EBU

OPERATING EUROVISION AND EURORADIO

TR 037

VIDEO SYSTEM REQUIREMENTS FOR UHDTV AND AN ADVANCED 1080P TELEVISION FORMAT

EBU TECHNICAL REPORT

Geneva
July 2016

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Executive Summary

Through research undertaken by its technical groups, the EBU has recognised and provided evidence (EBU TR028) to the various international organisations studying UHDTV, that a simple increase in spatial resolution will not meet the requirements of a new television system that can deliver a clearly perceptible better image quality.

Technical solutions and standards for UHDTV are still being defined and the options under discussion range widely causing confusion and leading to potential mistakes and waste in both the broadcast and consumer industries. Key to the development of efficient and interoperable systems is limiting the technical options and standards to clearly defined milestones.

This report highlights that the EBU needs urgently to study the issues it raises in order that member broadcasters are fully informed when making decisions about infrastructure and flexible workflows. The report shows that although the technology gaps are rapidly filling, making the formats discussed in the report ready for pilot implementations, there is a lack of focused technical and operational guidance when considering larger operational adoption in the next 3 - 5 years.

Best practise guidelines on the operational impact of parameters such as higher dynamic range production and higher frame rates from a technical and creative perspective are needed.

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Video System Requirements for UHDTV and an Advanced 1080p Television Format

EBU Committee	*First Issued*	*Revised*	*Re-issued*
TC	2016		

Keywords: Ultra High Definition Television, UHDTV, ITU-R BT.2020, HFR, HDR, WCG, 1080p HDTV.

1. Purpose of Report

This report presents the current view of the EBU on the fundamental image parameters required for future systems that includes both an advanced 1080p HDTV system that is described in the proposed ITU Recommendation ITU-R BT.[HDR][1]), as well as the UHDTV systems, described in ITU-R BT.2020 and the proposed ITU Recommendation ITU-R BT.2100.

The report also outlines the questions that still need to be addressed and the further work required in order that members and the wider industry understand the impact the new format on infrastructure and production workflows

2. Definitions

UHDTV Ultra High Definition Television. First proposed by NHK under the name "Super Hi-Vision" and originally only 7680 x 4320 (8k). During the standardisation process at the ITU, the intermediate resolution of 3840 x 2160 (4k) was added to the proposal.

ITU-R BT.2020 International Telecommunication Union (ITU) Recommendation containing the two resolutions and the new colour primaries. The new colour scheme is often referred to as "2020 Colour".

WCG Refers to the Wider Colour Gamut that is offered by the ITU-R BT.2020 colour primaries.

HDR Higher Dynamic Range images. A term that refers to the ability of a television system to acquire, produce and display images with higher brightness levels especially in highlights, whilst supporting the visibility of fine detail throughout the range.

HFR High Frame Rate. In television, HFR refers to temporal resolutions above 50 or 60 images a second[2]. This should not be confused with the cinema studios' definition of HFR being any frame rates above 24 fps (frames per second).

HDR10 Currently US terminology for the use of 2160p/60 with HDR and 10-bit/sample quantization. This represents some but not all of the parameter values in ITU-R BT.2020. The CTA definition: SMPTE ST 2084 + ITU-R BT.2020 at 10-bit depth, with SMPTE ST 2086 metadata containing "MaxFALL" and "MaxCLL"

[1] The Rec. is currently going through the approval stage of the ITU process, which completes on 4th July 2016.

[2] Note that current interlaced 25 and 30 fps 1080 line HDTV systems have temporal resolutions equivalent to 50/60 fps.

	parameters.
PQ	Perceptual Quantization is an HDR specification that achieves a very wide range of brightness levels for a given bit depth using a non-linear transfer function that is finely tuned to match the human visual system. It is one of the two HDR specifications given in ITU-R BT.2100, (PQ is also described in SMPTE ST 2084).
PQ10	Ultra HD Forum definition = PQ EOTF, ITU-R BT.2020 colour gamut, 10-bit depth.
HLG	Hybrid Log Gamma is the reverse compatible HDR system developed by the BBC and NHK. It is one of the two HDR specifications described in IITU-R BT.2100 (HLG is also described in ARIB B67).
HLG10	An Ultra HD Forum definition which includes the HLG OETF, ITU-R BT.2020 colour gamut, 10-bit depth.
Quad HD	Simply a four quadrant 2160p HD signal where each quadrant is a standard 1920 x 1080 progressive signal as described in ITU-R BT.709.

3. UHDTV

UHDTV (Ultra-High Definition Television), as a package, was approved by the ITU as the next generation television standard in October 2015 when ITU-R BT.2020 was published.

This standard allows the improvement of virtually all parameters of the current HDTV formats namely,

- Spatial Resolution ("more pixels"),
- Temporal Resolution ("more images a second")
- Colour Gamut ("more colours")
- Bit-Depth ("more bits/pixel")

The ITU propose to add a Higher Image Dynamic Range (HDR) specification to these giving improvements

- Highlights and Lowlights ("more detail in the highlights and lowlights")

3.1 UHDTV Technical Parameters

UHDTV is an end-to-end progressive scan television system, removing the interlaced scanning options used in current SD and some HDTV formats.

3.2 System Specifications

The following system specifications are described in ITU-R BT.2020 and ITU-R BT.2100,

3.2.1 Resolution

There are two resolutions described in ITU-R BT.2020:

- UHD (2160p): 3840 pixels x 2160 lines (corresponds to 4 x 1080p)
- UHD (4320p): 7680 pixels x 4320 lines (corresponds to 16 x 1080p)

The proposed recommendation ITU-R BT.2100 contains the same two resolutions but adds:

- HD (1080p): 1920 pixels x 1080 lines

3.2.2 Frame Rate

It is important to understand that many of the improvements in the quality of the images described in ITU-R BT.2020 and ITU-R BT.2100 highlight the shortfall of lower frame rates (images per second) in some genre. Both ITU-R Recommendations contain a range of frame rates from 24/1.001 (fractional frame rates are included) up to 120 images a second. The table below gives the available frame rates for both 50 Hz and 60 Hz territories.

50 Hz		25				50		100
60 Hz	24/1.001	24	30/1.001*	30*	60/1.001	60	120/1.001	120

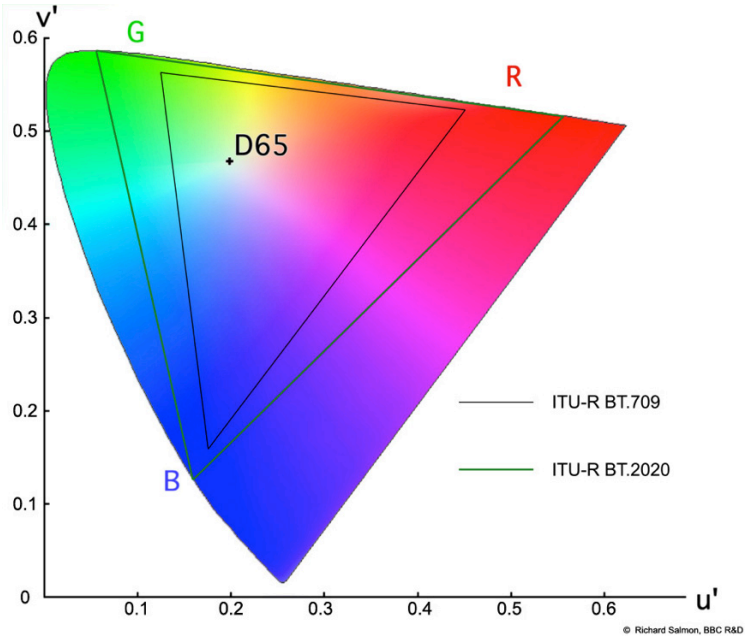
**It is not expected that these two frame rates will be used in the future (if at all for UHDTV)*

100 fps (for the 50 Hz territories) together with 120/1.001 and 120 fps (for 60 Hz territories) improve the motion portrayal and decreases the motion blur on fast moving material, particularly Sport.

It should be noted that 50 Hz territories prefer to use 50 fps and later, 100 fps. Drama and documentaries however will continue to use 25 fps for some time to come.

3.2.3 Colour Gamut

One the most striking features of ITU-R BT.2020 was the introduction of a major improvement in the range of colours that may be represented. Colour Space triangles clearly show the improvement over the current HD television system.



3.2.4 Higher Dynamic Range

Higher Dynamic Range defined in ITU-R BT.2100 gives a far greater sense of reality and of "being there" especially when combined with the improved colour palette.

There are number of misconceptions about HDR video (see ITU-R BT.2390), such as:

- It's just brighter pictures.
- It's all about bit-depth.
- It's an image capture issue.
- It's a display capability issue.

The misconception that HDR is simply brighter pictures arises from the fact that the maximum luminance *capability* is indeed much higher than standard dynamic range (SDR) television.

HDR enables more natural images that contain wider variations in brightness. While HDR does allow the picture average brightness to increase, the expectation is that indoor scenes produced in HDR will generally be at a similar brightness as with legacy TV systems.

The brightness range available with HDR enables outdoor sunlit scenes to appear noticeably brighter than indoor scenes, thus providing a more natural look. All scenes, especially outdoor, will be able to produce small area highlights such as specular reflections or emissive light sources at much higher brightness.

Added to this is an improvement in the ability to show details in dark areas; this feature is dependent on the black level of the display and the viewing environment.

4. Practicalities of delivering Improved Quality of Experience

While all of the parameters described contribute to an improved visual Quality of Experience (QoE), broadcasters have to accept some compromises to optimize the use of the available technical and financial resources in the production and distribution of audio-visual contents.

Systems must provide the necessary flexibility to let content providers to freely select the mix of parameters that best render the artistic intent of the programme and that are compatible with the available resources.

It is often desirable to produce content in a format with the richest combination of features to preserve the investment in the programme while delivery to the user will employ different reduced specifications depending on the available "bit budget" in the various distribution channels.

A primary driver in the choice of parameters will be the programme genre. This suggests that for general linear broadcast services, the ability to switch dynamically between format parameters (e.g., frame rate or colour volume) may be necessary.

Adaptive streaming will prove to be an invaluable tool for managing the audience's QoE, for example, where there is insufficient bit rate for full resolution images, a reduced resolution would be more acceptable than switching from HDR to SDR or HFR to "traditional" frame rates.

4.1 Resolution

In production both UHD (3840 x 2160) and HD (1920 x 1080) resolutions need to be supported but in the progressive scanning format only. Distribution encoders may be set to provide an intermediate resolution within those supported by MPEG (square pixel only) to best allocate the available bit budget. Professional and consumer interfaces are not required to support these intermediate resolutions.

There is no longer a technical reason for the Production format and Distribution format to be the same. For example: cameras and/or the production chain may operate with higher spatial and temporal resolution than the image format in distribution. This idea could easily be taken as far as the final platform encoder or even the consumer receiver.

4.2 Dynamic Range

HDR is resolution and frame rate independent and delivers potentially the greatest improvement in the QoE for the audience. HDR should be applicable to all the square pixel resolutions supported by MPEG. Although it may be advisable that a single OETF be used in the production chain to avoid the need for format converters, the Recommendation IITU-R BT.2100 and Report ITU-R BT.2390 explain the conversion process as a purely "mathematical" operation carried out in the "Reference Environment" (during production).

The HDR system used however, must be properly signalled throughout production interfaces (e.g. HD-SDI), programme files), into the encoded bit streams and most importantly though consumer HDMI interfaces. HDR and SDR programmes will co-exist within broadcast infrastructure and distributed services.

Note *A minimum of 10 bits per component video sample is required to minimize the visibility of quantization artefacts.*

4.3 Colour

It is very important to note that UHDTV has only one colour space container that is prescribed in ITU-R BT.2020. This means the Quad HD system cannot be called UHDTV.

It is expected that for the next few years, some cameras and most displays will not be able to fully exploit the "2020" colour specification. This situation will gradually resolve itself as display technology improves for both broadcast and consumer products use and the technology currently only available in high-end cameras becomes more affordable and moves down the camera value chain to the consumer models.

4.4 Frame Rate

Higher frame rates beyond 50 fps or 60 fps have been investigated and their benefits have been clearly identified for particular genres. As has been stated, UHDTV supports only progressive frame rates up to and including 120 fps. The expected benefit to the QoE gained by using these higher frame rates is typically genre dependent, i.e. content that contains "fast" action or motion such as sport will benefit the most.

Programme makers and other content providers must be able to freely choose the preferred frame rate in order to balance the final content quality with the production and distribution costs. During distribution this may well translate into the need to be able to seamlessly switch the frame rate between or even during programmes in the same service.

5. Advanced 1080p image format

It is now commonly accepted (through research carried out by the EBU and by other groups) that the optimum HDTV image format is a 1920 x 1080 progressive scanning system (1080p) with a minimum bit depth of 10. Several EBU Members are now adopting the 1080p/50 (as currently defined in ITU-R BT.709) image format for DVB-T2 services.

It is found that the 1080p HDTV image format benefits from the advanced parameters UHDTV offers;

- higher image dynamic range
- wider colour gamut

- higher frame rates

Adding these parameters to 1080p images has two advantages; it allows:

1. Programme makers and broadcasters to use a phased approach to the transition between current HD services and future UHD services.

2. Content that does not have a long term value (daytime programming etc.) to use HDR and WCG without the more expensive UHD resolution[3].

3. Early introduction of 100/120p content especially where practical broadcast infrastructure and consumer products capable of 3840 x 2160 HFR, may be some years away.

It also offers distributors an opportunity to deploy bit-rate-efficient advanced HDTV services ahead of full UHD services with HFR.

6. Recommended image formats overview

The following table outlines the potential image formats that could be used during the migration from current HDTV formats to a fully specified UHDTV format.

Image format	Resolution	Frame Rate* (fps)	Higher Dynamic Range	Bit-Depth	Colorimetry
1080p Advanced 1	1920 x 1080	24, 25, 50, 60	In Production ITU-R BT.2100 In Distribution PQ10, HLG10	Production (10, 12) Distribution (10)	ITU-R BT.2100
1080p Advanced 2	1920 x 1080	[24, 25, 50, 60] 100, 120			
UHD-1 Phase 2	3840 x 2160	24, 25, 50, 60			
UHD-1 Phase 2	3840 x 2160	[24, 25, 50, 60] 100, 120			
Future use					

** This includes the fractional frame rate variants.*

7. Higher Dynamic Range Metadata and Compatibility

7.1 Overview

When any new service is introduced it is standard practice that only some programmes are natively produced in the new system, HDR is no exception to this practice. HDR productions will also make use of legacy non-HDR material.

Programme makers and broadcasters with therefore not only need to convert between the two HDR formats and non-HDR (SDR) content and production formats, but also be confident that their content will be acceptably reproduced on HDR and SDR displays.

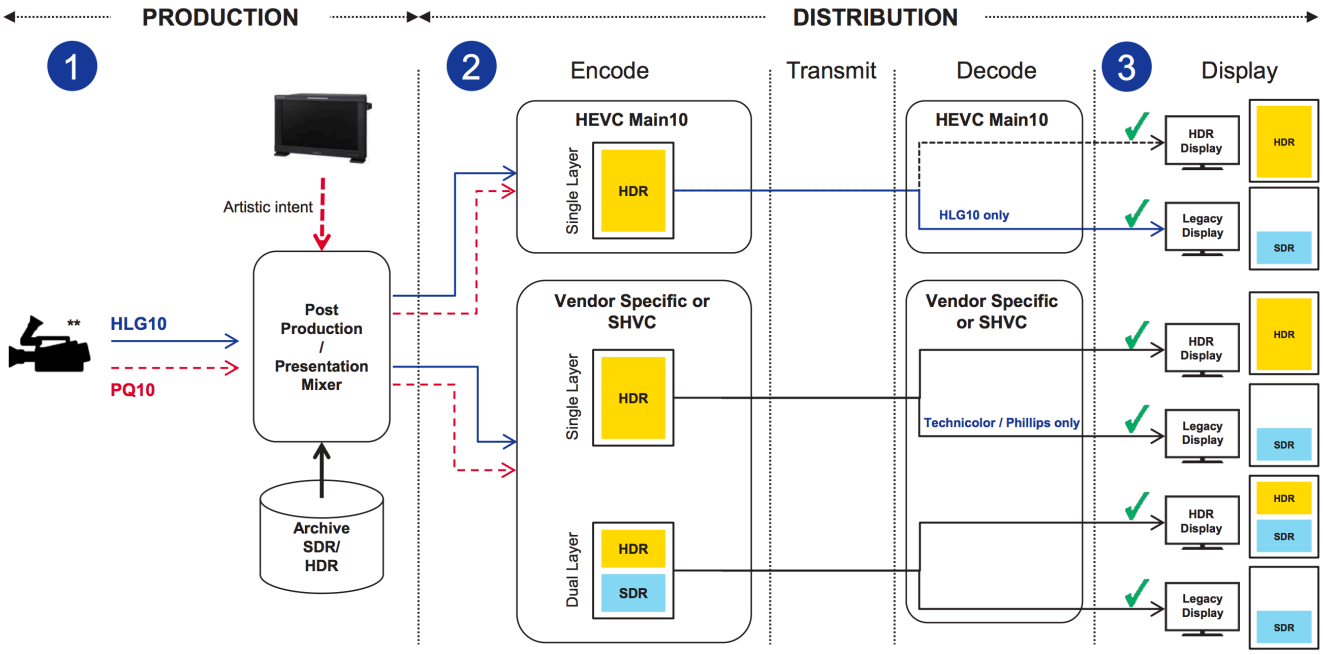
In addition, HDR programmes will also need to be delivered to current HD and SD SDR services for both live and non-live programmes.

[3] HDR and WCG offer an immediate QoE improvement that is easier and more cost efficient to produce.

7.2 HDR Backwards compatibility in Distribution

The overview below shows example options (high-level view only) for the various proposals currently under investigation by several organisations and groups.

It is clear that there are areas where information is not yet clearly understood and that there is an urgent review required before clear guidance can be given.



*** In a live production the workflow complexity may increase depending on the EOTF choice*

7.2.1 Single layer vs. dual layer

Depending on the selected encoding solution the requirement for guaranteed backward compatibility for legacy TV sets can be fulfilled in two ways; either using a single layered approach for HEVC/HLG10 only, or dual layered approach for vendor specific solutions.

7.2.2 Choice of the encoder

There are many HDR encoding schemes based on either of the two OETF curves. At the moment the encoders at the most advanced status are:

- HEVC/HLG10 and HEVC/HDR10 are non-vendor specific solutions already supported by default in the most part of receiving equipment.
- Scalable HEVC (SHVC) is also a standardised, non-vendor specific solution requiring compliant decoders to address the additional enhancement layer.
- Vendor specific.

7.3 HDR Backwards compatibility in Production

In production, the number of HDR options should be kept to a minimum and be firmly based on:

1. The programme production requirements for the primary distribution platforms and
2. The most efficient television distribution options

It is therefore vital that the HDR signal is compatible with non-HDR displays (that meet the minimum UHDTV display requirements) or that it is possible to extract a backward compatible signal from the HDR signal.

This can be realised either via standardised metadata or via providing a separate SDR signal in a bit rate efficient manner. Legacy material must be seamlessly and easily integrated into HDR productions.

7.4 Metadata management through production and distribution

7.4.1 System aspects

HDR Metadata may be separated into two distinct types.

- Signalling Parameters and
- Content Related parameters.

A display will need to know which variant of HDR is being presented to its inputs and if needed, may need to know some or all of the parameters required to correctly display the HDR images (preserving the artistic intent throughout the whole end-to-end chain).

Two terms are used to describe Content Related Metadata:

- *Static* Metadata does not change during the programme, and
- *Dynamic* Metadata may even change on a frame-by-frame basis.

The HLG system does not use or require any Content Related metadata. A UHD display only needs to know the signal presented to its input is an HLG signal.

The distributed PQ based systems may use both static and dynamic metadata. For example, dynamic Metadata are required to preserve the artistic intent in case the presentation display differs significantly from the reference display used for grading.

7.4.2 Production Metadata

A fundamental requirement for broadcasters is the ability to perform live productions. It is known from experiences with surround audio metadata that the success of passing production metadata through the system is highly dependent on the infrastructure and is totally dependent on every interface in the end-to-end chain fully supporting the system requirements.

Metadata systems that require “look-ahead” mechanisms are not suitable, especially for live programme production and for the successful management of programme junctions on linear multi-genre channels.

For the highest level of broadcaster continuity, any HDR system must require only minimal additional intervention and be capable of passing through infrastructure without the need to significantly change existing workflows.

All interfaces between production equipment and the end point of distribution will need to recognise and handle such metadata (either transparent pass-through or processing) in a standardised way.

For example, using dynamic metadata will require a redesign of vision mixers, routers, editing suites and distribution chains.

7.4.3 Distribution Metadata

Distribution to the home is rarely a single path. There may be many third party processing points and technologies between the broadcaster's play-out point and the viewer. This will have an impact the capability and transparency of the system's ability to deliver such metadata to the home receiver and the receiver's ability to successfully translate the data into the intended image.

The use of dynamic metadata will only be possible if it can be regenerated from the decoded signal after processing.

It should be noted that distribution chains often use other embedded data services. Any process to generate these must be standardised, automated and support live environments.

7.4.4 CE devices and Metadata

CE devices from different vendors will have different performance characteristics for HDR displays. For broadcast applications a fundamental requirement is that CE devices support at least the two dynamic range systems of ITU-R BT.2100, as outlined in this document.

8. Wider Colour Gamut

The majority of current "state of the art" cameras and displays are able to cover a colour gamut wider than that of ITU-R BT.709. However, only the best high-end cameras and virtually no displays are able to reproduce the full ITU-R BT.2020 colour range. The immediate adoption of the ITU-R BT.2020 colour space is recommended, as both ITU-R BT.2020 and ITU-R BT.2100 arguably provide sufficient "headroom" to fulfil the needs for next generation video systems.

For a system to be legitimately described as "UHD", it must be based on the ITU-R BT.2020 colour space even if the source material or the display cannot currently capture or reproduce the full range of colour.

Note *A minimum of 10 bits per component video sample is required to minimize the visibility of quantization artefacts.*

8.1 Backwards compatibility

UHDTV contents are not required to be backwards compatible with legacy ITU-R BT.709 systems without adaptation. This is no different to the current conversions from HD (ITU-R BT.709) to SD (ITU-R BT.601).

The ITU has published ITU-R BT.2087 that recommends the conversion requirements from ITU-R BT.709 to ITU-R BT.2020.

It is also due to publish a report on the conversion from ITU-R BT.2020 to ITU-R BT.709, but will leave the techniques to the broadcast equipment vendors to determine based on their own IPR and expertise.

9. High Frame Rate

Certain genres with fast moving content (e.g. sports) will gain significant added value by using the higher temporal resolutions of ITU-R BT.2100 for both UHD and HD 1080p. It should be possible to support higher frame rates in a production environment that at least double conventional frame rates.

9.1 Backwards compatibility

The ability to extract a backward compatible signal from the HFR signal and to transport both signals to the consumer in a bit rate efficient manner (including conversion from 60 Hz territories) is a fundamental requirement.

9.1.1 Examples for frame rate conversion

Standards conversion software packages must also use Motion Compensation processing when required.

24p and 24/1.001p to 25p	–	speed change
24p and 24/1.001p to 50p	–	speed change + frame doubling
24p and 24/1.001p to 100p	–	not recommended for complete programmes
25p to 50p	–	frame doubling or interpolation
25p to 100p	–	not recommended for complete programmes
30p and 30/1.001p to 25p	–	motion compensated conversion required
30p and 30/1.001p to 50p	–	motion compensated conversion required
30p and 30/1.001p to 100p	–	not recommended for complete programmes
60p and 60/1.001p to 25p	–	not recommended for complete programmes
60p and 60/1.001p to 50p	–	motion compensated conversion required
60p and 60/1.001p to 50p	–	motion compensated plus frame doubling
120p and 120/1.001 to 25p	–	not recommended for complete programmes
120p and 120/1.001 to 50p	–	motion compensated + alternate frames
120p and 120/1.001 to 100p	–	motion compensated conversion required

Content processed via a "pull-down" process, should first have the repeated fields/frames removed to produce the original frame rate. The resulting file can then be speed changed to replay at the appropriate 50 Hz based frame rate.

9.1.2 Examples of 50 Hz frame rate up conversion

HD and SD material will usually require de-interlacing and frame rate processing during up conversion to UHD.

Up conversion from:

25psf and 25p to UHD 25p	–	no frame rate conversion or de-interlacing
25psf and 25p to UHD 50p	–	frame doubling or interpolation, no de-interlacing
25psf and 25p to UHD 100p	–	not recommended for complete programmes
25i to UHD 25p	–	not recommended for complete programmes
25i to UHD 50p	–	De-interlacing to produce frames from fields
25i to UHD 100p	–	not recommended for complete programmes

Conversion from HD 60 Hz based frame rates to UHD 50 Hz based frame rates assume the conversion from 60 Hz to 50 Hz occurs at HD resolution before up conversion

10. Conclusions

Image parameters such as higher dynamic range, higher frame rate, increased colour and resolution can significantly enhance the image quality. Depending on the genre of content these parameters contribute differently to the enhanced quality of experience.

This document includes the clear requirement for a 1080p enhanced HDTV format which can benefit from HDR, HFR and WCG. The actual parameters and image format used will depend on the value of the production to the content owner. The fact that the production format no longer needs to be identical to the broadcast delivery or distribution format will be a key factor in the choice of "added value" parameters used.

Further work is needed to assess the impact of conversions between the different image formats (including colour space and dynamic range conversion).

The business need for international sales content to be of very high visual quality will require that parameters such a HDR and WCG are seriously considered before acquisition starts or the quality expectations of the final product will not be fulfilled.

The fact that several different technical options will have to co-exist in a broadcaster's infrastructure will challenge all members, and will demand a new far more flexible approach to infrastructure design and implementation.

In order to safeguard future investments, the EBU Members need to urgently study these flexible workflows, as well as produce best practise guidelines on the operational impact of parameters like higher dynamic range production.