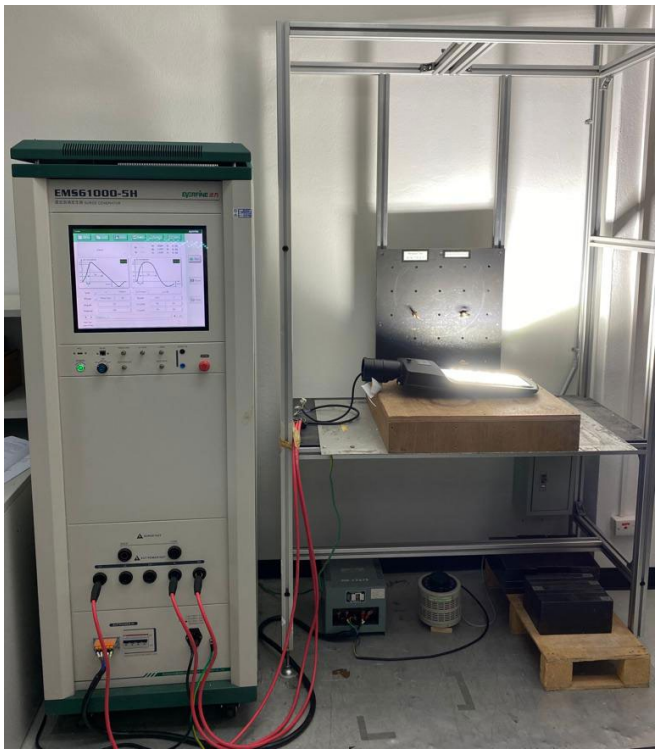
Picture 8. Inspection of fast response photometer for measuring temporal light modulation (viz flicker and stroboscopic effect visibility)

Before meaningful measurements can be undertaken, a light source has to be operationally stable. This requires the test item to reach it operating temperature, which can typically take between 30 minutes to 2 hours. Rather than waiting this entire period for the stabilisation to occur while set up in the measurement system (e.g., in an integrating sphere) effectively making the system non-productive, the test item can be operated in an ageing rack (shown in Pictures 9 and 10), while it attains its operating temperature. At this point it can be quickly transferred to the measurement system and only requires a short period of time to regain stability. This procedure significantly increases the number of tests that can be conducted in a day. The ageing racks are also used when conducting lifetime testing where extended operation time (i.e., thousands of hours) of lighting products is required.

Picture 9 and Picture 10. Inspection of lamp and luminaire ageing facility, used for endurance testing and lifetime measurement (based on light loss over time). Can be used for pre-burning (warm up) of lighting products prior to photometric and colorimetric measurements

Another important aspect of testing is the electrical safety of a product. This entails mechanical and electrical testing. Mechanical tests relate to product damage or incorrect lamp base dimensions, both of which can present exposed live electrical contact points. The torsion test on the cap is one such test (which uses the equipment shown in Picture 11). Voltage surges on electricity distribution networks due to lightning strikes or transmission line clashes in strong wind conditions make it necessary for lighting products to be tested for electrical protection against such events (The equipment used for this is shown in Picture 12).

Picture 11. Inspection of a mechanical test for electrical safety of lamps: torsion test for secure fixing of lamp cap to the lamp



Picture 12. Inspection of electrical test for safety for lamps: voltage surge test

The final inspection for the day was of the electromagnetic compatibility (EMC) test facility, where testing is conducted on the radio frequency emissions from electrical and electronic products which may interfere with the operation of other electrical and electronic products within the near vicinity. The facility can also test products for the opposite situation i.e., their immunity from radio emissions generated by an external source.

STUDY TOUR DAY 2

The second day was entirely filled with observing testing that was being carried out on lighting products as part of an inter-laboratory comparison activity being undertaken as part of the *Delivering the Transition to Energy Efficient Lighting in Residential, Commercial, Industrial and Outdoor Sectors in Pakistan* project. Prior to commencement of the study tour, each participating laboratory in Pakistan was required to undertake measurement of a listed number of several specified artefacts (lamps) in order to perform inter-laboratory comparison experiment exercises. These tested artefacts travelled with the Pakistan laboratory staff to Thailand and were handed over to the laboratory for comparison measurement and analysis as part of the training visit.

While observing the testing in the integrating spheres and two types of goniophotometer systems, the attendees asked pertinent, detailed questions in relation to the test procedures undertaken, including test item stabilisation time, baffle sizing and location in an integrating sphere, influence of test item orientation in a goniophotometer, centering of test items in test equipment. They were also able to observe the practices of the EEI technicians while conducting the tests. Pictures 13 and 14 show the delegates observing testing being carried out.

Picture 13. Observing testing of Pakistan lamp in integrating sphere. Discussion is on the positioning of the lamp at the optical centre of the sphere by use of a laser positioning system

Picture 14. Observing testing of Pakistan streetlight in the rotating-source goniophotometer with C,γ coordinate system. Discussion is on effects on test results of rotated operating position, stray light and dead angle

STUDY TOUR DAY 3

The third day comprised presentations on the topics of traceability and calibration methods. The presentations were provided remotely by staff at the National Institute of Metrology of Thailand (NIMT). The venue for the day is shown in Picture 15.

They included an introduction to the fundamentals of photometric and colorimetric measurements, specific measurement equipment and the associated principles of measurement. This helped the attendees to understand key operational aspects and appreciate the potential for measurement practices to influence measurement outcomes.

Picture 15. Presentation on fundamentals of photometry and colorimetry and the theory of operation/measurement of quantities by an integrating sphere and a goniometer

The hierarchy of traceability of calibrations for measurement equipment (e.g., a luminance meter) and reference materials (e.g., a reference lamp with known light output), were also discussed at length. All calibrated items should have an unbroken chain linking their calibration all the way back to the establishment of the Standard International (SI) Unit.

A real-time virtual tour of the NIMT laboratories was a highlight of the day. Here reference light sources are established using highly sophisticated cryogenic systems and very precise measurements are conducted.

STUDY TOUR DAY 4

The morning session of the final day was a presentation on laboratory housekeeping delivered by the EEI Quality Assurance Division Manager. This, not so glamorous part of laboratory work, is still a critical component to the integrity of product testing. It was explained that without (a) security of items to be tested (from arrival at facility to departure), (b) unique identification marking on test item, (c) traceability of all records associated with the item and the tests, and (d) monitoring and recording of laboratory environmental conditions, test results could be called into question and at worst challenged in a court of law when regulators are undertaking enforcement actions against non-compliance of regulations.

The afternoon session entailed a review of the results from the inter-laboratory testing comparison exercise for the LED products tested in Pakistan laboratories and then retested at EEI during Day 2. The products were three LED bulbs, one downlight fixture and one streetlight fixture. The results were presented to the group and significant variations between laboratories were discussed as to what might be the possible causes for the variations. This was an insightful activity for the attendees as they came to appreciate the processes and their value in resolving such inaccuracies of measurement.

The day ended with sincere thanking to EEI for hosting the training and to all the presenters from EEI and NIMT for excellent delivery of requested materials. In closing, EEI presented NEECA with a gift for attending the training event (Picture 16).

Picture 16. Presentation of a gift from EEI to NEECA (representing the collective attendees)

ACKNOWLEDGEMENTS

The United Nations Environment Programme United for Efficiency initiative would like to sincerely thank the Electrical and Electronics Institute (EEI) in Bangkok, Thailand, for conducting an exceptional training programme for our Pakistani and Sudanese sustainable energy colleagues. The excellent expertise and experience of all the EEI presenters and staff in Thailand supporting this important training was evident and is highly valued. We would also like to thank the management of EEI for the availability of the test facilities which was invaluable to the success of the lighting study tour, as well as all the National Institute of Metrology of Thailand (NIMT) colleagues for their valuable inputs and hospitality. Lastly, we would like to sincerely thank our United for Efficiency partner, the International Institute for Energy Conservation (IIEC), who made this successful Study Tour in Thailand possible with their flawless coordination.

ABOUT UNITED FOR EFFICIENCY

United for Efficiency (U4E) is a global initiative led by the United Nations Environment Programme (UNEP), funded by the Global Environment Facility (GEF), and supported by an array of leading companies, expert organizations, and public entities with a shared interest in transforming global markets for lighting, appliances and equipment to more energy efficiency alternatives saving all electricity consumers, including government, $ billions at the same time.

To learn more about United for Efficiency's work and tools, please visit: united4efficiency.org

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