Consultative Committee for Electricity and Magnetism (CCEM)
President G Rietveld, Executive Secretary M Stock

Meets every - 2 years **Last meeting** - March 2017 **Members/Observers** 25/2	**Working groups**: Low Frequency (WGLF); Radiofrequency Quantities (GT-RF); WGRMO; WG on the SI (WGSI); WG on electrical method to monitor the stability of the kilogram (WGKG)		
Comparison activity	**Completed**	**In progress**	**Planned**
CCEM KCs (& CC Supplementary)	30 + (2)	6	20
RMO KCs (& SCs)	48 + (66)	7 + (32)	?
BIPM comparisons (all on-going)	9	0	10
CC Pilot studies	0	1	2
CMCs	4367 CMCs in 194 service categories		

Pointers to the future, stakeholder needs and technological developments

- **Realisation of the "New SI":** Development of watt balances for "routine operation" requires development of reliable and economic electrical quantum standards.
- **Quantum standards:** The development of quantum standards (Josephson voltage standard, quantum Hall resistance standard) in the low frequency range may eliminate the need for some key comparisons such as Zener diodes and 100 ohm resistors.
- **Higher temperature quantum Hall standards:** Possible emergence of higher temperature QHR standards based on graphene offer potential for less complex QHR (and thus much wider uptake).
- **Quantum current standards:** current standards based on single electron tunnelling under research.
- **New applications of Josephson voltage standards:** advances offer the possibility of new Josephson voltage standards applied to ac power and ac voltage.
- **Voltage to waveform:** technology trend from voltage to waveform measurements, voltage comparisons will become waveform comparisons at higher frequencies.
- **Electrical transmission & distribution:** Increased focus on accurate measurement of transmission and distribution of electrical energy (Smart Grids, new ultra high voltage ac and dc transmission bringing new metrology demands for harmonic power, voltage and current phasors, current ratios up to 20 kA, voltage ratios up to 1000 kV (dc and ac), and characteristics of switching and lightning impulses.
- **Electromagnetic properties of materials** (first pilot study under way).
- **Digital communication, 5G, Internet of Things, THz technologies:** Need for traceability of fundamental RF&MW measurement quantities at higher frequencies.

Workload Trend & Workload Management

- The importance of KCs will not diminish. In the low frequency range it is planned to repeat KCs during the next 10 years. Completed RF/MW comparisons will not be repeated unless new techniques or problems emerge, due to limited resources and the needs for comparisons at higher frequencies.
- A total of 10 new RF KCs and 2 Pilot Studies in the existing seven Key Quantities required at higher frequencies as the importance of higher frequencies increases and more labs acquire measurement capabilities at higher frequencies are planned to 2023. For LF: repeat each existing comparison during the next 10 years with minor modifications to parameters.
- Resources to pilot a comparison vary greatly. Averaged piloting is about 6 months and participation per lab about 1.2 person months per comparisons. The workload on pilots is being reduced by sharing the organization of a comparison between several NMIs.
- Reducing the workload related to CMC reviews is an ongoing activity of the CCEM. The efficiency of CMC reviews has been improved by introducing selective sampling of the entries to be reviewed.

BIPM – references to laboratory activity at the BIPM

- The BIPM is organizing 9 on-going comparisons (of five different quantities), including two on-site comparisons of quantum standards. The BIPM traveling quantum standards are unique international reference facilities for voltage and resistance.
- Quantum electrical standards are required for the BIPM Watt Balance
- For NMIs that do not operate quantum standards BIPM organizes on-going bilateral comparisons using Zener voltage standards and resistance and capacitance standards. These services provide traceability to the SI for smaller NMIs, and allow larger NMIs to demonstrate the equivalence of their own primary standards. Activities will be continually evaluated as quantum standards continue be developed and disseminated.
- No BIPM RF/MW activity, so requirements will have to be met by the NMIs and by private industry.