



CCEM President's Report

28th CGPM (2026)

A large, decorative graphic consisting of numerous concentric, overlapping arcs in a variety of colors including red, orange, yellow, green, blue, and purple. These arcs are arranged in a circular pattern, creating a sense of depth and movement.

**Working together to
promote and advance
the global comparability
of measurement**

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Report by the President of the CCEM

Prof.dr.ir. Gert Rietveld, President of the Consultative Committee for Electricity and Magnetism (Comité Consultatif d'Électricité et Magnétisme, CCEM), reported on the activities of the CCEM since the 27th meeting of the CGPM (2022).

CCEM Executive summary

We live in an increasing electrical age: electrical measurements underpin almost every area of modern science, industry and daily life. The Consultative Committee for Electricity and Magnetism (CCEM) supports these developments by covering an exceptionally broad measurement space, ranging from very small currents and quantum electrical standards to high-voltage power systems and radiofrequency quantities above 100 GHz. Since the 27th CGPM, the CCEM has combined its core responsibility for world-wide measurement comparability with a stronger response to the energy transition, digital infrastructures, and rapidly developing quantum technologies.

The CCEM met in hybrid format in March 2023 and March 2025. At these meetings, the CCEM discussed a substantial programme of international comparisons, improved guidance and processes for Calibration and Measurement Capabilities (CMCs), supported the development of the SI Digital Framework, and initiated focused work on graphene quantum Hall resistance standards and stakeholder engagement. A scientific workshop on 'Metrology for future electricity grids' in March 2025 was organized, with nine speakers from NMIs, academia and industry. This workshop demonstrated the central role of accurate and traceable electrical measurements in future power systems. Capacity building and interactions with industry were promoted by continuing a series of [webinars](#) showcasing the relevance of EM metrology to the wider EM stakeholder community.

The updated [CCEM Strategy 2026-2035](#) reaffirms three CCEM priorities: promoting global comparability, progressing electrical measurement science and stakeholder involvement. The BIPM electricity laboratories are integral to these priorities through their comparison and calibration services, specialized quantum standards and knowledge-transfer role. Through these combined activities, CCEM aims to maintain a robust international measurement infrastructure while responding to emerging scientific, industrial and societal needs.

Scope, mission and vision of the CCEM

The CCEM advises the CIPM on measurement standards for electricity and magnetism and oversees the related work programme of the BIPM electricity laboratories. Its scope includes voltage, current, resistance, capacitance, inductance, electrical power and energy, voltage and current ratios, ac-dc transfer, electromagnetic fields, antenna parameters, radiofrequency power, attenuation and scattering parameters, and electromagnetic properties of materials.

Electrical metrology spans an unusually large parameter space. Current measurements alone extend over more than twenty orders of magnitude, from the manipulation of individual electrons to the kiloampere currents in electrical power grids. Electrical quantities may be static or dynamic and range from DC to frequencies of 100 GHz and beyond. Covering the industrial and societal needs over this wide span of parameters and frequencies requires a large range of technologies, facilities and expertise. The CCEM coordinates this technical work through the Working Group on Low-Frequency Quantities, the Working Group on Radiofrequency Quantities and the Working Group on RMO Coordination, supplemented by time-limited task groups.

The CCEM vision is to be the recognized international focus for electrical metrology, ensuring that trustworthy and traceable measurements are embedded at the heart of science, industrial innovation and the global economy. Its mission is to foster equivalence and global interoperability and to promote harmonization of electromagnetic measurements within the SI. It does this by providing an international forum for coordinating global comparability and the digital dissemination of results, and by providing collective leadership in advancing measurement science and integrating electrical metrology into society.

Strategy

A new [CCEM Strategy 2026-2035](#) has been developed in 2026 that responds to the CIPM Strategy 2030+ and to the strategic global importance of electrical technologies. Accurate and traceable electrical measurements enable progress in all five areas in which the CIPM has identified global metrology needs, in particular in the energy transition and advanced manufacturing. Their importance is especially visible in renewable generation, future electricity grids, electric vehicles and DC technologies, as well as in the rapidly growing digital infrastructure needed for data centres and artificial intelligence.

The strategy has three mutually reinforcing elements. First, the CCEM promotes global comparability by implementing the CIPM MRA, organizing CCEM key comparisons, coordinating RMO key and supplementary comparisons, maintaining the CMC service categories and improving comparison and review processes. More efficient comparison schemes, including shared coordination responsibilities and star or hybrid comparisons, continue to be pursued where appropriate. Digitalization is a recent part of the CCEM work, where it has contributed to the development of the SI Reference Point, machine-actionable metrological information and to harmonized approaches for digital calibration certificates.

Second, the CCEM progresses electrical measurement science by providing leadership and vision to NMIs and DIs. The particular focus is on quantum electrical standards and on new and existing technologies enabling precision electromagnetic metrology. Priorities include extending the parameter space accessible with quantum standards, supporting their reliable use beyond the most advanced NMIs, and addressing measurement challenges in smart grids, communications beyond 5G, sensor networks, the Internet of Things, semiconductor and on-wafer measurements, nanoscale devices and quantum computing and sensing.

Third, the CCEM will deepen its stakeholder involvement by engaging more systematically with international standardization bodies, industry, accreditation organizations, and academia. Workshops, invited presentations and public webinars will remain important instruments for understanding needs and transferring knowledge. This will be complemented with cross-disciplinary cooperation with other Consultative Committees and capacity building for developing NMIs.

The BIPM electricity laboratories provide an essential foundation across all three elements through on-site quantum comparisons, bilateral comparisons, calibrations, research and knowledge transfer.

Activities and achievements since the last meeting of the CGPM

Main activities and achievements

A central activity since 2022 has been the continued implementation of the CIPM MRA. The WGRMO coordinated a large volume of CMC work and the CCEM published an improved version of the Guidelines on Technical Evidence for the Acceptance of CMCs in the context of the CIPM MRA. This guidance clarifies acceptable supporting evidence and promotes more consistent review across the RMOs. The CCEM also completed arrangements that allow CMCs for linearity and influence coefficients in applicable service categories. The CMC service category list was updated to include DC power and energy, responding in particular to measurement needs associated with electric vehicles. At the same time, the working group worked hard to ensure correct CMC submissions including adequate use of matrices, meeting CMC review deadlines, and an effective intra-RMO review.

The comparison programme made substantial progress. In the low-frequency area, the primary power comparison CCEM-K5.2017 was completed, with good agreement for most participants and no significant outliers. The combined comparisons for ac-dc voltage transfer, CCEM-K6.a, K6.c and K9, completed their circulation and moved into analysis. The power-harmonics comparison CCEM-K13 approached completion of its measurement phase after earlier delays caused by

device failures, the pandemic and problems in implementing the test waveforms. These experiences reinforced the need for robust travelling standards, careful protocols and realistic schedules.

New low-frequency comparisons were also brought forward. CCEM-K12.2025 on ac-dc current began circulation in 2025 with broad participation and shared organizational responsibilities. For high-voltage ratio, CCEM-K14 was started where two-stage voltage transformers will be used as the travelling standard. Preparations progressed for comparisons of inductance and high-voltage ratio. The inductance work included detailed investigations of temperature and humidity effects and evaluation of simulated inductors as potential travelling standards. Looking further ahead, support groups are formed for future comparisons on DC voltage ratio, low-voltage ac-dc transfer and high resistance, potentially extending to the teraohm range. The CCEM has also continued to question whether established key quantities and repetition intervals remain appropriate, so that comparisons address current needs rather than being repeated automatically.

In radiofrequency metrology, three activities reached completion: comparisons of attenuation (CCEM.RF-K26) and RF power (CCEM.RF-K27.W and CCEM.RF-K28.W), and a pilot study on electromagnetic properties of materials. Ongoing work includes RF power from 75 GHz to 110 GHz (CCEM.RF-K29.W) and S-parameters in 2.4 mm coaxial line up to 50 GHz (CCEM.RF-K5.d.CL). The latter uses a collapsing-star topology with eighteen participants. Measurements at the central laboratory were completed much faster than would be expected for a traditional round robin, demonstrating the value of alternative comparison designs. Planned activities cover noise, antenna gain from 140 GHz to 220 GHz and field strength. Pilot comparisons are also being considered for modern thermoelectric power sensors and on-wafer S-parameters.

Digital transformation became a new CCEM activity through the Task Group on Digitalization. The group compiled the quantities used in each CCEM service category, checked their implementation in the pre-production SI Reference Point and provided feedback to the BIPM and to the CIPM Forum on Metrology and Digitalization (FORUM-MD). The CCEM digitalization TG work supports authoritative, machine-actionable information on EM quantities and units, unique identifiers for electromagnetic CMCs, and future links between calibration certificates and the KCDB. Discussions at the CCEM 2025 meeting also showed that practical understanding and adoption remain uneven, underlining the need for concrete use cases and continued engagement with national NMI digital initiatives.

The Task Group on Graphene developed a [new guidance document](#) on the reliable use of graphene as a quantum Hall resistance standard. The guidance document supports formal acceptance and wider use of graphene-based primary resistance standards. In 2025, the BIPM included a participant's graphene QHR standard in its comparison measurements, confirming its suitability for demanding uncertainty requirements. The BIPM EM laboratories also launched the extension of its on-site Josephson voltage comparison to AC signals and continued research on AC quantum Hall impedance standards, more compact graphene-based systems and continued electrical support for the BIPM Kibble balance.

Stakeholder engagement and knowledge transfer were strengthened. Six public CCEM webinars had been organized by early 2026, covering quantum, radiofrequency, power and electrochemical metrology. The 2025 workshop on future electricity grids was a particularly successful example of engagement across NMIs, universities and industry. Cooperation with other Consultative Committees also continued. The joint CCQM-CCEM task group on lithium-ion batteries identified relevant measurands across electrical and chemical metrology and stimulated engagement with the stakeholder battery community via a well-attended workshop. The earlier CCEM-CCRI task group on small-current measurements completed its input to the ionizing-radiation community resulting in more effective maintenance of ionizing radiation standards.

The BIPM electricity laboratories remained a cornerstone of the CCEM programme. Five ongoing comparisons cover on-site Josephson voltage and quantum Hall resistance standards and bilateral comparisons using conventional voltage, resistance and capacitance standards. Demand for on-site comparisons of quantum Hall resistance standards and Josephson voltage standards at DC and AC has filled the schedule until at least 2030. The number of calibrations continued to increase, with

the largest number of 97 calibrations performed in 2023. The BIPM installed a helium liquefier to improve continuity of cryogenic services and continued research on graphene QHR devices, frequency-dependent resistance, the calculable capacitor and updates and modernization of their calibration systems.

Challenges and difficulties

The breadth of electrical metrology creates a continuing tension between comprehensive coverage and available resources. Comparison schedules remain vulnerable to fragile travelling standards, customs and transport constraints, participant delays, and difficulty finding pilots and report authors. CMC publication is also delayed when submissions lack suitable technical evidence, matrix formats are used inconsistently, or review deadlines are missed. The CCEM is addressing these issues through comparison 'champions', shared coordination, star and hybrid schemes, realistic repetition intervals, and stronger review discipline. A further challenge is turning broad stakeholder and digitalization ambitions into focused activities that clearly support the wider CCEM stakeholder community.

Outlook in the short and long term

In the short term, the CCEM will begin implementing the Strategy 2026-2035 by completing the current comparison programme and further improving CMC review discipline. It will continue the work of the digitalization and graphene task groups, support the SI Digital Framework, and develop practical approaches to machine-actionable metrological information and digital calibration certificates. Workshops, technical presentations and webinars will remain central to knowledge transfer and stakeholder engagement. Preparations are also under way for celebrating the centenary of the CCE/CCEM in 2027, combining the regular meeting with a special workshop and a young scientist poster competition.

The BIPM electricity laboratories will remain essential to the CCEM and the world-wide EM community. Their ongoing comparison and calibration services provide both high-level equivalence for NMIs with primary quantum standards and direct SI traceability for institutes without such realizations. The extension of the Josephson comparison to AC signals, the development of graphene QHR systems and AC impedance routes, and modernization of calibration facilities will strengthen this role. A joint CCEM-BIPM workshop on practical operation of quantum electrical standards is planned for the 2028-2031 work programme.

In the longer term, the CCEM will strengthen the measurement foundations for future electricity grids, digital and AI infrastructures, advanced communications, semiconductor and nanoscale manufacturing, and quantum technologies. It will seek more systematic engagement with standardization bodies, industry, accreditation organizations, academia and other Consultative Committees, while expanding capacity building for developing NMIs. The overall long-term objective remains to support and ensure reliable and interoperable electrical measurements world-wide, that are continuously adapting to a rapidly-changing technological landscape.

CCEM Data

CCEM set up in 1927 (as the CCE)

President:	Prof.dr.ir. G. Rietveld
Executive Secretary:	Dr M. Stock
Membership:	27 members and 2 observers

List of CCEM members and
observers:

<https://www.bipm.org/en/committees/cc/ccem/members>

Meetings since the 27th CGPM

meeting:	8-9 March 2023; 6-7 March 2025
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Full reports of the CCEM

meetings:

<https://www.bipm.org/en/committees/cc/ccem/publications>

Working Groups and Task Groups: <https://www.bipm.org/en/committees/cc/ccem>

- RMO Coordination (WGRMO)
- Low-Frequency Quantities (WGLF)
- Radiofrequency Quantities (GT-RF)

- Task Group on Digitalization (TG-DIG)
- Task Group on Graphene (TG-Graphene)
- Discussion Group on Magnetism (DG-Magnetism)

CCEM Comparison activity	Completed	In progress	Planned
CCEM key comparisons (and supplementary comparisons)	36 + (2)	9	8
BIPM comparisons	1	5 (ongoing)	5 (ongoing)
CCEM pilot studies	1	0	2
CMCs	4 692 CMCs in 191 service categories registered in the KCDB		