Publishable Summary for 20SCP01 Smart PhoRa
Supporting smart specialisation and stakeholder linkage in Photometry and Radiometry

Overview

Within Europe there are emerging national metrology institutes (NMIs) and designated institutes (DIs) that provide the highest order in the traceability chain within their country for photometry and radiometry, but who are not able to fulfil the needs of stakeholders for the measurement and traceability of particular quantities / parameters due to a lack of necessary metrological expertise. This project enabled emerging NMIs and DIs to develop their metrological knowledge and expertise concentrated in those metrology fields, which are of major interest for the stakeholders (industry and society) in their countries with respect to smart specialisation in the field of photometry and radiometry. This was achieved through the delivery of web-based seminars, training lectures and hands-on laboratory experience to support the development of the metrology infrastructures within these countries, thus enabling a better and more effective linkage between the participating NMIs and the stakeholders to address their needs.

Need

Reliable measurement capability in photometry and radiometry is required to support industry, regulation and research related to lighting based on LEDs and safe illumination, the optical appearance of products, fibre optics, photovoltaics and solar cells, to name a few.

Within the EURAMET Technical Committee for photometry and radiometry (TC-PR), and before this project, there were emerging NMIs and DIs that provided the highest order within the traceability chain for photometry and radiometry, but who were not able to fulfil the needs of the stakeholders within their countries. Furthermore, mainly due to a lack of resources (primarily labour) and lack of expertise, they were also not able to participate or only to participate in a very limited manner in European funded research projects e.g. within EMPIR. Within this project an emerging NMI was defined as an NMI which could not fulfil the requirements of its country in that specific metrology area, whereas a highly developed (highly experienced) NMI was an NMI that was able to provide teaching and training for the emerging NMIs in specific metrology areas. At the TC-PR meetings held in recent years, both the necessity to develop metrological expertise to address the specific stakeholder needs as well as the lack of possibilities to develop this expertise, became more and more clear. Therefore, a new process was started within the TC-PR. Since 2018, there have been yearly workshops, collocated with the TC-PR Annual Meetings, on support, collaboration and coordination (SCC) within the TC-PR. This process started with a workshop on the identification of the specific needs of each TC member with respect to the stakeholders' requirements within their country. Each TC member briefly presented their needs, drawn from stakeholder consultations and needs identified within their countries. This workshop series had the aim to address the specific needs of each NMI and DI within the TC-PR, especially for the emerging ones. At the end, a structured workplan for the development and support for smart specialisation of specific topics in the emerging NMIs/DIs was developed. The topics identified as the most urgent where emerging NMIs/DIs needed to specialise and improve their expertise were photometry, spectrophotometry and appearance, fibre optics and photovoltaics. In the context of this project, smart specialisation referred to the decision of NMIs/DIs to develop or improve capabilities in particular fields based on stakeholders' needs and a coordinated European approach (through EURAMET TC-PR) to identifying the priority areas.

Objectives

The overall aim of the project was to enable emerging NMIs/DIs to develop their metrological knowledge and expertise concentrated in areas that are important to their specific needs of the stakeholders within their region with respect to smart specialisation in the field of photometry and radiometry.

The specific objective of the project was:

1. To provide training and transfer knowledge to enable emerging NMIs/DIs to develop their metrological knowledge and expertise in the field of photometry and radiometry to support smart-specialisation (i) under consideration of the specific national and regional stakeholder needs, (ii) based on the identified

stakeholder needs presented in workshops on support, collaboration and coordination held within the TC-PR, (iii) by improving the linkage between NMIs and stakeholders based on enhanced expertise and (iv) by building mutual trust between the project partners.

Results

This project aimed to increase the expertise of Aalto, BIM, CNAM, CSIC, GUM, INM, Metrosert and TUBITAK, so that they could fulfil the requests from their stakeholders. Four priority fields were identified: photometry (P&R calibration of LEDs, safety of light sources), appearance (gloss, colour reflectometry, reflectometry), fibre optics and photovoltaics. Emerging NMIs/DIs only received training in those fields / sub-fields where they needed to specialise, and which had been identified as a priority for them.

The training events were organised by experienced NMI/DIs and held as webinars for the relevant partners.

PTB held a 1-day webinar in March 2022, focused on photometry and radiometry, in particular calibration of LEDs and spectral measurements of light sources. It was attended by BIM, CNAM, TUBITAK and INM. A webinar on the measurement of gloss was held in June 2022. CNAM, KU-Leuven and international experts outside of the consortium (NIST and NRC) gave lectures on the history of specular gloss, ASTM D523 'Standard Test Method for Specular Gloss' and ISO 2813 'Paints and varnishes' standard, as well as standard artefacts and commercial glossmeters. It should be noted that more than 49 participants from 27 institutes attended the seminar, which was open to members outside of the project. From this webinar, 5 videos were recorded and uploaded on the YouTube channel of the project, here: SmartPhora - YouTube. A webinar on colour measurements was performed in February 2022, for co-workers of three European NMIs (GUM, Metrosert, TUBITAK) within the consortium. A seminar on reflectometry was prepared by CSIC with support of Aalto, and held in March 2022. There were 14 attendees from partners within the consortium (BIM, Aalto, TUBITAK and GUM). In January and June 2022, a total of 4 webinars were organised and held by CSIC on optical fibre metrology, in particular optical detectors and power meters, spectrum analysis (optical spectrum analysers, wavelength meters), calibration of optical time domain reflectometers (OTDR) and linear properties of fibre optics calibration of Chromatic Dispersion (DC) & Polarization Mode Dispersion (PMD) instruments. The seminars were attended by Metrosert and TUBITAK. In March 2022, a webinar on photovoltaics and photovoltaic measurements was organised and held by PTB for co-workers of TUBITAK and Aalto, sharing knowledge partially gained within EMPIR project 16ENG02 PV-Enerate.

The webinars were followed by trainings at the corresponding experienced NMI/DI, which included theoretical and practical lectures at their facilities.

PTB held a training course on photometry with CNAM, BIM, INM and TUBITAK between 19 and 23 September 2022. The course included topics dealing with the photometric bench, spectroradiometry, integrating spheres and goniophotometry / goniospectroradiometry. Eight attendees from 5 countries participated in this hands-on training course (including one participant from Ukraine). During the hands-on training PTB, BIM and INM provided on-site spectral measurements of light sources relevant to the safety of such light sources.

A training course on the measurement of gloss was organised from between 28 November and 1 December 2022. The content of the course included the standard ISO 2813 'Paints and varnishes', gloss standard artefacts, gloss measurements using commercial glossmeters, visual gloss and specular gloss, CNAM primary glossmeter, cleaning of samples and advanced gloss measurement.

PTB organised a training course on colour measurements between 7 and 10 June 2022. The course included theoretical and practical lectures on colour reflectometry, sources of uncertainty and estimation, correlations in uncertainty calculations using tristimulus values, practice measurements using spectrophotometers, and uncertainty budgets. It was attended by 8 participants from the consortium (PTB, GUM, TUBITAK and Metrosert).

A training course on the measurement of reflectometry was held by CSIC between 11 and 15 July 2022. The participants were given hands-on training on the measurement of BRDF (Bidirectional Reflectance Distribution Function), BTDF (Bidirectional Transmittance Distribution Function) and BSSRDF (Bidirectional scattering-surface reflectance distribution function) using a goniospectrophotometer. A 3-min video was produced explaining the procedure for measuring BRDF, and a report was written.

Aalto organised a one-week duration training course in January 2023. The course focused on reflectance and transmittance, diffuse, specular, and relative sphere-based methods. It was attended by BIM and TUBITAK.

CSIC organised hands-on trainings on fibre-optics between 12 and16 September 2022 (for TUBITAK) and between 20 and22 February 2023 (for Metrosert). In total three people were trained on measurements and calibrations of various fibre-optic measurement devices.

PTB organised a hands-on training on photovoltaics between 9 and 13 January 2023. TUBİTAK and Aalto were trained on i) I-V measurements of bifacial PV devices in accordance with IEC 60904-1-2:2021 standard, ii) simulator performance measurements in accordance with IEC 60904-9 standard, iii) measurements of spectral irradiance responsivity of a photovoltaics devices with Differential Spectral Responsivity (DSR) technique, iv) mismatch calculations and v) uncertainty evaluations of measurements.

Furthermore, in the final stage of the training and knowledge transfer, experts from an experienced NMI/DI visited the relevant partners to provide on-site training at the partners' sites:

- TUBITAK organised a visit of experts from PTB to TUBITAK for 2-day on-site training course in the field of photometric and radiometric calibration of LEDs. The training was held in November 2022.
- BIM organised visits of experts from PTB and INM to BIM for a 3-day training on spectral measurements relevant to the safety of light sources. The training was held in November 2022.
- CSIC visited TUBITAK and Metrosert to provide training and transfer knowledge in the field of fibre optics. The visits took place from 14 to 16 February 2023 (TUBITAK) and from 7 to 9 March 2023 (Metrosert).
- PTB visited TUBITAK between 16 and 20 January 2023 for providing training in the field of metrology in photovoltaics, mainly on measurements of emerging photovoltaics devices and bifacial modules.

Finally, the success of the various training activities was evaluated by the investigation of measurement results achieved by the emerging NMIs/DIs in the relevant sub-field in either an interlaboratory comparison, interlaboratory pilot study or laboratory tests, as appropriate.

1. Luminous intensity of LED-based transfer standards (interlaboratory pilot study) - PTB, CNAM, TUBITAK

PTB values were accepted as reference values. The results of the three NMIs were compatible with each other, therefore indicating that the NMIs have achieved the targeted outputs to validate themselves within the scope of the project.

2. Spectral measurements of harmful radiation of different non-coherent light sources (laboratory tests) - BIM, INM, PTB

Spectral measurements of radiation of different non-coherent light sources were carried out. The results will contribute to knowledge transfer to laboratories which deal with monitoring of harmful light radiation. The main outcome is the assured vision safety.

3. Gloss (interlaboratory pilot study) - CSIC, Aalto, CNAM, GUM, Metrosert

Gloss measurements of four samples, covering the gloss range from 20 GU to 93 GU, were performed with different measuring systems and procedures, including commercial instruments and alternative methods. The measurements were analysed, and the results show compatible values for the 'glossier' studied samples when using the alternative methods. In addition, the results obtained with a conoscopic detection system developed at CNAM were compatible with less 'glossier' samples, proving that this methodology is applicable in a meaningful range of gloss values. The main challenge in reaching better consistency with the alternative methods seemed to be the realisation of the exact geometrical conditions specified by the standards in the measurement of the reflectance. The measurements with the commercial glossmeters were compatible with the calculated reference value within a confidence interval of 95 % (approximately ± 2 GU).

4. Colour (interlaboratory pilot study) - GUM, Metrosert, PTB, TUBITAK

The results of the interlaboratory pilot study were analysed and shown to be consistent. However, the consistency analysis was preliminary, in the sense that a complete evaluation according to usually applied guidelines for comparisons was not performed. Once this is done, it is expected that at least some of the results will turn not be consistent, and that the uncertainty evaluations of some of the partners must be revised accordingly.

5. Diffuse reflectance (Interlaboratory comparison) - TUBITAK, Aalto, CSIC

An interlaboratory comparison on BRDF measurements was performed. In the analysis of the measurement results, the reference value and the uncertainty were taken as the average of the measurements of Aalto and CSIC. The results of TUBITAK were shown to be within the reference values, which indicates that TUBITAK achieved the targeted outputs in terms of the measurement of diffuse reflectance.

6. Fibre optic power responsivity (interlaboratory comparison) - TUBITAK, CSIC, Metrosert

An interlaboratory comparison on the calibration of fibre optic power meter was performed. In the comparison, TUBITAK was the pilot laboratory, CSIC and Metrosert were participating laboratories. The analysis of the comparison results of the three participants at agreed wavelengths (1310 nm and 1550 nm) and power levels (0 dBm and -23 dBm) showed good agreement.

7. Electrical performance of bifacial PV modules and WPVS devices (interlaboratory comparison) - TUBITAK, Aalto, PTB

Using the measurement results for the cell measurements from TUBITAK and Aalto, the E_n-values were analysed. All bilateral E_n-values were considered successful according to the criteria of E_n-evaluation. Using the measurement results from TUBITAK and PTB for two modules, E_n-values were evaluated. The analysis of the results showed that only part of the E_n-values was successful. Future work (outside of the project) will include an investigation of the reasons for the observed discrepancy.

The web-based lectures, reports and documents produced within this project have been made available not only to the project partners, but also more widely to TC-PR. These include a compendium of webinars and a compendium of training courses for capacity building within the TC-PR, as well as a report describing the knowledge transfer within the TC-PR. Additionally, the capacity building material prepared within the project is also available within the countries of the partner NMIs/DIs, in order to transfer knowledge to non-NMI actors.

Impact

A project website was created and updated regularly during the lifetime of the project. The results of the project were presented at EURAMET TC-PR meeting in Jan 2023.

Early impact on user communities

As a result of the project, emerging NMIs and DIs within the photometry and radiometry field were able to receive the necessary knowledge in specialised areas to fulfil the duties and necessities within their countries within a short time, i.e., within the duration of this project. This happened due to the webinars and training courses. Both during the project's lifetime and, in a more enhanced way directly after the project, these NMIs/DIs will be able to address better the specific needs of their customers within their countries and their neighbouring countries. This is a direct impact on the user communities of metrological services within photometry and radiometry. In addition, the coordinated approach undertaken within this project, facilitated by EURAMET TC-PR and based on previously identified stakeholders' needs, enables these NMIs/DIs to avoid unnecessary duplication of work in the development of capabilities they specialise in with respect to the wider NMI/DI community.

As a result of the pilot study on gloss measurements and the presentation of its results at TC-PR, METAS, the Swiss NMI, has initiated a call for EURAMET comparison measurements between laboratories aiming at the primary realisation of gloss scale.

The project partners from emerging NMIs/DIs have gained expertise that enabled them to join other European metrology projects. For example, as a result of the knowledge and experience gained in this project, TUBITAK joined the consortium of the Partnership 21GRD03 PaRaMetric project.

In the field of fibre optics, TUBITAK expanded the scope of the fibre optic measurements trainings service (G1FO-010) given to the industry. Additionally, TUBITAK added the calibration of Optical Spectrum Analyzer devices (OSA) measurement service (G1FO-8600) to the industrial services list to provide measurement services in this. Metrosert is developing a calibration service for fibre optic power meters.

In the field of photometry, TUBITAK added LEDs calibration of luminous intensity measurement service (G1SP-1150) to the industrial services list to provide measurement services in this.

In the field of appearance, TUBITAK added the BRDF measurement service (G1SP-6000) to the industrial services list to provide measurement services in this, while Metrosert maintained the list of services for calibration of gloss and colour coordinate meters for industrial users. CNAM is conducting research on how to obtain the specular gloss defined in the EN ISO 2813 standard by measuring the bidirectional reflectance with a goniospectrophotometer. GUM are going to increase the uncertainty budget with additional components for reflectance factor measurements to improve measurement services in this regard.

In the field of photovoltaics, TUBITAK added the bifacial PV module performance measurement service (G1FV-0200) to the industrial services list to provide measurement services in this.

Longer-term economic, social and environmental impacts

In the longer term, due to the knowledge developed within the participating NMIs/DIs, and later presumably also for all members of the TC-PR, this project will impact the economic, social, and regulatory situation in these countries. Some of the issues and challenges related to the limited metrological and quality infrastructure in the fields of photometry and radiometry within these countries are directly addressed with this project and will be reduced or even overcome. In the much longer term, companies and small businesses will have the potential to become more competitive and the countries will become more attractive to foreign investments and joint ventures. This will simultaneously lead to an improved social situation in these countries, because of the creation of new and attractive jobs and a better ability to comply with health and safety requirements. Also, the environment will profit, because better measurements will lead to a more efficient use of energy and raw materials.

List of publications

There are no publications.

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:	01 September 2021, 18 months
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SCP Funded Partners: 1. PTB, Germany 2. Aalto, Finland 3. BIM, Bulgaria 4. CNAM, France 5. CSIC, Spain 6. GUM, Poland 7. INM, Republic of Moldova 8. Metrosert, Estonia 9. TUBITAK, Türkiye	