

Rules for review of CMC claims and requirements for supporting evidence

1. INTRODUCTION

This document sets out the guidelines to be followed when reviewing the acceptability of CMCs submitted for inclusion in the BIPM KCDB. It describes the approach used to determine what level of review is needed for each quantity and the evidence that is required to support this review.

2. CMC CATEGORIES

2.1 General Principles

In line with the JCRB requirement to review the scope and breadth of CMCs, measurement quantities in the fields covered by CCPR are split into three basic categories:

1. Key Comparison Quantities

The Key Comparison Quantities are the quantities that are considered to be critical for the demonstration of general proficiency in the areas of radiometry, photometry and spectrophotometry (i.e. the key areas covered by CCPR), and that underpin (provide traceability to primary SI scales) for a number of other quantities. They can all be independently realised. Appendix A gives details of the CCPR Key Comparison Quantities and the associated Key Comparisons.

2. Core Quantities

These are quantities which, additional to the Key Comparison Quantities, are of prime importance for the demonstration of proficiency in each of the principal areas and techniques covered by CCPR. Many of these can be independently realised, but this is not a requirement. Examples are:

- Spectral radiance (crucial for the demonstration of competence in spectral measurement of sources used in calibration of cameras, EO imagers etc. but not a Key Comparison Quantity);
- Fibre optic power meter responsivity (crucial for the demonstration of competence in fibre optics but not a Key Comparison Quantity).

3. Secondary Quantities

These are quantities that are not considered critical for the demonstration of general proficiency in the areas covered by CCPR but are of sufficient significance to warrant a separate entry in the KCDB. They are generally not realised independently, but fall into one of the following categories:

- a) derived directly from a Key Comparison or Core Quantity;
- b) traceable to a Key Comparison or Core Quantity via another Secondary Quantity;
- c) closely linked to a Key Comparison or Core Quantity but not derived directly from it;
- d) not linked to any other Key Comparison, Core or Secondary Quantity.

Examples are:

- Surface colour, which is typically derived directly from the Key Comparison Quantity diffuse spectral reflectance i.e. category (a) above;

- Correlated colour temperature response of a colour temperature meter, which is obtained from measurements using a source of known correlated colour temperature (Secondary Quantity), which in turn is derived directly from the spectral irradiance of that source (Key Comparison Quantity) i.e. category (b) above;
- Average luminous intensity of an LED source, which is closely linked to the Key Comparison Quantity luminous intensity of a tungsten lamp, but not derived directly from it i.e. category (c) above;
- Haze of a general material, which is not derived from or otherwise linked to any other Key Comparison, Core or Secondary Quantity i.e. category (d) above.

2.2 Responsibility for Decisions on Quantities

The CCPR Key Comparison Quantities are as listed in Appendix A. They have been agreed by CCPR.

The relevant Core Quantities for each of the principal areas (branches) covered by CCPR are defined in the Excel file "[Supporting evidence for CMCs in PR](#)". CCPR-WG CMC has responsibility for maintaining this file and for accepting, or rejecting, proposals for new Core Quantities. The decision will take into consideration the importance of the quantity as a link to SI or as a basis for demonstrating competency for the dissemination of other quantities.

Any other quantity not designated as a Key Comparison or Core Quantity can be included in the KCDB as a Secondary Quantity, provided that CCPR WG-CMC agrees the proposed quantity is appropriate for inclusion as a separate entity and cannot be adequately covered via another quantity. For example, although in general additional types of artefact should simply be listed in the 'Comments' column for an existing CMC entry, in some cases it may be appropriate to have a separate CMC entry for an artefact that is of particular importance. Thus CCPR WG-CMC has agreed that it is appropriate to have a separate quantity "Luminous flux, LED", rather than simply including the ability to calibrate LEDs in the comments column for the quantity "Luminous flux, tungsten lamp" due to the importance of LEDs to industry and the particular measurement problems they pose. However separate entries for luminous flux measurements for other types of source, such as fluorescent lamps, have not been agreed.

CCPR WG-CMC has responsibility for maintaining the list of Service Categories for Photometry and Radiometry and for accepting, or rejecting, proposals for new Secondary Quantities to be added to the Service Category file "[Classification of services in PR](#)". The decision will take into consideration the importance of the quantity and/or artefact for the users of the KCDB. Where relevant, CCPR WG-CMC will also define the associated Core Quantity (or Quantities) to which each Secondary Quantity should be linked and any acceptable intermediary Secondary Quantities through which a link to SI may be demonstrated. This information is given in the Excel file "[Supporting evidence for CMCs in PR](#)".

2.3 Approach for Review of CMCs

A **risk-based approach** is used by CCPR for the intra-regional and inter-regional reviews of CMCs in accordance with JCRB Resolution 38/1. CMCs for quantities designated as Key Comparison or Core Quantities are regarded as high risk and are always subject to detailed review at both intra- and inter-regional level, regardless of which other CMCs the NMI already has listed in the database.

Full intra- and inter-regional review, with a high level of supporting evidence, is also required in the case of Secondary Quantities that are considered high risk. This occurs when one or more of the following apply:

- The NMI does not already have an approved CMC entry for the Key or Core Quantity to which the Secondary Quantity is linked;
- The NMI does not already have an approved CMC entry for an appropriate intermediary Secondary Quantity through which a direct link to SI may be demonstrated;
- The NMI does not already have an approved CMC entry for a closely-linked Core or Secondary Quantity;
- No approved linked Key Comparison, Core or Secondary Quantity is listed in the Excel file "[Supporting evidence for CMCs in PR](#)" i.e. all category (d) Secondary Quantities.

In all other cases, the submitted CMC is considered low risk. It may be reviewed at RMO level only (inter-regional review is not required), and the level of supporting evidence required is lower than for a high-risk CMC. This does not, however, preclude a more in-depth review; any RMO has the right to carry out a review of a Secondary Quantity, and to request additional evidence, if they so wish. The decision to carry out a detailed review is at the discretion of the RMO TC-PR Chair or RMO TC-PR WG-CMC Chair. It is the responsibility of the submitting NMI to indicate whether, and on what basis, they believe the CMC should be considered low risk and the associated RMO TC-PR Chair must also confirm that the relevant conditions have been satisfied; the checklist in Appendix B should be used to record this information. Other RMO TC-PR Chairs can use this information when deciding whether to carry out a review. Note that although it is possible to challenge an already-published CMC, this should only be done in exceptional circumstances and all necessary reviews should normally be carried out prior to publication.

3. SUPPORTING EVIDENCE

The following sections detail acceptable supporting evidence for CCPR CMCs. These requirements are also summarised in the form of flowcharts in Appendix C.

3.1 General Principles

Key Comparison Quantities as listed in Appendix A must be supported by evidence from Key Comparisons wherever possible. If this is not possible, due to the timing of a CCPR or RMO Key Comparison, then other forms of evidence¹ as detailed in 3.3 below may be used on an interim basis only and the NMI must take part in the next available CCPR or RMO comparison. If results from a Key Comparison are not available within 5 years of the publication of the CMC in the KCDB, the CMC will be "greyed out"; in that case the CMC may be resubmitted with additional, more recent, evidence to support the claim, again on an interim (5 year maximum) basis only. It is the responsibility of the associated RMO TC-PR Chair to maintain a record of all interim CMC entries and to report on these at WG-CMC meetings.

Comparisons are not required in the case of other CMCs. However comparisons obviously provide the clearest possible evidence of technical proficiency, not just in terms of the performance of the actual

¹ For an NMI requesting a change to an already-approved Key Comparison CMC entry (e.g. a change to the uncertainty following improvements to the measurement facility), all forms of evidence detailed in 3.3 may be considered. For a completely new CMC entry for a Key Comparison Quantity, however, only Hybrid Comparison (3.3.4) is applicable.

measurements but also the evaluation of the associated measurement uncertainties. Thus although it is not a strict requirement, CCPR strongly encourages all NMIs to take part in at least one comparison for each of the principal areas (branches) for which it wishes to publish CMCs. CCPR or RMO comparisons are preferable, where available, but bilateral comparisons or Hybrid Comparisons (see 3.3.4) are also acceptable.

3.2 Comparison-based evidence

Comparisons are carried out in order to provide confidence in measurements made at each participating NMI, by evaluating the Degree of Equivalence (DoE) between the measurement results obtained at each NMI and confirming that claimed measurement uncertainties are consistent with these DoEs. The rules governing the evaluation of CMCs that are directly supported by “official” comparisons (i.e. Key Comparisons, Supplementary Comparisons and RMO or Bilateral Comparisons that have been registered in the BIPM Comparison database) are given in CCPR G8 “Guidelines for the evaluation of CMC claims in light of comparison results”.

By their very nature comparisons cannot provide direct support for every measurement. Instead, they are intended to demonstrate measurement capability for specific types of artefact, under specific measurement conditions and for specific measurement parameters. Generally, NMIs perform a much broader range of measurements than those directly tested by the comparisons. This extension from the comparison measurements is verified through the CMC review process. The level of additional information needed to give confidence in measurements that are not directly tested via comparisons will vary depending on the closeness of these measurements to the comparison measurements. The evaluation criteria detailed in 3.2.1 to 3.2.3 will be used within CCPR to ensure consistent review process.

3.2.1 Measurements at wavelengths other than those directly evaluated in a comparison

Comparisons related to spectral quantities (spectral irradiance, spectral responsivity etc.) are performed at a limited number of wavelengths across defined spectral ranges. The results therefore strictly relate only to those specific wavelengths, but it has always been accepted that they can be used to provide confidence in measurement capability between these points without the need for additional supporting information during CMC review. The results can also be used to provide confidence in measurement capability over a broader range of wavelengths without additional supporting information, provided the conditions in 3.2.1.1 to 3.2.1.4 are all met. It is the responsibility of the submitting NMI to confirm that these conditions have been met and that all additional information required is provided; the checklist in Appendix B should be completed and provided with the submitted CMC in order to ensure this.

- 3.2.1.1 The same facility as used for the comparison is also used for the extended wavelength range. If this is true, the only further information required for the CMC review is as detailed in 3.2.1.2 below. If this is not the case, the comparison results cannot be used and other forms of evidence must be provided (see 3.3).
- 3.2.1.2 The uncertainty budget at the wavelengths beyond the range covered by the comparison has been evaluated specifically for those wavelengths. Information on the adjustments (if any) made to the comparison uncertainty budget for the extended wavelength range must be provided during the CMC review, but it is not necessary to re-justify the uncertainty budget since this has already been confirmed through the comparison.

- 3.2.1.3 The claimed CMC uncertainty for the extended wavelength range cannot be lower than that demonstrated² during the comparison for the wavelength at the corresponding upper or lower limit of the comparison wavelength range, even if the uncertainty budget provided for 3.2.1.2 would support a lower uncertainty. For example, if the comparison covers 400 nm to 800 nm and an NMI wishes to extend the CMC to cover the range up to 900 nm, the CMC for wavelengths above 800 nm cannot be lower than that demonstrated during the comparison at 800 nm.
- 3.2.1.4 In the case of CCPR Key Comparisons (KCs), the extended wavelength range shall not cover a significant proportion of the wavelength range covered by another KC and an extension of the wavelength range cannot be used to avoid participation in a KC covering a different wavelength range. For example, in the case of CCPR detector spectral responsivity comparisons:
- K2.a (designated range 900 nm – 1600 nm) could support CMCs from 800 nm to beyond 1600 nm;
 - K2.b (designated range 300 nm – 1000 nm) could support CMCs over the range from approximately 250 nm to approximately 1100 nm;
 - K2.c (designated range 200 nm to 400 nm) could support CMCs from approximately 200 nm to approximately 500 nm;
 - the highly specialised nature of the measurement facilities and transfer detectors required for wavelengths below 200 nm means not only that participation in K2.d (designated range 100 nm to 200 nm) is essential for these wavelengths, but also that results from K2.d cannot be used to support measurements at higher wavelengths.

3.2.2 Measurements under conditions different from those directly evaluated in a comparison

In order to ensure that comparison results from all participants can be reliably compared, the comparison protocol must define boundary conditions for all measurement parameters that may have a significant influence on the results. These may include, for example, factors such as temperature, bandwidth, power level, distance, beam divergence and beam size. The comparison results therefore strictly apply only to measurements made under these same conditions. In practice, measurements are made under a range of different conditions, depending on the requirements of the end user. The comparison results can be used to provide confidence in measurement capability over a broader range of conditions without additional supporting information during the CMC review, provided the conditions in 3.2.2.1 and 3.2.2.2 are met. It is the responsibility of the submitting NMI to confirm that these conditions have been met and that all additional information required is provided; the checklist in Appendix B should be completed and provided with the submitted CMC in order to ensure this.

- 3.2.2.1 The same facility as used for the comparison is also used for the subsequent measurements using a broader range of conditions. If this is true, the only further information required for the CMC review is as detailed in 3.2.2.2 below. If this is not the case, the comparison results cannot be used and other forms of evidence must be provided (see 3.3).
- 3.2.2.2 The uncertainty budget for conditions other than those covered by the comparison has been evaluated specifically for those conditions. Information on the adjustments (if any) made to the comparison uncertainty budget for measurement parameters different from those

² The uncertainty demonstrated during a comparison is the uncertainty claimed by the NMI during the comparison adjusted, if necessary, to take account of the DoE for the NMI for that comparison (see CCPR-G8).

directly evaluated in the associated comparison must be provided during the CMC review, but it is not necessary to re-justify the uncertainty budget since this has already been confirmed by the comparison.

3.2.3 Measurements using artefacts other than those directly evaluated in a comparison

Comparisons are generally carried out using specially designed or selected artefacts, which are intended to enable results to be compared with the lowest possible uncertainties. However, these are often different from the types of artefact that are used for routine dissemination of the quantity, especially to commercial calibration laboratories or industrial laboratories. For example, comparisons for spectral reflectance and related quantities are usually carried out using high-quality, white matte, diffuse reflectance standards, but commercial calibration laboratories often prefer to take traceability via a set of calibrated coloured glossy tiles, since using these can help to minimise systematic errors in their measurement systems. Generally, the Comments column for the CMC entry in the KCDB can be used to list the other types of artefacts that can be calibrated for any given quantity such that no further evidence is needed and a separate CMC entry is not necessary.

CCPR WG-CMC may decide that a separate CMC entry is appropriate, however, e.g. where the lower quality artefact would commonly be used as a search term by users of the database (see Section 2.2). In this case, the CMC entry is a Secondary Quantity, and the conditions given in Section 1 for Secondary Quantities must be fulfilled. The comparison results can still be used to provide confidence in measurement capability for the lower quality artefact without additional supporting information during the CMC review, provided the conditions in 3.2.3.1 and 3.2.3.2 are met. It is the responsibility of the submitting NMI to confirm that these conditions have been met and that all additional information required is provided; the checklist in Appendix B should be completed and provided with the submitted CMC in order to ensure this.

3.2.3.1 The same facility as used for the comparison is also used for the subsequent measurements using the lower quality artefact. If this is true, the only further information required for the CMC review is as detailed in 3.2.3.2 below. If this is not the case, the comparison results cannot be used and other forms of evidence must be provided (see 3.3).

3.2.3.2 The uncertainty budget for the lower quality artefact has been evaluated specifically for it. Information on the adjustments (if any) made to the comparison uncertainty budget for using an artefact of a type that is different from that directly evaluated in the associated comparison must be provided during the CMC review, but it is not necessary to re-justify the uncertainty budget since this has already been confirmed by the comparison.

3.3 Other forms of evidence

Although comparisons provide the best evidence of capability, it is impossible to conduct comparisons for all quantities. Most quantities are not directly tested via a comparison, and other evidence is therefore needed to support CMC claims for these. The CIPM MRA lists the following as examples of other acceptable forms of evidence:

- Knowledge of technical activities by other NMIs, including publications
- On-site peer-assessment reports
- Active participation in RMO projects
- Other available knowledge and experience

Within CCPR, the forms of evidence detailed in 3.3.1 to 3.3.5 are accepted for those cases where comparison evidence is not available. Note these other forms of evidence do not negate the requirement to take part in relevant Key or Supplementary Comparisons wherever possible; in particular they can only be used in exceptional circumstances, on an interim basis, to support Key Comparison Quantities (see 3.1).

3.3.1 Third party technical assessment to ISO 17025

Several NMIs within CCPR have third party accreditation to ISO 17025. In order to gain and maintain accreditation, the laboratory is subjected to regular, formal, technical assessment by an independent expert from another NMI, coupled with formal external assessment of the NMI's quality system by an expert from the associated accreditation body (e.g. NATA in Australia, SANAS in South Africa, UKAS in UK). The technical assessment covers all aspects of the calibration services for which the NMI is accredited, such as traceability, equipment, laboratory environment, staff technical competence, technical procedures, validation processes (including results from international comparisons), and uncertainties. Accreditation is typically externally reviewed on an annual basis and a full re-assessment on a 4-year cycle is mandatory. The Schedule of Accreditation is publicly available and includes details of the scope of the calibration and measurement services for which accreditation has been granted (i.e. details of the quantities, artefacts, ranges and uncertainties which have been assessed and approved).

The degree of scrutiny to which accredited laboratories are subjected is intense, and the depth of review is greater than can be achieved through the normal intra- and inter-regional CMC review process. Where such formal third-party accreditation is in place, therefore, CCPR permits that for Secondary Quantities where the submitted CMCs fulfil the conditions required to be considered as low-risk, the associated CMCs are accepted without the need for further review, provided that the CMC parameters (quantities, artefacts, ranges and uncertainties) are consistent with those given in the Schedule of Accreditation.

3.3.2 On-site peer review or self-declaration

Several CCPR NMIs undergo a less formal evaluation of their measurement capabilities through regular technical assessment by an independent expert from another NMI (external on-site peer review) or by self-declaration (internal peer review). Similarly as for formal (third-party) ISO 17025 accreditation, this technical assessment covers all aspects of the NMI's calibration services, including traceability, equipment, laboratory environment, staff technical competence, technical procedures, validation processes, comparison activities and uncertainties. The outcomes from the assessment must be summarised in a report and include details of the quantities, artefacts, ranges, and uncertainties that have been examined and successfully demonstrated.

As in the case of formal accreditation, peer review is an intensive process and provides a level of scrutiny exceeding that which can be achieved through the normal intra- and inter-regional CMC review process. Where up-to-date evidence from such a peer review is available (i.e. within a maximum period of 4 years), CCPR permits that for Secondary Quantities where the submitted CMCs fulfil the conditions required to be considered as low-risk, these CMCs can be accepted without the need for further review, provided that the CMC parameters (quantities, artefacts, ranges and uncertainties) are consistent with those given in the peer review report.

3.3.3 Peer-reviewed publications

Information given in peer-reviewed publications can be used to support CMCs, provided that these include a full description of the measurement facility together with a detailed breakdown of the measurement uncertainties and the basis for their evaluation. In the case of Secondary Quantities where the submitted CMCs fulfil the conditions required to be considered as low-risk, these CMCs can be accepted without the need for further evidence, provided that the CMC parameters (quantities, artefacts, ranges and uncertainties) are consistent with those given in the peer review publication.

3.3.4 Comparison via traceability (also called Hybrid Comparison, see JCRB Recommendation 40/1)

JCRB Recommendation 40/1 states: “JCRB agrees that the Hybrid Comparison Scheme proposed by APMP may be used as an example of “Other available knowledge and experience” in Section 3 of CIPM MRA D-04, which underpins CMCs. It was noted that the use of Hybrid Comparisons is not an alternative to participation in key or supplementary comparisons when accessible.” Further details relating to this Hybrid Comparison approach are given in Appendix D.

In line with this recommendation, CCPR will accept Hybrid Comparison results as supporting evidence for all CMCs, including Key Comparison, Core and other high-risk CMCs, provided that the CMC parameters (quantities, artefacts, ranges and uncertainties) are consistent with those demonstrated through the comparison. If the Hybrid Comparison relates to a CCPR Key Comparison quantity, then it can only be used on an interim basis (as described in 3.1) and the NMI must commit to take part in the next available CCPR or RMO comparison. If the Hybrid Comparison relates to a Secondary Quantity where the submitted CMCs fulfil the conditions required to be considered as low-risk, these CMCs can be accepted without the need for further detailed review.

3.3.5 Other documentary evidence

If evidence of the form detailed in 3.2 or 3.3.1 to 3.3.4 is not available, the submitting NMI may provide other written evidence, such as a technical measurement procedure or work instruction, to support a CMC claim. Such documents should be subjected to detailed scrutiny as part of the intra-regional review and the reviewer(s) should provide written confirmation that this has been done. In the case of Secondary Quantities where the submitted CMCs fulfil the conditions required to be considered as low-risk, these CMCs can then be accepted without the need for further review at the inter-regional level, provided that the CMC parameters (quantities, artefacts, ranges and uncertainties) are consistent with those given in the documentation provided.

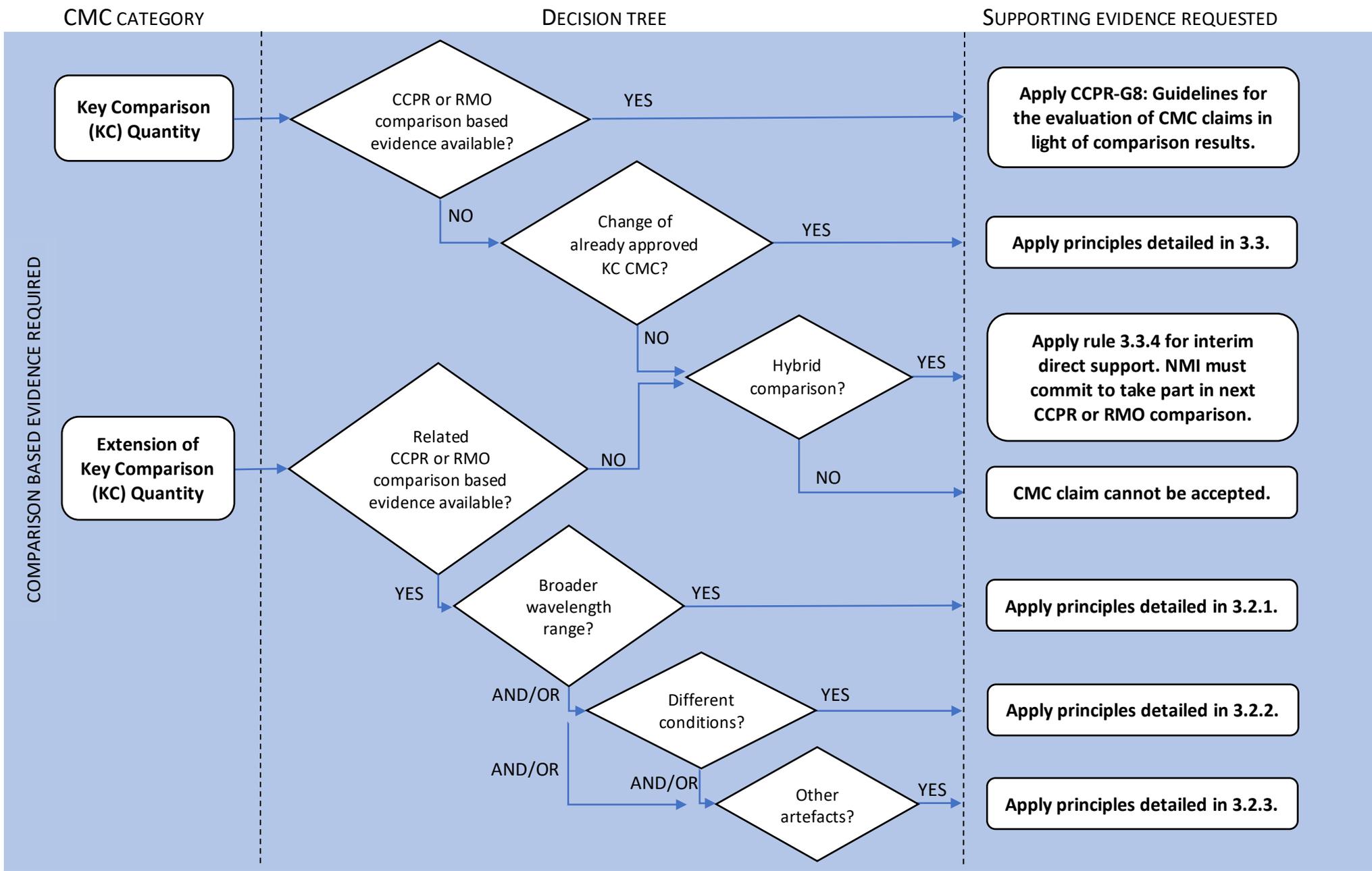
APPENDIX A – LIST OF KC QUANTITIES AND COMPARISONS

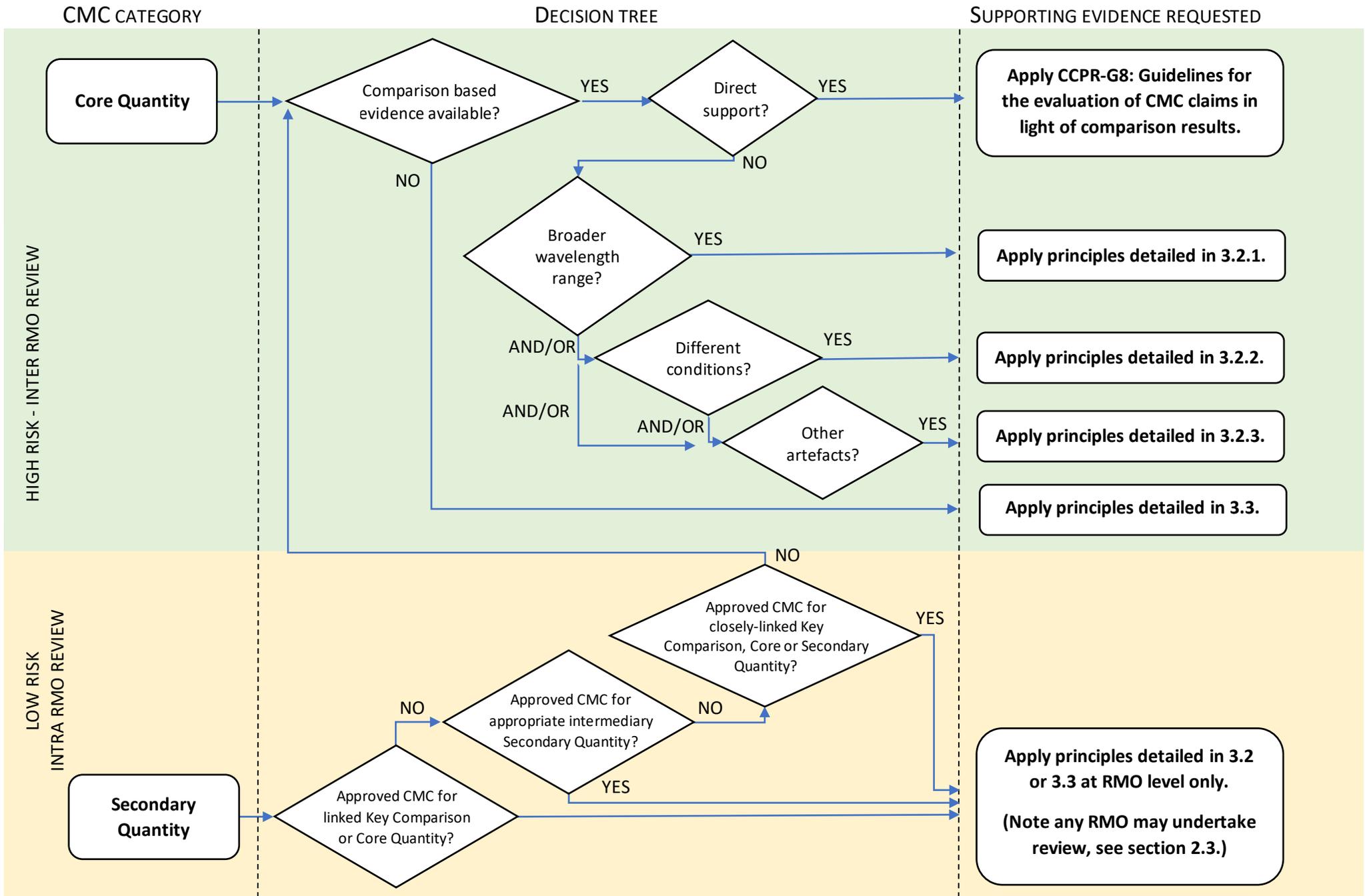
Comparison ID	Key Quantity	Wavelength range (nm)	Artefact	Parameters
CCPR-K1.a	Spectral irradiance	250 nm – 2500 nm	Tungsten lamp	
CCPR-K1.b	Spectral irradiance	200 nm - 350 nm	Deuterium lamp	
CCPR-K2.a	Spectral responsivity	900 nm – 1600 nm	InGaAs photodiode	
CCPR-K2.b	Spectral responsivity	200 nm – 400 nm	UV Si photodiode	
CCPR-K2.c	Spectral responsivity	300 nm – 1000 nm	Si photodiode	
CCPR-K2.d	Spectral responsivity	10 nm – 200 nm	Not decided	
CCPR-K3	Luminous intensity	N/A	Tungsten lamp	
CCPR-K4	Luminous flux	N/A	Tungsten lamp	CCT [K]: 2800 to 2900
CCPR-K5	Diffuse spectral reflectance	360 nm – 830 nm	White diffuser	Geometry: 0/d, d/0, R: 90%
CCPR-K6	Regular spectral transmittance	380 nm – 1000 nm	Neutral density filters	Transmittance [%]: 0.1, 1, 10, 56, 92

APPENDIX B – CHECKLIST FOR LOW RISK CMC SUBMISSIONS AND WIDER USE OF COMPARISON EVIDENCE

1.	<p>What is the justification for this CMC submission to be considered low risk? Include details of:</p> <ul style="list-style-type: none"> • The approved CMC entry for the Key or Core Quantity to which the CMC submission is linked; or • The approved CMC entry for the intermediary Secondary Quantity through which a direct link to SI may be demonstrated; or • The already-approved CMC entry for a closely-linked Core or Secondary Quantity. 	
2.	Details of any additional supporting evidence provided	
3.	<p>In the case of comparison-based evidence:</p> <p>a) Which comparison is this submission based on?</p> <p>b) Have CMCs for this supporting comparison already been accepted?</p> <p>c) Is the same facility used as for the supporting comparison?</p> <p>d) Do the conditions of the claimed CMC differ from the conditions of the corresponding comparison? (Give details if so.)</p> <p>e) Has an updated uncertainty budget been provided, detailing the adjustments made or explaining why no increase in uncertainty is needed? (Give name of document providing this information.)</p>	

APPENDIX C – FLOWCHARTS OF THE RULES FOR REVIEW OF NEW CALIBRATION AND MEASUREMENT CAPABILITY (CMC)





APPENDIX D – HYBRID COMPARISON

Although participation in an international comparison (IC) is the most objective method by which to provide evidence to support a new or revised CMC submission (particularly for Key and Core Quantities) this is often not possible because:

- The time intervals between ICs are very long (typically at least 10 years for CCPR-KCs);
- For many calibration services, ICs have never been conducted;
- The measurements involved require a lot of time and effort, particularly for the pilot;
- Submission and approval of the report often takes a long time;
- Developed NMIs must participate as link labs in many ICs on a voluntary basis.

Following a proposal from APMP, JCRB has recommended (Recommendation 40/1) that a Hybrid Comparison Scheme may be used as an example of “Other available knowledge and experience” as given in Section 3 of CIPM MRA D-04. This uses the outcomes of routine calibration services provided by NMIs and DIs that have appropriate CMCs already registered in the KCDB evidence to support the submission of CMCs from another NMI; the term “Hybrid Comparison” refers to the fact that it is neither a Key or Supplementary Comparison nor a pure calibration service, but something in between. Under this approach, the difference between the measurement result obtained by the NMI submitting a CMC claim and the result of a routine calibration provided by another NMI is used as supporting evidence in a similar way to the use of the degree of equivalence (DoE) from a comparison, provided that specific procedures are followed to ensure the process is transparent and impartial.

The APMP guideline for using Hybrid Comparisons as CMC evidence is available through: <http://www.apmpweb.org/documents/hybrid.phpn>