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Energy-aware images: Quality of Experience vs Energy Reduction

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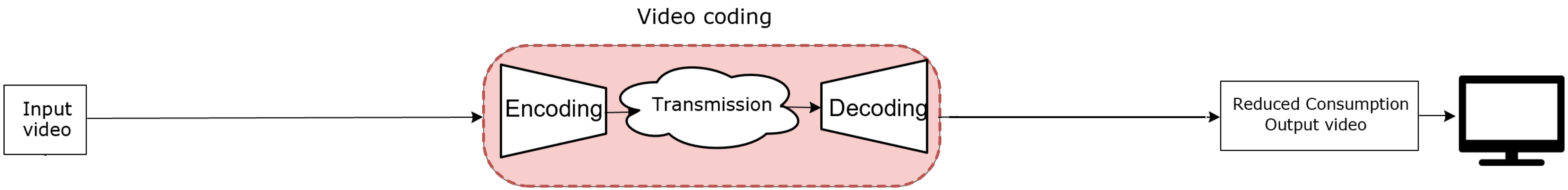
Existing Green Metadata are **dedicated to backlit displays** via a **global scaling** of the brightness.

OLED displays enable **pixel-wise** energy reduction techniques.

Our Proposal



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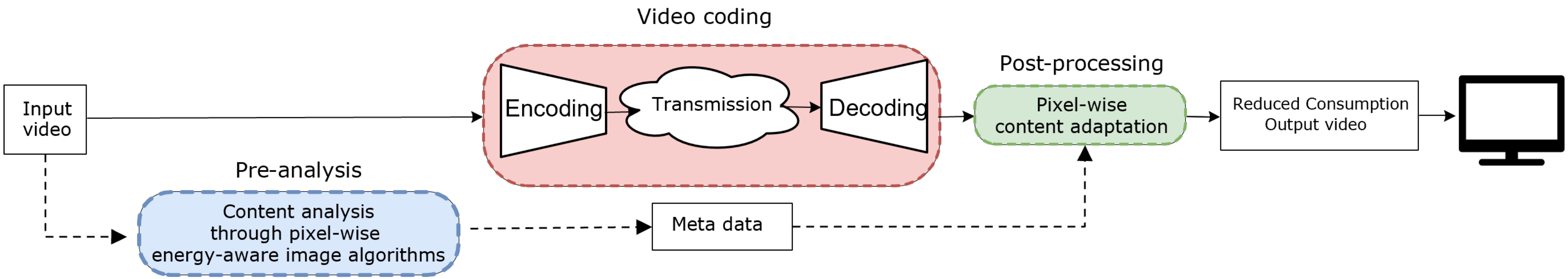


A global framework for pixel-wise energy reduction at display side

- To account for more modern, emissive, pixel-wise displays
- For two different use cases:
  - **energy is reduced as much as possible** under the constraint that **visual quality is maintained** (broadcast, artistic intent)
  - highest quality is searched under the **constraint of a fixed reduction of energy use** (streaming)

Standards

In JVET 29th meeting, contribution AHG9: Attenuation Map Information SEI for reducing energy consumption of displays it was proposed to:

- Carry the Attenuation Maps as auxiliary pictures
- Add a new SEI message to transmit metadata related to the use of the Attenuation Maps

attenuation_map_info (payloadSize) {	Descriptor
ami_cancel_flag	u(1)
if (!ami_cancel_flag) {	
ami_display_model	u(4)
ami_global_flag	u(1)
ami_map_approximation_model	u(4)
ami_map_number	u(4)
for (i=0; i<ami_map_number; i++) {	
ami_layer_id[i]	u(8)
ami_ols_number[i]	u(4)
for (j=0;j<ami_ols_number[i]; j++) {	
ami_ols_id[i][j]	u(8)
}	
ami_energy_reduction_rate[i]	u(8)
if (!ami_global_flag or (i = = 0)) {	
ami_attenuation_use_idc[i]	u(4)
ami_attenuation_comp_idc[i]	u(4)
ami_preprocessing_flag[i]	u(1)
if(ami_preprocessing_flag[i]) {	
ami_preprocessing_type_idc[i]	u(4)
}	
ami_preprocessing_scale_idc[i]	u(8)
ami_backlight_scaling_idc[i]	u(4)
}	
}	
}	
}	

ami_display_model specifies the targeted display
ami_map_number specifies the number of transmitted Attenuation Map
ami_approximation_model specifies the model used to extrapolate/interpolate a set of received Attenuation Map sample values

ami_attenuation_use_idc specifies how to use the Attenuation Map
ami_attenuation_comp_idc specifies the mapping between Attenuation Maps and color components

ami_preprocessing_flag specifies whether some pre-upsampling is to be used on the Attenuation Map sample values
ami_preprocessing_type_idc specifies the interpolation used to resample the Attenuation Map samples values
ami_preprocessing_scale_idc specifies the scaling applied to the Attenuation Map sample values

ami_backlight_scaling_idc specifies the process to compute the scaling factor of the backlight of transmissive pixel displays, derived from the Attenuation Map sample values
ami_energy_reduction_rate indicates the expected energy saving rate when the video is displayed after applying the Attenuation Map sample values

Standards

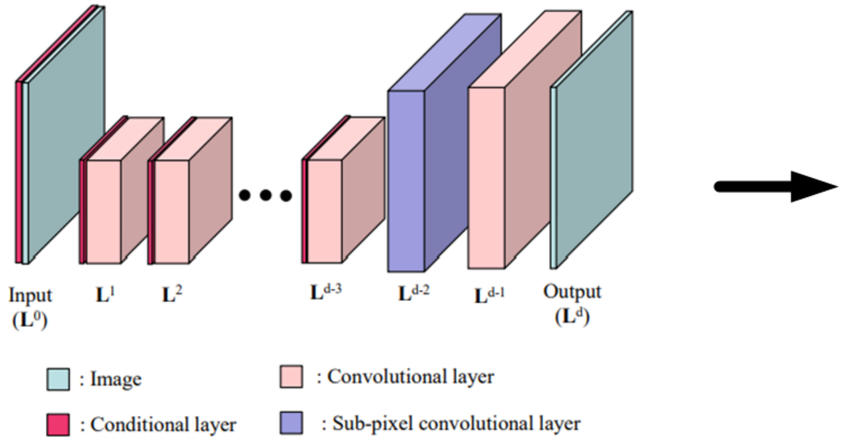
Since then, **two new contributions**:

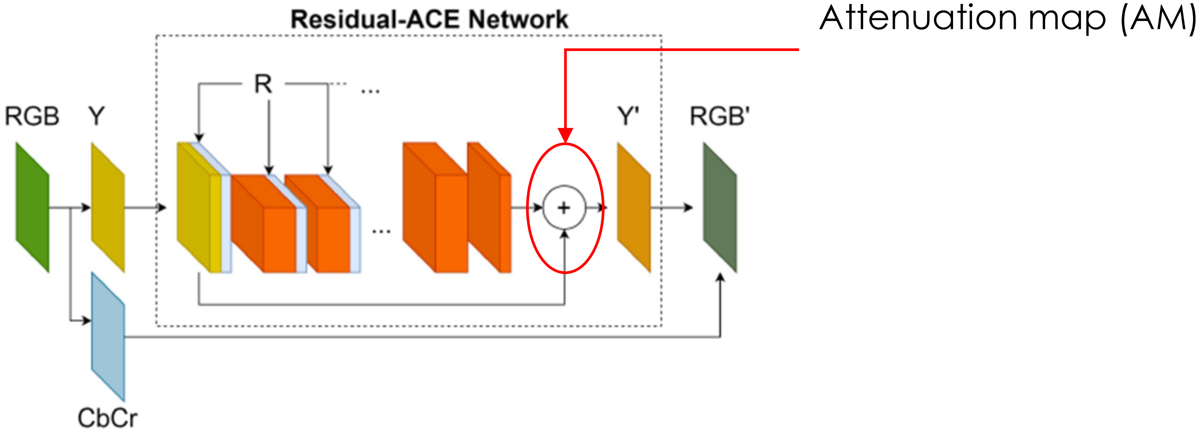
- **Informative document** at JVET 30th meeting:
  - **m62762 AHG9: Attenuation Map Information SEI for reducing energy consumption of displays**
  - TV settings and screens **do not influence** pixel-wise methods and **are not influenced** by them
  - **Comparison of two pixel-wise methods** with current implementation in **Green Metadata** and a **global linear scaling** of the luminance
  - Evaluation of the **transmission cost** of the Attenuation Maps

- **Proposal document** in last GreenMPEG meeting:
  - **m63305: Proposed new amendment of 23001-11 for signaling attenuation map metadata for display energy saving**
  - **Addition** with a very similar syntax in **existing SEI**
  - **Accepted to be defined in a new amendment of the Green MPEG specification 23001-11**

Implementation: R-ACE method [1]

ACE network architecture



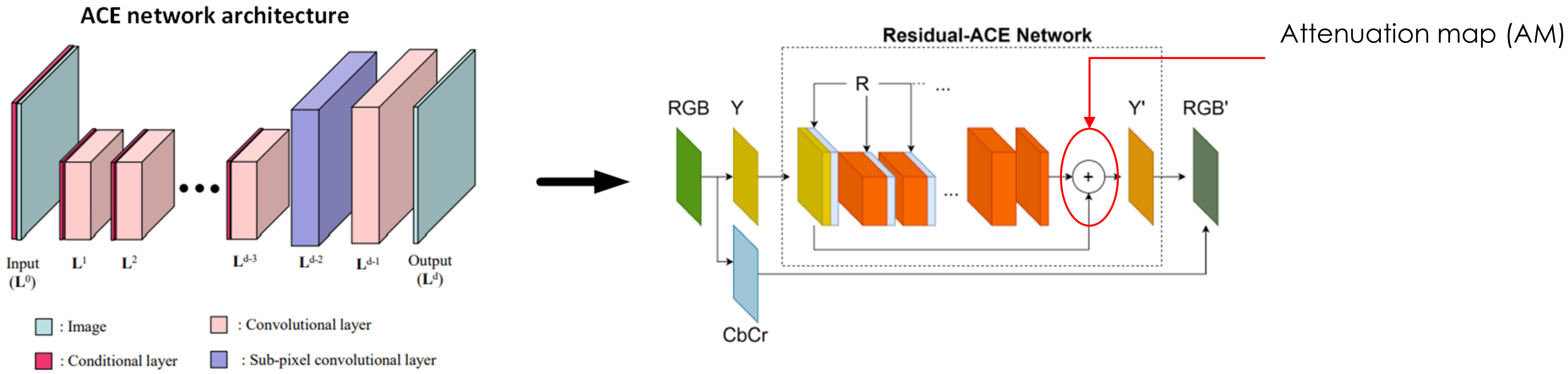


[1] Kuntoro Adi Nugroho and Shanq-Jang Ruan. 2022. R-ACE Network for OLED Image Power Saving. In 2022 IEEE 4th Global Conference on Life Sciences and Technologies (LifeTech). IEEE, 284–285.

[2] Yong-Goo Shin, Seung Park, Yoon-Jae Yeo, Min-Jae Yoo, and Sung-Jea Ko. 2019. Unsupervised deep contrast enhancement with power constraint for OLED displays. IEEE Transactions on Image Processing 29 (2019), 2834–2844.

[3] D. Martin, C. Fowlkes, D. Tal, and J. Malik. 2001. A Database of Human Segmented Natural Images and its Application to Evaluating Segmentation Algorithms and Measuring Ecological Statistics. ICCV 2001, Vol. 2. 416–423.

Implementation: R-ACE method [1]



On BSD300 dataset [3]. **No annotation needed**, based on a **display energy model** $P_Y = \sum_{i=1}^{N} Y_i^{\gamma}$ with $\gamma = 2.2$

Four different losses:

Quality: $L_{MAE} = \frac{1}{N}\sum_{i=1}^{N}\left|Y_i - \hat{Y}_i\right|$

Quality: $L_{SSIM} = 1 - SSIM(Y, \hat{Y})$

Power reduction: $L_{pow} = \|P_{\hat{Y}} - (1-R)P_Y\|^2$ with $R \in [0,1]$ the target reduction rate

Smoothness: $L_{TV} = \frac{1}{N}\sum_{i=1}^{N}((\nabla_v AM_i)^2 + (\nabla_h AM_i)^2)$

Training in two passes:

- Quality-driven: $L_{MAE} + L_{SSIM}$
- Power and smoothness-driven: $\alpha L_{MAE} + L_{SSIM} + L_{TV} + \beta L_{pow}$ with $\{\alpha, \beta\} = \{0.5, 2000\}$

[1] Kuntoro Adi Nugroho and Shanq-Jang Ruan. 2022. R-ACE Network for OLED Image Power Saving. In 2022 IEEE 4th Global Conference on Life Sciences and Technologies (LifeTech). IEEE, 284–285.

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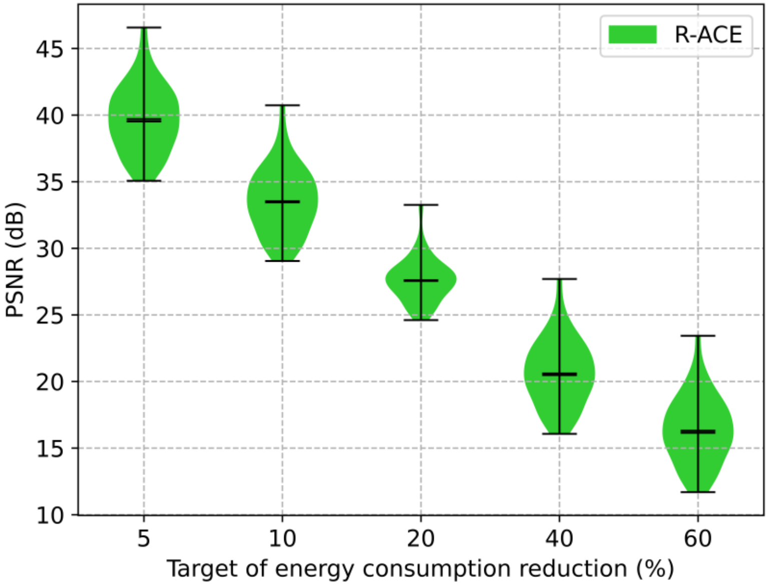
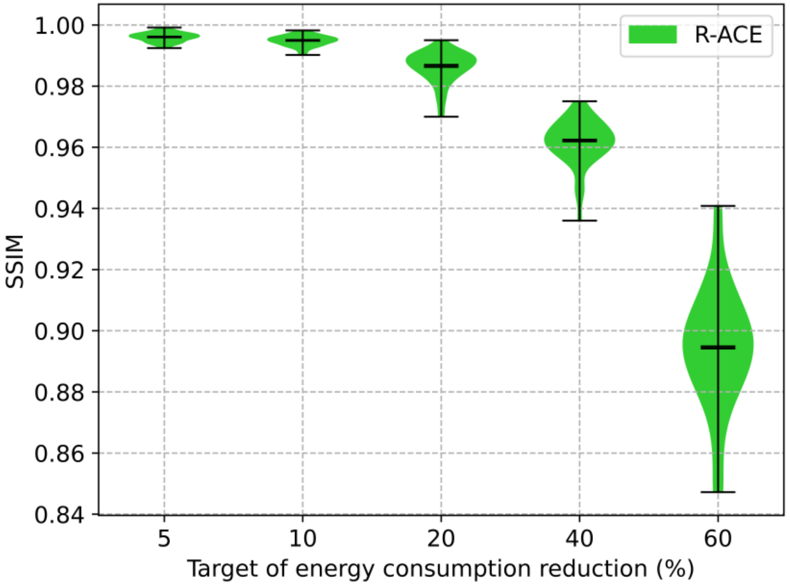
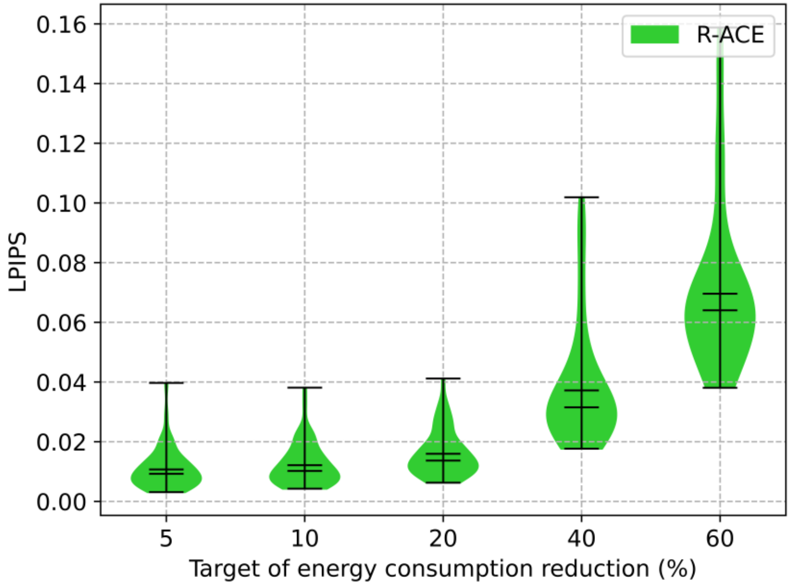
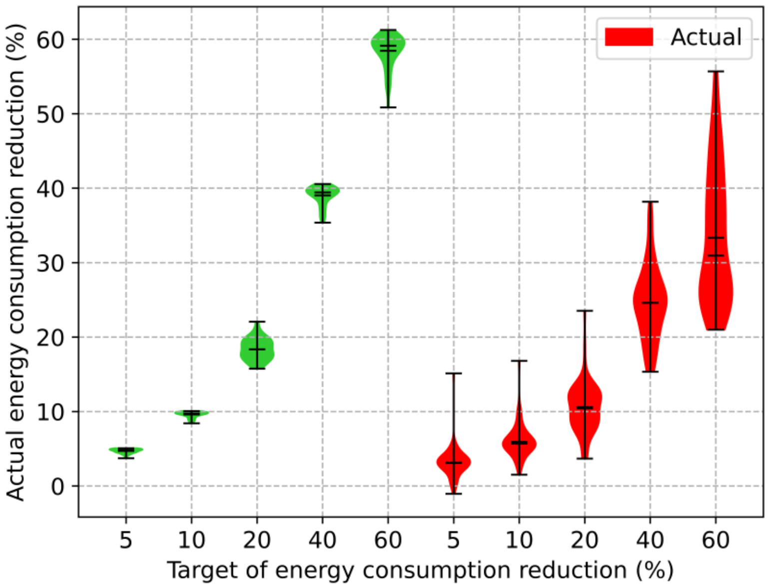
Objective results (still images)









On 60 test images from BSD300 dataset. Power measures on Sony OLED KD – 55AF9 screen.

- ✓ Objective quality is decreasing with energy reduction
- ✓ **For 5 to 10%,** objective quality (PSNR, SSIM, LPIPS) is **very high**
- ✓ For higher reductions (**up to 40%**), PSNR is low but also much more sensitive to the dimming process. **SSIM, LPIPS are still ok.**
- ✓ **Significant difference** between **estimated and measured** energy reductions
- ➢ **Power display model** needs to be **further investigated** (RGB vs RGBW displays)

Image results on BSD dataset

Original | 10% | 20% | 40% | Maps for 40%

Results on video sequences [RACE, linear scaling]

Sequences	Features	VMAF R=10%	VMAF R=20%	VMAF R=40%	PSNR R=10%	PSNR R=20%	PSNR R=40%
BBC_ThemePark_Part1	1080p50, 420, #600	[94.1; 90.7]	[94.1; 78.1]	[62.1; 51.8]	[37.03; 35.99]	[29.24; 30.23]	[24.54; 23.87]
BBC_ThemePark_Part2	1080p50, 420, #369	[99.54; 99.12]	[99.72; 94.12]	[74.19; 69.49]	[30.60; 30.58]	[25.62; 24.57]	[18.06; 18.08]
BBC_ThemePark_Part3	1080p50, 420, #489	[96.96; 93.65]	[95.64; 81.07]	[64.29; 54.27]	[37.57; 36.43]	[29.72; 30.68]	[25.56 ; 24.32]
EBU_Aloha	1080p50, 420, #500	[99.97; 99.65]	[99.97; 87.68]	[72.59; 60.89]	[34.16; 34.00]	[27.95; 28.12]	[21.75; 21.68]
EBU_dance	1080p50, 420, #502	[98.84; 97.77]	[98.13; 86.06]	[61.26; 58.61]	[32.20;32.32]	[26.87;26.36]	[19.67;19.89]
NTT_BQTerrace	1080p60, 420, #601	[96.9; 93.5]	[98.51; 81.11]	[68.4; 54.3]	[31.04; 31.07]	[25.97; 25.06]	[18.51; 18.57]
Average		[97.6; 91.78]	[97.56; 84.68]	[67.13; 58.22]	[33.76; 33.39]	[27.56; 27.50]	[21.33; 21.06]

Using full reference metric VMAF [1] between original videos and modified ones. On some JVET test sequences.

Comparison with a linear scaling of the luminance.

- ✓ **Objective quality is decreasing** with higher energy reductions.
- ✓ **RACE** achieves **better quality** than linear scaling.
- ✓ **Difference between both methods increases** with energy reduction.

[1] Reza Rassool. 2017. VMAF reproducibility: Validating a perceptual practical video quality metric. In 2017 IEEE international symposium on broadband multimedia systems and broadcasting (BMSB). IEEE, 1–2.

Conclusion

- Proposal of a global framework for pixel-wise energy reduction at display side
- First implementation showed benefit compared to other global methods
- Standardisation process on going
  - Request for Amendment 2 of ISO/IEC 23001-11 MPEG systems technologies — Part 11: Energy-efficient media consumption (green metadata)

Further work:

- Investigate more accurate display model
- Continue the standardization process

CD (Committee Draft)	2023-08-31
DIS (Draft International Standard)	2023-11-30
FDIS (Final Draft International Standard)	2024-01-31
IS (International Standard)	2024-05-31