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TECHNICAL REPORT

colour inside

Dynamic metadata high dynamic range impacts on TV power consumption

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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DYNAMIC METADATA HIGH DYNAMIC RANGE IMPACTS ON TV POWER CONSUMPTION

FOREWORD

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
100/3862/DTR	100/3886/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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INTRODUCTION

HDR technologies affect the entire video ecosystem from production and processing, through to distribution and presentation. HDR-capable television sets typically have higher peak luminance and better low-luminance capabilities than non-HDR TVs and can take advantage of HDR video signals which typically represent scenes with much higher luminance and more detailed low-luminance levels than was possible in traditional analogue and digital non-HDR video systems.

As the luminance range of an HDR signal might not match the luminance range capabilities of the display device, the signal must be adjusted before being displayed. This luminance adjustment is called tone-mapping and is implemented as a processing step in the TV. The tone mapping process can be improved with metadata, which describes the properties of the content to be displayed.

Dynamic metadata based HDR tone-mapping approaches and behaviours are seeing an ever-increasing application in consumer televisions; however, representative standardized test content for measurement of the power consumption impact of those technologies on televisions is not available. To prepare objective test materials (video clips), a study of power and luminance behaviour was conducted, the results of which are described in Clauses 5 and 6.

This document assesses the impact of dynamic HDR on TV luminance and power consumption using two technologies currently in deployment.

A small sample of TVs that supported the two technologies were studied using "representative" content prepared by PT100-24 members. Test results show that dynamic metadata HDR content, delivered to a dynamic metadata capable TV, can provide pictures with even greater dynamic range (higher peak luminance and more detailed luminance levels with wider colour gamut) than static HDR at the same or lower TV power consumption versus static HDR or SDR content delivered to that same TV.

DYNAMIC METADATA HIGH DYNAMIC RANGE IMPACTS ON TV POWER CONSUMPTION

1 Scope

This document presents a study of the impact of high dynamic range (HDR) technologies with "dynamic metadata" on TV luminance and power consumption. It compares the power consumption of content with dynamic metadata to the same content without dynamic metadata. Non-dynamic "static metadata" HDR technologies such as HDR10 and non-metadata HDR such as HLG, were previously studied in IEC TR 63274:2021.

This document also reviews the current HDR TV market and analyses existing HDR TV power measurement methods and considerations for any changes to those power measurement standards.

While this document studies the results of content that include Dolby Vision® and HDR10+ dynamic metadata, any comparison of these two technologies is outside of the scope of this document.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Terms and definitions

3.1.1
average picture level
APL
average level of all the pixels of a single video signal frame in the linear luminance domain

EXAMPLE Display equipment such as television sets or computer monitors that internally use linear encoding after undoing the non-linearity of the input signal.

[SOURCE: IEC TR 63274:2021, 3.1.10]

3.1.2
average picture level based on non-linear input signal
APL′
average level of all pixels of a single video signal frame in the non-linear luminance domain

EXAMPLE Display equipment such as television sets or computer monitor receive input signals that encode luminance in a non-linear way. Examples for such non-linear encoding are PQ or HLG EOTFs (ITU-R BT.2100).

Note 1 to entry: APL′ is defined as a percentage of the range between reference black and reference white level.

Note 2 to entry: This is not a measure of the linear signal that might be available inside of some display equipment and delivered to the display device. The external and internal video signals are shown in Figure 1.

[SOURCE: IEC TR 63274:2021, 3.1.11]

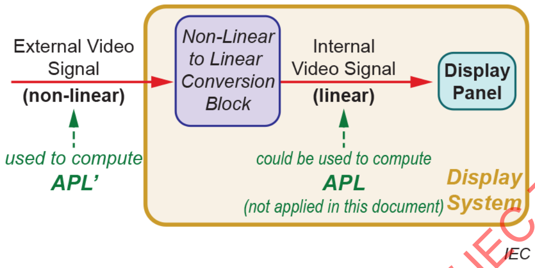

Figure 1 – Occurrence of linear and non-linear signal encodings in context of a typical display processing pipeline and how they can be used to compute APL and APL'

3.1.3
colour gamut
maximum area of chromaticity reproducible by a display

[SOURCE: IEC 62977-2-1:2021, 3.1.5, modified – "area" deleted from term]

3.1.4
colour volume
three-dimensional space of all colours and intensities that a device or signal can reproduce or convey

[SOURCE: ISO/IEC TR 23091-4:2021, 3.6, modified – "three-dimensional" added to definition]

3.1.5
content light level
CLL
integer static HDR metadata value defining the luminance of any single pixel within an encoded HDR video sequence

Note 1 to entry: The CLL is provided in candelas per square metre (cd/m^2).

3.1.6
maximum content light level
MaxCLL
integer static HDR metadata value defining the maximum luminance of any single pixel within an encoded HDR video sequence

Note 1 to entry: The MaxCLL is provided in candelas per square metre (cd/m^2).

Note 2 to entry: CTA-861 provides further explanation.

3.1.7
dynamic metadata
metadata that can be different for different portions of the image essence

[SOURCE: SMPTE ST 2094-1:2016, 4.6]

3.1.8
electro-optical transfer function
EOTF
mathematical function for transferring an electrical signal into a desired optical signal

EXAMPLE EOTFs are typically non-linear and monotonic and aim to incorporate behaviour of the human visual system, e.g. on a display device. Some are absolute, addressing luminance values directly, while others are of relative nature.

[SOURCE: IEC TR 63274:2021, 3.1.1]

3.1.9
frame average light level
FALL
integer static HDR metadata value defining the average luminance for all pixels of any single frame within an encoded HDR video sequence

Note 1 to entry: The FALL is provided in candelas per square metre (cd/m^2).

3.1.10
maximum frame average light level
MaxFALL
integer static HDR metadata value defining the maximum average luminance for all pixels of any single frame within an encoded HDR video sequence

Note 1 to entry: The MaxFALL is provided in candelas per square metre (cd/m^2).

Note 2 to entry: CTA-861 provides further explanation.

3.1.11
high definition
HD
spatial video resolution ranging from 1 280 × 720 to 1 920 × 1 080

[SOURCE: IEC TR 63274:2021, 3.1.6]

3.1.12
high dynamic range video
HDR video
capability of components in a video pipeline to capture, process, transport or display luminance levels and tone gradations that exceed capabilities of conventional SDR imaging pipelines components

Note 1 to entry: An HDR video signal typically uses a greater bit depth, luminance and colour volume than standard dynamic range (SDR) video. It also typically utilizes different tone curves such as perceptual quantizer (PQ) as specified in SMPTE ST 2084 or hybrid log gamma (HLG) specified in ITU-R BT.2100 instead of gamma, as used with SDR. When the HDR video signal is rendered on an HDR display, it is possible to see greater luminance ranges and wider colour gamuts.

Note 2 to entry: HDR video can provide an enhanced viewer experience and can more accurately reproduce scenes that include, within the same image, dark areas and bright highlights, such as emissive light sources and reflections. The luminance range of an HDR image is typically constrained between 0,005 cd/m^2 to 4 000 cd/m^2.

[SOURCE: IEC TR 63274:2021, 3.1.2, modified – The last sentence of Note 2 to entry has been added.]

3.1.13
hybrid log-gamma
HLG
one set of HDR transfer functions offering a degree of backwards compatibility to SDR by more closely matching the previously established television transfer curves

Note 1 to entry: Sets of transfer functions related to HDR signals are specified in Rec. ITU-R BT.2100-1.

Note 2 to entry: HLG is used both as a description of a dedicated transfer function and as a video format name.

[SOURCE: IEC 62087-2:2023, 3.1.9, modified – Added 'to SDR'.]

3.1.14
image-related metadata
identifiers describing intrinsic image properties in form of both static metadata valid throughout the content and dynamic metadata for frame-specific image parameters

EXAMPLE 1 Minimum and maximum luminance, average picture level, properties of the grading display.

EXAMPLE 2 HDR image related static metadata are MaxCLL and MaxFall as specified in CTA-861-G, section 6.9.1 and Appendix P, sections P.1 and P.2 for algorithms to calculate each.

EXAMPLE 3 Dynamic metadata is utilized by Dolby Vision® (SMPTE ST 2094-10) and HDR10+ (SMPTE ST 2094-40).

Note 1 to entry: They can be used as recommendations and guidance for image rendering and display.

[SOURCE: IEC TR 63274:2021, 3.1.9]

3.1.15
perceptual quantizer
PQ
one set of HDR transfer functions addressing a very wide range of absolute luminance levels for a given bit depth using a non-linear transfer function that is finely tuned to match the sensitivity of the human visual system

Note 1 to entry: Sets of transfer functions related to HDR signals are specified in Rec. ITU-R BT.2100-1.

[SOURCE: ISO/IEC TR 23008-15:2018, 3.8, modified – In the definition, "brightness" has been replaced with "luminance".]

3.1.16
signal identification metadata
identifiers describing the properties of an image stream

EXAMPLE Format, resolution, colour space, chroma subsampling, bit-depth, image compression, image transport.

[SOURCE: IEC TR 63274:2021, 3.1.8]

3.1.17
standard dynamic range video
SDR video
capability of components in a video pipeline to capture, process, transport or display luminance levels and tone gradations that can be characterized by the dynamic range, colour rendering and tone gradation capabilities essentially compatible with cathode ray tube (CRT) displays

EXAMPLE ITU-R BT.709 /BT.1886 and IEC 61966-2-1 (sRGB).

Note 1 to entry: The luminance range of an SDR image is typically constrained between 0,1 cd/m^2 to 100 cd/m^2.

[SOURCE: IEC TR 63274:2021, 3.1.3]

3.1.18
television set
TV
equipment for the reception and display of television broadcast and similar services for terrestrial, cable, satellite and broadband network transmission of analogue and/or digital signals

Note 1 to entry: A television set can include additional functions that are not required for its primary function.

[SOURCE: IEC 62087-3:2023, 3.1.1]

3.1.19
ultra high definition
UHD
Ultra HD
spatial video resolution above 1 920 × 1 080

[SOURCE: IEC TR 63274:2021, 3.1.7]

3.1.20
wide colour gamut
WCG
colour space that covers a larger percentage of visible colours compared to the sRGB/Rec. ITU-R BT.709 colour space

EXAMPLE ITU-R BT.2020 is considered to provide WCG while BT.709 does not.

[SOURCE: IEC TR 63274:2021, 3.1.4]

3.2 Abbreviated terms

ARC	audio return channel
ATSC	Advanced Television Systems Committee
BDP	Blu-ray™ disc player[1]
CIE	International Commission on Illumination (Commission Internationale de l'Éclairage)
CLASP	non-profit organisation supporting the development and implementation of policies and programs to improve the energy and environmental performance of appliances and equipment we use every day (formally known as Collaborative Labelling and Standards Program)[2]
CRT	cathode ray tube
CTA	Consumer Technology Association (formerly Consumer Electronics Association)
DV	Dolby Vision®[3]
FPS	frames per second

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2 CLASP, https://www.clasp.ngo/

3 Dolby® and Dolby Vision® are trademarks of Dolby Laboratories, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

HDMI®	High-Definition Multimedia Interface[4]
HDR10	HDR10[5] media profile
HDR10+	HDR10+[6] media profile
HEVC	high-efficiency video coding
Hz	hertz
ITU-R	International Telecommunication Union, Radiocommunication Sector
NABA	North American Broadcasters Association
NEEA	Northwest Energy Efficiency Alliance
OTT	over-the-top
PCL	Pacific Crest Labs[7]
SMPTE	Society of Motion Picture and Television Engineers
sRGB	standard Red Green Blue colour space specified in IEC 61966-2-1:1999
TV	television set

4 Dynamic metadata high dynamic range video

4.1 Introduction to dynamic metadata HDR video

4.1.1 Overview

Older video creation, broadcast and television receiver technologies, collectively called "Standard Dynamic Range" (SDR) for the purposes of this technical report, do not provide images that accurately represent the light distribution and detail of real-world scenes[8]. Significant technological progress in video content creation, distribution and displays now permit consumers to receive and display almost life-like programming by adding several key aspects missing from older SDR technologies. Specifically:

– higher pixel counts (up from 1 920 × 1 080 image pixels Full HD to UHD with 3 840 × 2 160 or more image pixels);
– higher image frame rates (up from a maximum of 60 Hz to 120 Hz or more);
– greater dynamic range (image peak brightness up to 10 000 cd/m^2);
– wider colour gamut embracing more of the CIE 1931 (x, y) chromaticity space vs the common limit to ITU-R BT.709 colour primaries with SDR images.

Roughly a decade ago, HDR technologies entered the market. Since then, many consumers have been enjoying video content offering much of the key aspects described above in a form this report refers to as "static metadata HDR". Static metadata in this report's context means that for a given "static metadata" HDR video programme, the content author provides ancillary data along with the programme. This data describes several characteristics of the video which

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4 HDMI® and HDMI® High-Definition Multimedia Interface are trademarks of HDMI Licensing Administrator, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5 HDR10 is an open standard HDR media profile announced in August 2015 by the Consumer Technology Association. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

6 HDR10+ is a trademark of HDR10+ Technologies, LLC. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

7 Pacific Crest Labs, https://www.pacificcrestlabs.com/

8 'Real-world' refers to physically accurate representations of light distribution as well as spatial and temporal detail that are captured e.g., by a camera but also includes artistically created or adjusted content.

for example represent the peak luminance, minimum luminance, and colour gamut of the entire programme. The receiver can only make a single set of tone-mapping adjustments based on this information, which then remains constant or 'static' throughout the display of the full programme. A previously published technical report, IEC TR 63274:2021, discussed static metadata HDR technologies and their impact on television energy use.

In addition to static metadata, another metadata approach is available in the market which this report refers to as "dynamic metadata HDR". Dynamic metadata in this report's context refers to metadata provided by the content author on a frame-by-frame or scene-by-scene basis which allows video production and television receivers to make adjustments frame-by-frame when processing and displaying such programmes. This has several benefits to the content author's creative needs and provides useful information allowing a receiver to display the content author's intended rendering of that programme more accurately.

Subclauses 4.1.2 and 4.1.3 detail the main properties of the two "dynamic metadata HDR" formats Dolby Vision® and HDR10+ considered by this Technical Report.

NOTE There are other dynamic HDR technologies such as SL-HDR2 (ETSI TS 103 433-2), SL-HDR3 (ETSI TS 103 433-3) and HDR Vivid which were not evaluated as content and televisions employing those technologies were not globally available.

4.1.2 Dolby Vision®

Dolby Vision® is a commercial imaging format created by Dolby Laboratories, Inc. This format enables a modular ecosystem that provides an extensive set of implementations and methods to facilitate imaging features such as HDR. These features are implemented in a wide range of soft and hardware products used with image capture, processing, and display, both in the consumer and professional market segments. This includes many of today's TVs.

On a foundational level, the Dolby Vision® image signal uses the PQ EOTF (SMPTE ST 2084) with a quantization granularity of up to 12 bits, but the HLG EOTF is also supported through compatibility profiles. To support accurate and perceptually meaningful transformations such as mapping the current content scene to a TV's capabilities, individual Dolby Vision® enabled devices can rely on comprehensive image-related metadata. This metadata offers several distinct parameters supporting how the image signal is encoded, decoded, mapped, rendered, and ultimate appears within input, processing, and output scenarios.

One metadata type of Dolby Vision® is frame accurate dynamic metadata, derived from statistical analysis of the content imagery. This facilitates the preservation of the creative intent, independent of the target display capabilities (see SMPTE ST 2094-10 for more details). In addition to computational analysis, manual creative input can be assigned to the dynamic metadata through Dolby Vision® Trim Passes, which give content creators the opportunity to adjust the colour volume mapping to their exact requirements and preference.

To guarantee the accurate interpretation of the aforementioned metadata, Dolby Vision® offers a dedicated colour volume-mapping engine that is implemented in Dolby Vision® enabled devices. This mapping engine can in many cases also facilitate real-time adjustments to guide the HDR tone mapping, e.g., taking into account the display reflectivity and surrounding illumination in the viewing environment.

4.1.3 HDR10+

HDR10+ is a royalty-free HDR format with a certification, logo and licensing program by HDR10+ Technologies, LLC, a joint venture between Panasonic Corporation and Samsung Electronics.

It uses dynamic metadata as opposed to static (i.e. single value set established for a specific item of content) metadata used by standard HDR10. The use of dynamic metadata means that HDR10+ can change each frame's parameters, therefore frames are treated separately by their own set of brightness, colour and contrast values. Additionally, HDR10+ can signal a maximum luminance of 10 000 cd/m^2. It is an open format meaning it can be modified and deployed by organisations other than HDR10+ LLC stakeholders. The certification and logo licencing programme is royalty-free with some associated annual administrative fees as described on the LLC website.

HDR10+ technology includes:

- EOTF (Electro-Optical Function): SMPTE ST 2084 (PQ)
- Chroma subsampling: 4:2:0 (compression format)
- Resolution: agnostic (2K/4K/8K, etc.)
- Bit representation: 10-bit or more (up to 16-bit)
- Colour space: ITU-R BT.2020
- Pixel representation: up to 10 000 cd/m^2
- Metadata (Required): Mastering Display Colour Volume Metadata (SMPTE ST 2086)
- Metadata (optional): MaxCLL, MaxFALL
- HDR10+ is applicable for HEVC, AV1, VVC and VP9 compatibility via WebM as well as any codec that supports ITU-T T.35 metadata.

NOTE 1 VVC (Versatile Video Coding), also known as H.266, ISO/IEC 23090-3, and MPEG-I Part 3, is a licence-based video compression standard developed by ISO/IEC JTC 1/SC 29 (MPEG).

NOTE 2 VP9 is an open and royalty-free video coding format developed by Google and stated as the WebM Project's next-generation open video codec.

NOTE 3 WebM is an open, royalty-free, media file format for the web, developed by The WebM Project.

It is fully backward compatible with HDR10. HDR10+ dynamic metadata may be added to any HDR10 content.

4.2 Market relevance of dynamic metadata HDR video

4.2.1 Dolby Vision® market snapshot

Dolby Vision® is available through and used by (as of summer 2021):

- majority of HDR capable televisions;
- many Blu-ray™ and streaming set-top-boxes;
- variety of desktop, laptop and notebook computers;
- several manufacturers' gaming platforms, smartphones and mobile devices;
- numerous content creators and service providers;
- best-in-class leading video edit suite software providers;
- over 100 postproduction companies;
- hundreds of theatrical releases in 2020 and 2021.

Dolby Vision® is available for thousands of movies and TV episodes on Blu-ray™, via OTT providers and user-generated (UGC) content on major platforms.

4.2.2 HDR10+ market snapshot

HDR10+ is available through and used by (as of mid-2021):

- 28 content companies and service providers;
- 19 TV, projector, smartphone and notebook manufacturers;
- over 5 000 certified device models;
- 19 source device manufacturers and streaming platforms – BDP/set-top box/video recorders/projector, etc.;
- 22 SoC manufacturers;
- hundreds of millions of HDR10+-capable television sets shipped since 2018;
- over 30 video toolchain manufacturers and postproduction companies;
- HDR10+ Technologies LLC certification and logo program for the technology has 130 participating companies as of March 2022.

HDR10+ is available in 54 Blu-ray™ titles, numerous movies and episodic series via OTT providers, and a large amount of user-generated content (UGC) on YouTube uploaded from Android handsets and 3rd party HDR video makers.

4.3 Consumer availability of dynamic metadata HDR video technologies in TVs

While difficult to get an accurate tally of exactly how many dynamic metadata capable HDR TVs are in consumer's homes worldwide, the CTA's 23rd Annual U.S. Ownership and Market Potential Study (July 2021) provides an indication of consumer adoption of HDR TVs in the U.S. It should be noted that CTA's report does not cover the full 2021 calendar year and therefore the numbers provided here are estimates. In addition, CTA's study does not differentiate between static metadata HDR TVs and dynamic metadata HDR capable TVs. For reference, the relevant numbers from CTA's U.S. study are shown below:

- Total U.S. population = 328 million [U.S. Census Bureau December 2020]
- Total U.S. occupied housing units = 120 million [U.S. Census Bureau December 2020]
- Total U.S. TV households = 109 million [per CTA over 91 % of homes own a TV]
- Ownership of 4K UHD TVs (2021 est.) = 57 million units [per CTA over 50 % of TV households]
- Ownership of HDR TVs (2021 estimate) = 34 million units [per CTA over 30 % of TV households]

The North American Broadcasters Association (NABA) published its study and HDR Recommendation Overview (August 2021) which noted virtually all Smart TVs support both HDR10 and HLG. The study also reported that current HDR content production consists of HDR10 which is widely used for feature films and scripted TV content, while HLG is widely used for sports and other live production.

The NABA study also noted that U.S. broadcasters, cable operators and streaming providers use HDR10 and "optional" dynamic metadata (Dolby Vision® and HDR10+) content. However, the study did not compare the different HDR technologies in terms of percentage of programmes broadcast, but did note that video streaming, where HDR content is more prevalent, is increasing in U.S. viewing habits, and among streaming capable homes, accounts for as much as 25 % of total TV usage.

The NABA report concludes with a recommendation: "That systems based on an underlying PQ-based HDR transfer function (SMPTE ST 2084) with optional static (SMPTE ST 2086) and/or dynamic metadata (SMPTE ST 2094) be used for ATSC 3.0 program emission in North America."

In Germany, the Deutsche TV-Plattform, an association of private and public organisations involved in digital media, provides a database of UHD devices supporting HDR10, HLG, Dolby Vision® and HDR10+. German data for 2021/Q1 – Q3 UHD TV sales (ZVEI, Deutsche TV Platform, GfK) showed 98 % of UHD TVs support at least one HDR format and 77 % of UHD TVs support at least one dynamic HDR format (either Dolby Vision® or HDR10+).

5 Dynamic metadata HDR TV power consumption research

5.1 Overview

As both the content and the consumer TV landscape is shifting towards dynamic HDR use, investigations in this document are focused on:

1) understanding how TV power and luminance responds to dynamic metadata content available today as this content is largely limited to movies and series available through streaming services like Amazon Prime / Amazon Instant Video[9], NETFLIX[10] and on Blu-ray™ discs;
2) characterizing the impact of test media developed by 2050 Partners[11] and colour graded by their professional feature film digital mastering subcontractor, Company 3[12], to represent dynamic metadata video after the expected transition of broadcast content to include dynamic metadata.

Because many uncertainties remain in how dynamic metadata will progress in terms of technology, compatibility, content provider, distribution network practices, and market adoption, this report and its data represent a snapshot in time the project team used to increase its understanding of the ecosystem. Since the dynamic metadata HDR ecosystem is still evolving, the report's data might not be useful in answering questions policymakers might have related to this topic.

Subclause 5.2 describes the dynamic metadata test media developed by the project team to represent future broadcast content with dynamic metadata for the purpose of laboratory tests using current dynamic metadata capable televisions. Subclause 5.3 explains the methods, findings, and conclusions of that research, which focused on understanding the power and luminance impacts of both dynamic metadata test media and real-world content.

5.2 Dynamic metadata test media

As the basis for dynamic metadata test content, the project team chose to use the same raw video content captured by CLASP for the purpose of developing HDR test materials and on which the IEC HDR10 test media, proposed for IEC 62087-2:2023 was based. This content was created by a team of experts on professional equipment. Company 3 judged this content as high quality and suitable for this project's intended purpose.

9 Amazon, Amazon Prime, Amazon Prime Video and Amazon Instant Video are trademark of Amazon.com, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

10 NETFLIX is a trademark of Netflix, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

11 2050 Partners, Inc., https://www.2050partners.com/.

12 Company 3 and CO3 are trademarks and service marks of Company 3 / Method Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

The following instructions were provided to Company 3 to create the dynamic metadata test media:

- Use the provisionally approved IEC 62087-2:2023 static metadata HDR10 test media as shown in Table 1 below.
- Apply the same edits, tone mapping and workflow Company 3 typically does for Dolby Vision® and HDR10+ clients to the above IEC 62087-2:2023 HDR10 static metadata test media to yield new Dolby Vision® and HDR10+ dynamic test media that meet the requirements in Table 1 below. Annex A provides information on the test material workflows.
- Add a 10-second countdown timer over ITU-R BT.2111 colour bars to identify start of test sequence.

Table 1 – Static and dynamic metadata test media

Type	Resolution	Frame rate	Encoder	Container	Audio
IEC static metadata HDR10	3 840 × 2 160	59,94p	HEVC	MP4	AAC, 1 kHz sine wave, −18 dB
Dolby Vision®	3 840 × 2 160	59,94p	HEVC	MP4	AAC, 1 kHz sine wave, −18 dB
HDR10+	3 840 × 2 160	59,94p	HEVC	MP4	AAC, 1 kHz sine wave, −18 dB

The names of the three test media, in the same order as shown in Table 1 are:

1) IEC_Broadcast_UHD_5994p_HDR10_HEVC_AAC.mp4
2) IEC_DynamicMetadata_UHD_5994p_DV_HEVC_AAC.MP4
3) IEC_DynamicMetadata_UHD_5994p_ HDR10Plus_ HEVC_AAC.MP4

NOTE All 3 test media are in 16:9 aspect ratio and stereo 2.0 audio.

The UHD video signals named above can be streamed or downloaded from the publicly accessible IEC online repository at https://www.iec.ch/tc100/supportingdocuments. The test media can be downloaded individually. For file download, readers might have to use specific download functions and/or windows depending on the specific computer browser used.

The resulting metadata as reported by MediaInfo[13] for the two new UHD (2160p) versions of the dynamic metadata test media are shown in Table 2 (HDR10+) and in Table 3 (Dolby Vision®). The Dolby Vision® clips have a bit depth of 10. While 12 bits is more common, 10 bits is a valid Dolby Vision® format suitable for the purpose of this research.

13 MediaInfo is a free, cross-platform and open-source program that displays technical information about media files, as well as tag information for many audio and video files [https://mediaarea.net/en/MediaInfo].

Table 2 – HDR10+ test media metadata

General	
Complete name	IEC_DynamicMetadata_UHD_5994p_ HDR10Plus_ HEVC_AAC.MP4
Format	hvc1
Codec ID	hvc1 (isom/hvc1)
File size	1,31 GB
Duration	5 min 19 s
Overall bit rate	35,1 Mb/s
Encoded date	UTC 2020-12-22 20:27:05
Tagged date	UTC 2020-12-22 20:27:05
Video	
ID	1
Format	HEVC
Format/Info	High Efficiency Video Coding
Format profile	Main 10@L5.1@High
HDR format	SMPTE ST 2094 App 4, Version 1, HDR10+ Profile B compatible
Codec ID	hvc1
Codec ID/Info	High Efficiency Video Coding
Duration	5 min 19 s
Bit rate	35,0 Mb/s
Maximum bit rate	85,0 Mb/s
Width	3 840 pixels
Height	2 160 pixels
Display aspect ration	16:9
Frame rate mode	Variable
Frame rate	59,940p (60 000/1 001) FPS
Minimum frame rate	59,920p FPS
Maximum frame rate	59,960p FPS
Colour space	YUV
Chroma subsampling	4:2:0 (Type 2)
Bit depth	10 bits
Bits/(Pixel*Frame)	0,070
Stream size	1,30 GiB (100 %)
Writing library	ATEME Titan File 3.9.6 (4.9.6.2)
Encoded date	UTC 2020-12-22 21:00:56
Tagged date	UTC 2020-12-22 21:00:56
Colour range	Limited
Colour primaries	BT.2020
Transfer characteristics	PQ
Matrix coefficients	BT.2020 non-constant
Mastering display colour primaries	Display P3
Mastering display luminance	min: 0,005 0 cd/m^2, max: 4 000 cd/m^2
Maximum Content Light Level	599 cd/m^2
Maximum Frame-Average Light Level	139 cd/m^2

SEI_rbsp_stop_one_bit	Missing
Codec configuration box	hvcC
Audio	
ID	2
Format	AAC LC
Format/Info	Advanced Audio Codec Low Complexity
Codec ID	mp4a-40-2
Duration	5 min 19 s
Duration_FirstFrame	50 ms
Bit rate mode	Constant
Bit rate	128 kb/s
Channel(s)	2 channels
Channel layout	L R
Sampling rate	48,0 kHz
Frame rate	46,875 FPS (1 024 SPF)
Compression mode	Lossy
Stream size	4,87 MiB (0 %)
Language	English
Default	Yes
Alternate group	1
Encoded date	UTC 2020-12-22 21:00:56
Tagged date	UTC 2020-12-22 21:00:56

Table 3 – Dolby Vision® test media metadata

General	
Complete name	IEC_DynamicMetadata_UHD_5994p_DV_HEVC_AAC.MP4
Format	iso6
Codec ID	iso6 (isom/hev1/dby1)
File size	1,15 GiB
Duration	5 min 19 s
Overall bit rate	35,2 Mb/s
Encoded date	UTC 2020-12-12 15:25:15
Tagged date	UTC 2020-12-12 15:25:15
Video	
ID	1
Format	HEVC
Format/Info	High Efficiency Video Coding
Format profile	Main 10@L5.1@High
HDR format	Dolby Vision®, Version 1.0, dvhe.08.09, BL+RPU / SMPTE ST 2086, HDR10 compatible
Codec ID	hev1
Codec ID/Info	High Efficiency Video Coding
Duration	5 min 19 s
Bit rate	35,1 Mb/s
Maximum bit rate	87,9 Mb/s

General	
Width	3 840 pixels
Height	2 160 pixels
Display aspect ratio	16:9
Frame rate mode	Variable
Frame rate	59,940p (60 000/1 001) FPS
Minimum frame rate	59,920p FPS
Maximum frame rate	59,960p FPS
Colour space	YUV
Chroma subsampling	4:2:0
Bit depth	10 bits
Bits/(Pixel*Frame)	0,071
Stream size	1,30 GiB (100 %)
Encoded date	UTC 2020-12-12 15:25:15
Tagged date	UTC 2020-12-12 15:25:15
Colour range	Limited
Colour primaries	BT.2020
Transfer characteristics	PQ
Matrix coefficients	BT.2020 non-constant
Mastering display colour primaries	Display P3
Mastering display luminance	min: 0,005 0 cd/m^2, max: 4 000 cd/m^2
Maximum Content Light Level	599 cd/m^2
Maximum Frame-Average Light Level	139 cd/m^2
Codec configuration box	hvcC+dvvC
Audio	
ID	2
Format	AAC LC
Format/Info	Advanced Audio Codec Low Complexity
Codec ID	mp4a-40-2
Duration	5 min 19 s
Duration_FirstFrame	67 ms
Bit rate mode	Constant
Bit rate	128 kb/s
Channel(s)	2 channels
Channel layout	L R
Sampling rate	48,0 kHz
Frame rate	46,875 FPS (1 024 SPF)
Compression mode	Lossy
Stream size	4,87 MiB (0 %)
Language	English
Default	Yes
Alternate group	1
Encoded date	UTC 2020-12-12 15:25:15
Tagged date	UTC 2020-12-12 15:25:15

5.3 Dynamic metadata laboratory tests

5.3.1 General

Using the content created per 5.2, Pacific Crest Labs (PCL) conducted three rounds of testing to understand the impact of dynamic metadata on TV power consumption. In early 2021, PCL tested 11 TVs with UHD resolution HDR10, HDR10+ and Dolby Vision® test media, the latter two being colour graded by Company 3, and defined in Table 1. In September 2021, PCL tested 6 TVs with the same test media and a sampling of real-world content, mostly streamed from NETFLIX and Amazon. Finally, in November 2021, PCL did more in-depth research to better understand whether the HDR10+ test media should be edited to reduce their signal level and resulting luminance when played by TVs under test. Subclause 5.3 begins with an overview of general methods followed by test specifics and results of each of these research phases.

5.3.2 General research method

5.3.2.1 Identification of supported video technology

TV documentation (manual, spec sheet, etc.) was used to determine which dynamic metadata HDR technologies were supported by each tested model. The tester verified, typically with on-screen information, that the TV was receiving and playing the intended content format (e.g. visible HDR10+ logo in the upper right-hand corner of the screen).

5.3.2.2 Configuration of TV sets under test

All content was delivered by one of the following means to the TV:

- Panasonic DP-UB820 Blu-ray™ disc player (BDP) connected to TV by HDMI®
  - Most real-world internet content streamed via BDP
  - Some movies on optical disk media played from BDP
  - IEC test media via USB stick inserted in BDP, except for IEC TR 63449 HDR10+ test clips
- USB stick with HDR10+ test clips inserted in the TV because the BDP did not support HDR10+ file play back from USB stick.

For BDP content, the HDMI® cable was plugged into the first manufacturer-designated non-ARC HDMI® port on the TV. Use of non-ARC input avoids any potential influence from the ARC features. The TV was factory reset prior to testing, and the TV's software updated to its latest version.

The TV's preset picture setting was the first preset picture setting that is activated when receiving the test signal – the only change that was made to the default preset picture setting was to disable any ambient light response (Automatic Brightness Control) and motion detection dimming. The preset picture setting and any notable setting discrepancies were recorded. The TV's audio volume was set to 2 % of the maximum volume. The TV was powered at 115 V/60 Hz via a stabilized power conditioner. The TV was also turned on and played the IEC SDR test media on continuous loop for at least 10 minutes prior to testing, to ensure thermal and electric stability.

5.3.2.3 Measurement method

Power consumption was measured via a Wattman HPM100-A power meter[14], logging integrated power at 1-second intervals. Full-screen dynamic luminance was measured via a camera photometer, the specifications and position of which meet the requirements of ANSI/CTA-2037-C, and screen-average luminance was logged at 1-second intervals. For each test media/measurement period, average power consumption and luminance during the test media playback period were recorded.

Test media measurements spanned the entire length of the clip tested. Real-world content tests often involved testing sample periods of the title as detailed in 5.3.3, 5.3.4 and 5.3.5.

5.3.3 Phase I testing: assessing the overall impact of dynamic metadata

PCL tested several TV models that support dynamic metadata HDR video using the Dolby Vision® and HDR10+ test media developed by 2050 Partners as described in 5.2, including Table 1, Table 2 and Table 3.

Table 4 – Results of phase I testing

TV model		1	2	3	4	5	9	6	7	8	10	11	Average
Evaluated HDR10 content vs. the same HDR10 content		with Dolby Vision® dynamic metadata added						with HDR10+ dynamic metadata added					
HDR	Screen-avg. dynamic luminance[a] (cd/m²)	18	18	31	35	30	13	32	29	51	32	36	29,5
HDR with dynamic metadata		34	30	30	27	31	34	17	55	88	50	62	41,6
HDR	Clip avg. power consumption (W)	75	136	148	172	176	84	86	158	255	57	125	133,8
HDR with dynamic metadata		77	137	150	181	181	93	42	160	263	59	126	133,5
Luminance ratio (Dynamic/HDR10)													140,9 %
Power ratio (Dynamic/HDR10)													99,7 %

[a] Luminance averaged spatially over the TV screen and temporally over the duration of the dynamic test clip.

Table 4 shows the data collected for 11 TV models, comparing the screen-average dynamic luminance (cd/m²) and clip average power consumption (W) with and without dynamic metadata. On average, the presence of dynamic metadata increased the screen-average dynamic luminance by 40,9 percent. On average, the presence of dynamic metadata decreased the clip average power consumption by 0,3 percent.

In 8 of the 11 cases, the presence of dynamic metadata increased the screen-average dynamic luminance, often by a significant margin. In two cases (TVs 3 and 4), there was a small decrease in screen-average dynamic luminance. One case (TV 6) showed a significant decrease in screen-average dynamic luminance. This case appears to be anomalous.

PCL was unable to determine the causes of variation including the fact that TVs 3, 4 and 6 exhibited lower luminance when playing content with dynamic metadata.

[14] The Wattman HPM100-A is a product supplied by ADPower. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

The typical cases show significant luminance increases with minimal effect on power consumption. In the one case where there was a significant decrease in luminance, there was an accompanying significant decrease in power consumption. Overall, the performance gains reflected by this data do not come with any significant power consumption penalty.

Table 5 summarizes phase I results.

Table 5 – Summary of phase I testing

Overall	Luminance (cd/m^2)	Power (W)	Power/Luminance
All HDR (static metadata)	29,5	133,8	4,54
All HDR with dynamic metadata	41,6	133,5	3,21
Ratio dynamic /static metadata	1,41	1,00	

5.3.4 Phase II testing: next level of detail

Phase II testing involved additional exploratory testing to further our understanding of the impact of dynamic metadata on TV power and luminance. This research is subject to the following limitations:

- small sample of TVs and real-world video content were tested;
- available real-world content was limited to streamed movies and series; whereas future dynamic metadata content may include live news and sports and other content types not represented in this data set;
- no clear categories are defined for the content types tested;
- available HDR content spans a wide range of light level and colour grading practices, so different real-world programs can be expected to have vastly different impact on TV luminance and power.

Table 6 – Characteristics of TV models used for the test media validation

Model	Backlight	Size (inches)	HDR10	HDR10+	Dolby Vision®
1	quantum dot LED	50	✓	✓	
2	quantum dot LED	55	✓		✓
3	LED	40	✓	✓	✓
4	OLED	55	✓	✓	✓
5	OLED	55	✓		✓
6	LED	43	✓		✓

Power and screen-average luminance of 6 TV models using 3 different display technologies (Table 6) were recorded for each of the 5-minute 4K test media (HDR10, HDR10+ and Dolby Vision®), and for minutes 10:00 to 20:00 of the 4K real-world content listed in Table 7, in both static and dynamic metadata HDR formats.

Table 7 – 4K real-world content used for tests

Dolby Vision® only TVs	HDR10+ only TVs
Chef's Table episode 1 (NETFLIX)	Disaster Artist (Amazon Prime)
Godless episode 1 (NETFLIX)	Philip K Dick's Electric Dreams episode 1 (Amazon Prime)
Chasing Coral episode 1 (NETFLIX)	Moonlight (Amazon Prime)
Star Wars: The Last Jedi (Blu-ray™ disc)	Alita: Battle Angel (Blu-ray™ Disc)
Jumanji (Blu-ray™ disc)	A Beautiful Planet (Blu-ray™ Disc)

Comparing real-world content (streamed movies/series) with and without dynamic metadata yields the results in Table 8.

Table 8 – Phase II: real world content (streamed movies/series)

Overall	Luminance (cd/m^2)	Power (W)	Power/Luminance
All HDR (static metadata)	21,8	69,1	3,17
All HDR with dynamic metadata	20,1	67,1	3,34
Ratio dynamic /static metadata	0,92	0,97	

Figure 2 plots the ranges of power consumption observed per dynamic metadata HDR test media or real-world content. To make this chart, the research team calculated the clip-average power for each TV across all clips. Then the maximum, average and minimum clip-average power levels across all TVs tested was plotted. Figure 3 plots the screen-average luminance for the different media with dynamic metadata versus static metadata. Figure 4 plots the relative efficiency of TVs clip-average luminance versus power for each dynamic HDR technology tested.

It is important to note that for these tests, Dolby Vision and HDR10+'s dynamic metadata results were intended to be compared individually with HDR10's static metadata results. Due to lack of identical Dolby Vision and HDR10+ content, it was not possible to make direct comparisons of these two dynamic metadata formats.

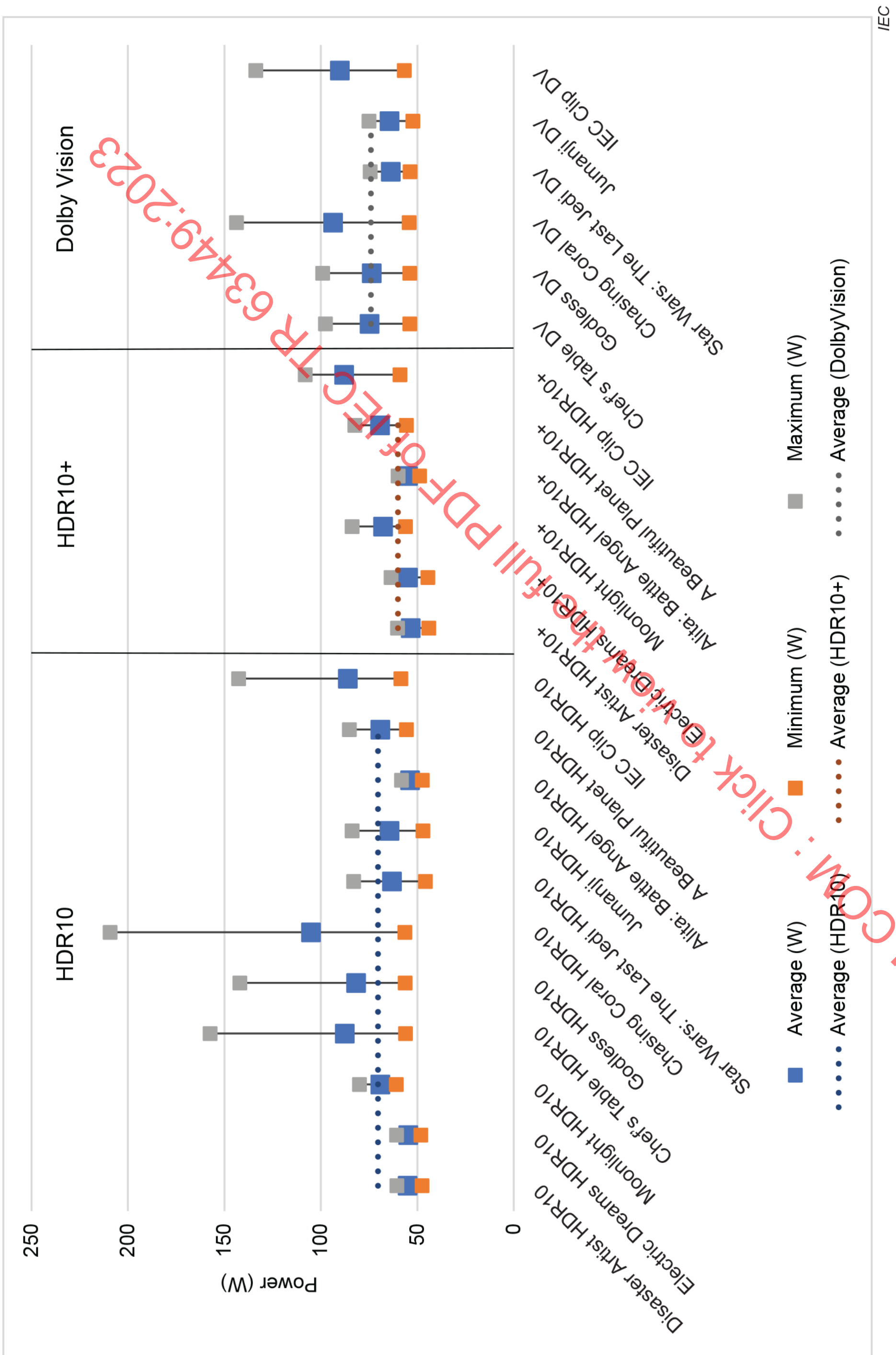

Figure 2 – Power use with dynamic metadata

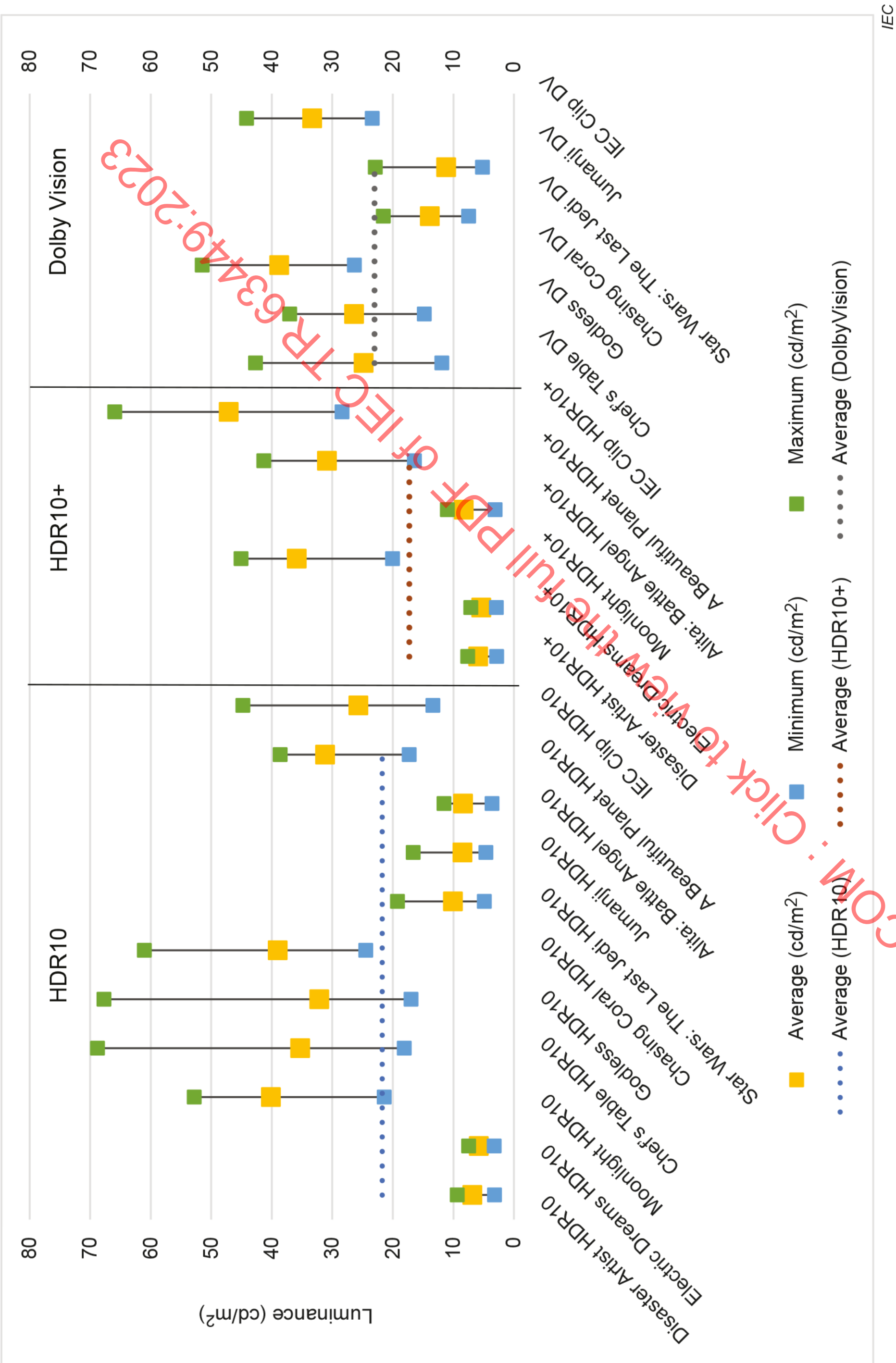

Figure 3 – Screen-average dynamic luminance with dynamic metadata vs static metadata

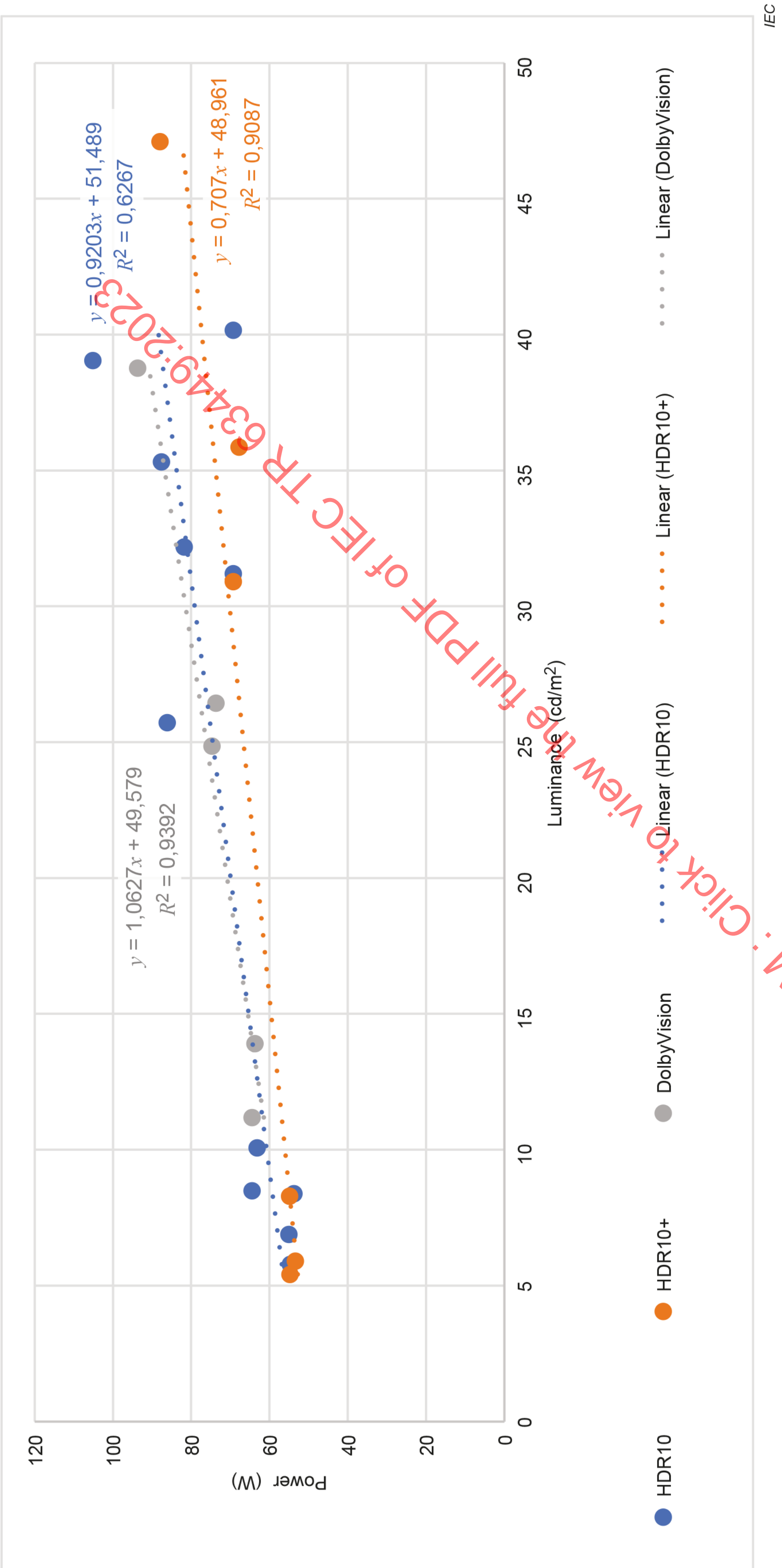

Figure 4 – Relative efficiency of TVs when playing different content formats

In Figure 4, the dotted lines represent linear trend lines, which are also described by y = mx + b equations in the chart, where y = power and x = luminance. R squared values provide an indication of correlation, which happens to be lower for HDR10 than the dynamic metadata formats. This chart format can help identify data points and trends where more light is delivered for less power. Given the limitations noted above, we draw no conclusions from this data except to note that content formats with dynamic metadata are not clearly differentiated from HDR10 in terms of the resulting ratio of power to luminance.

During testing, the research team made the following observations:

- One LED TV changed preset picture settings from "Dark" when playing HDR10 to "Normal" when playing Dolby Vision® content.
- One OLED TV changed preset picture settings from "Standard" when playing HDR10 to "Cinema Home" when playing Dolby Vision® content.
- Changing preset picture setting can have a significant impact on luminance and power. This observation is not limited to content with dynamic metadata.

Finally, in order to understand how different TVs respond to the two different types of dynamic metadata HDR evaluated, the research team compared luminance time plots. While some TVs can play both HDR10+ and Dolby Vision®, most cannot as it was the case with the two TVs we selected for this test, so we normalized relative to the clip-average luminance value for each TV and then compared time plots, where the x-axis represents seconds of video play.

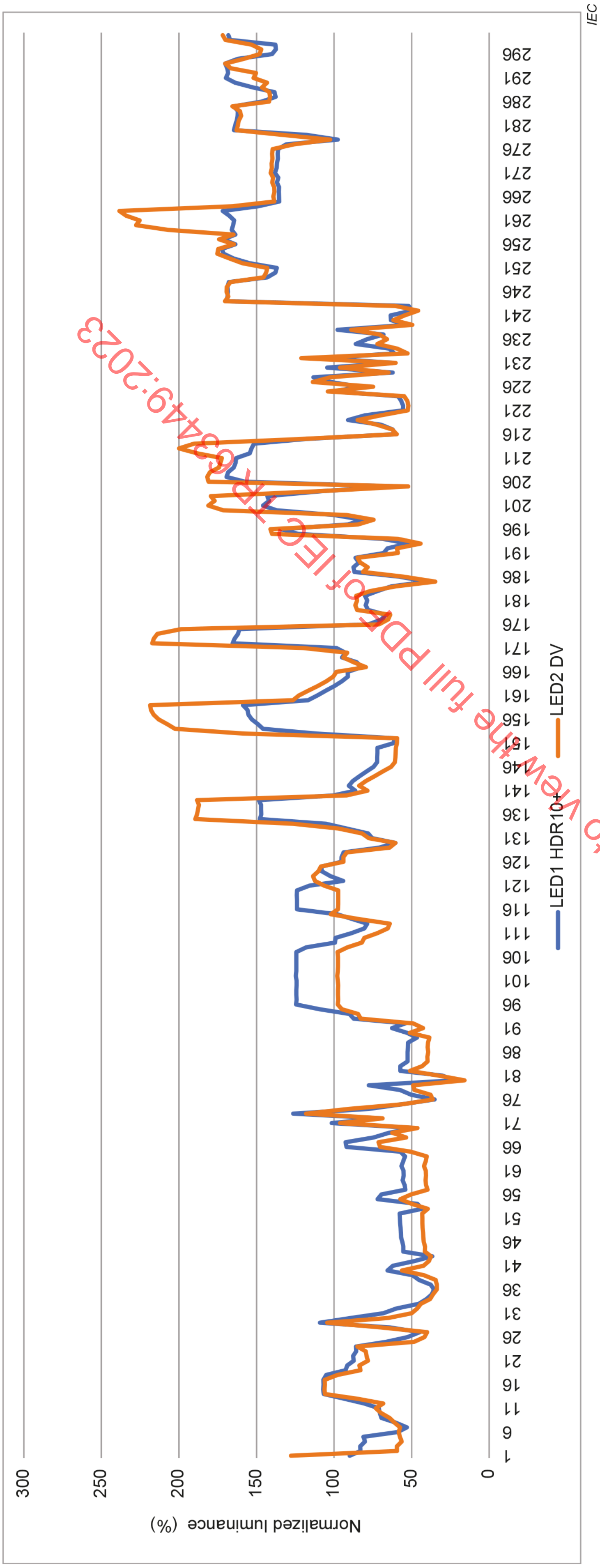

Figure 5 – Normalized comparison of LED TVs playing Table 1 UHD Dolby Vision® and HDR10+ 5 min test clips

Figure 5 compares the results from the two LED TVs. HDR10+ content results in higher average luminance for the first 121 seconds of the test media, but in rest of the test, Dolby Vision® results in higher luminance. In a test with other TVs, relative luminance remained about the same throughout clip play. And in another case, HDR10+ content resulted in higher luminance in the latter 2/3 of clip play. We conclude from this data and input from experts familiar with the process of converting video content signals to TV light output that the relationship between video clip signals and TV luminance is complicated. We do not assume that this complexity is limited to content with dynamic metadata.

5.3.5 Phase III: in-depth testing with one TV

Phase III research involved testing more than 45 hours of real-world content with the OLED TV listed in Table 5 that supports both HDR10+ and Dolby Vision® content types. This research focused on better understanding how representative the HDR10+ test clip is and whether we would want to edit the HDR10+ clip for TR 63449 or MT 62087 research use. A single test of the Dolby Vision® test clip was included for benchmark purposes. SDR content was included in an attempt to further understand the role that content pipeline plays in determining TV power and luminance. Phase III testing is subject to the same limitations as phase II testing. Table 11 provides a comparison of similar or same content in different formats.

Before this testing phase, the tested TV was factory reset, which forced a software update. This update included an adjustment to an advanced picture setting that apparently reduced luminance across picture settings.

The results of phase III testing are summarized in Table 9 and Table 10.

Table 9 – Phase III: HDR10+ and SDR using non-test clips

Non-test clips	Luminance (cd/m²)	Power (W)	Power/Luminance
HDR10+ (avg. of 12)	4,7	47,2	10,04
SDR (avg. of 11)	18,1	69,6	3,85
Ratio HDR10+/SDR	0,26	0,68	

Table 10 – Phase III: test clips only

Test clips only	Luminance (cd/m²)	Power (W)	Power/Luminance
HDR10	7	55	7,86
HDR10+	14	68	4,86
Dolby Vision®	11	63	5,73
SDR	23	78	3,39

Table 11 – Phase III test results

Detailed data table	Type	Format	Length (minutes)	Luminance (avg. cd/m^2)	Power (avg. W)
All or Nothing Man U	Unicast Sports	HDR10+	50	9	53
Le Mans – Racing is Everything	Unicast Documentary	HDR10+	120	11	59
Moonlight[a]	Unicast Movie	HDR10+	45	6	47
Moonlight SDR[a]	Unicast Movie	SDR	45	20	66
Photograph	Unicast Movie	HDR10+	110	4	46
Chi-Raq[b]	Unicast Movie	HDR10+	120	1	42
Chi-Raq – SDR[b]	Unicast Movie	SDR	120	8	55
As Good as it Gets	Unicast Movie	SDR	120	8	60
Jack Ryan S2, E8[c]	Unicast Series	HDR10+	45	2	44
Jack Ryan S2, E8 SDR[c]	Unicast Series	SDR	45	14	58
Brads Status	Unicast Series	HDR10+	100	3	47
Good Girls Revolt	Unicast Series	HDR10+	190	1	42
Red Oaks	Unicast Series	HDR10+	120	8	53
The Big Beast Called the Global Economy	Unicast Series	HDR10+	340	8	46
The Patriot Series	Unicast Series	HDR10+	60	1	44
White Dragon	Unicast Series	HDR10+	40	2	43
Ten Weeks Season 1	Unicast Series	SDR	105	23	69
Family Series	Roku "Live TV Zone"	SDR	80	18	75
Movies	Roku "Live TV Zone"	SDR	240	11	61
Sports channel – range of sports covered	Roku "Live TV Zone"	SDR	55	16	66
Sports channel – soccer	Roku "Live TV Zone"	SDR	240	26	88
CBS Sports Headquarters	Roku "Live TV Zone"	SDR	350	26	81
CBS News	Roku "Live TV Zone"	SDR	60	29	87
SDR[d]	IEC Test media	SDR	10	23	78
HDR10[d]	IEC Test media	HDR10	5	7	55
HDR10+[d]	IEC TR 63449 Test media	HDR10+	5	14	68
Dolby Vision®[d]	IEC TR 63449 Test media	Dolby Vision®	5	11	63

[a] The project team considers these media as representative for comparing HDR10+ vs SDR formats.

[b] The project team considers these media as representative for comparing HDR10+ vs SDR formats.

[c] The project team considers these media as representative for comparing HDR10+ vs SDR formats.

[d] The video signals in these formats available from the publicly accessible IEC online repository at https://www.iec.ch/tc100/supportingdocuments are also considered as useful and representative for comparison for formats.

Phase III test results, aggregated by content category, are plotted in Figure 6.