Smart Sustainability in Lighting and Controls SSLC

LED Lighting Performance Analysis: Temporal Light Modulation, 2014-2025

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Content

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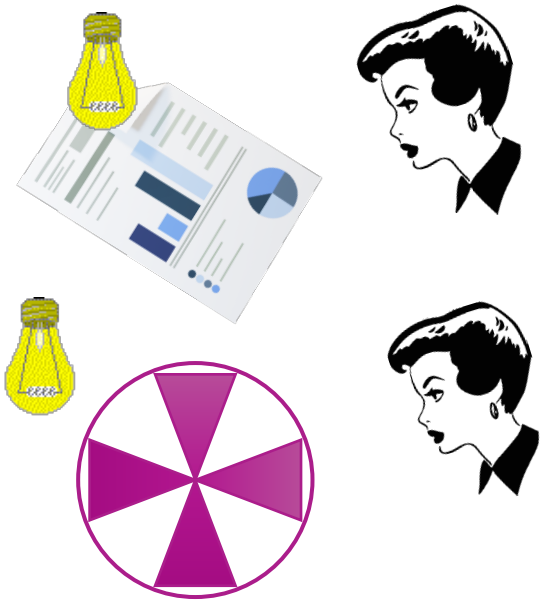
- Conclusions

Temporal Light Modulation

Is the temporal variation in the luminance or spectrum of light output from light sources. Temporal Light Artefacts (TLA) are the undesired effects on an observer's visual perception that occur in response to TLM

Flicker (< 80 Hz)
perception of visual unsteadiness induced by light that fluctuates with time, for a **static observer** in a **static environment**

Stroboscopic effect (80 Hz – 2000 Hz)
change in motion perception induced by light that fluctuates with time, for a **static observer** in a **non-static environment**



Metrics:
Short term flicker indicator P_{st}^{LM} in IEC TR 61547-1:2020

Stroboscopic effect visibility measure **SVM** (M_{VS}) in IEC TR 63158:2018

These may can lead to negative health impacts particularly for sensitive observers, including headache, migraine and photosensitive epileptic seizures. They can also reduce task performance and cause eyestrain and fatigue.

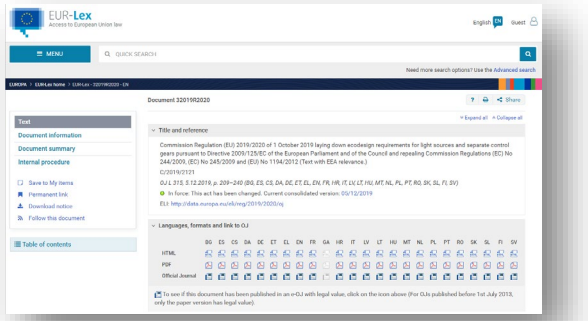
Hence, very important for consumers of lighting products to know their TLM properties.

EU regulation

- Ecodesign directive published Sept 2019 contains legislation on levels of flicker and stroboscopic visibility. Entered into force 1 September 2021
- Applies to mains connected LED/OLED light sources only at full load
- SVM does not apply to outdoor lighting products

TLA	Limit
Flicker	$P_{st}^{LM} \leq 1$
Stroboscopic effect	SVM ≤ 0.9 SVM ≤ 0.4 from 1 Sept. 2024

https://eur-lex.europa.eu/eli/reg/2019/2020/oj



Worldwide regulation

- Harmonised lighting regulations to be adopted in 22 African countries across the Southern African Development Community (SADC) and the East African Community (EAC)
- Regulation for LED lamps in Australia from March 2026, $P_{st}^{LM} \leq 1$ and SVM ≤ 0.9
- India's August 2026 regulation updates requires for LED lamps P_{st}^{LM} & SVM ≤ 1
- South Korea's High Efficiency Certification Program (HEPS) requires $P_{st}^{LM} \leq 1$ and SVM ≤ 0.9
- California Energy Commission has TLM limits for dimmable lighting products under dimmed conditions (2016), *based on percent flicker at specified frequencies (JA10)*

Data sources: EPREL

Flicker metric

Stroboscopic effect metric

EPREL - European Product Registry for Energy Labelling

- Downloaded on 19 May 2025
- 499,251 LED products on the market at the download date

- Data provided by the product supplier → "reported" data for P_{st}^{LM} and SVM values
- Permitted data entry from 0.0 to 9.9 with 1 decimal place
- All product types are analysed together in this analysis (i.e. lamps, luminaires and modules)
- Only using products reported as placed "on the market" in the years 2014 –2025

- Not all product registrations include TLM values,
  - **267,913** lighting products with reported $\boldsymbol{P_{st}^{LM}}$ **values**
  - **236,133** lighting products with reported **SVM values**

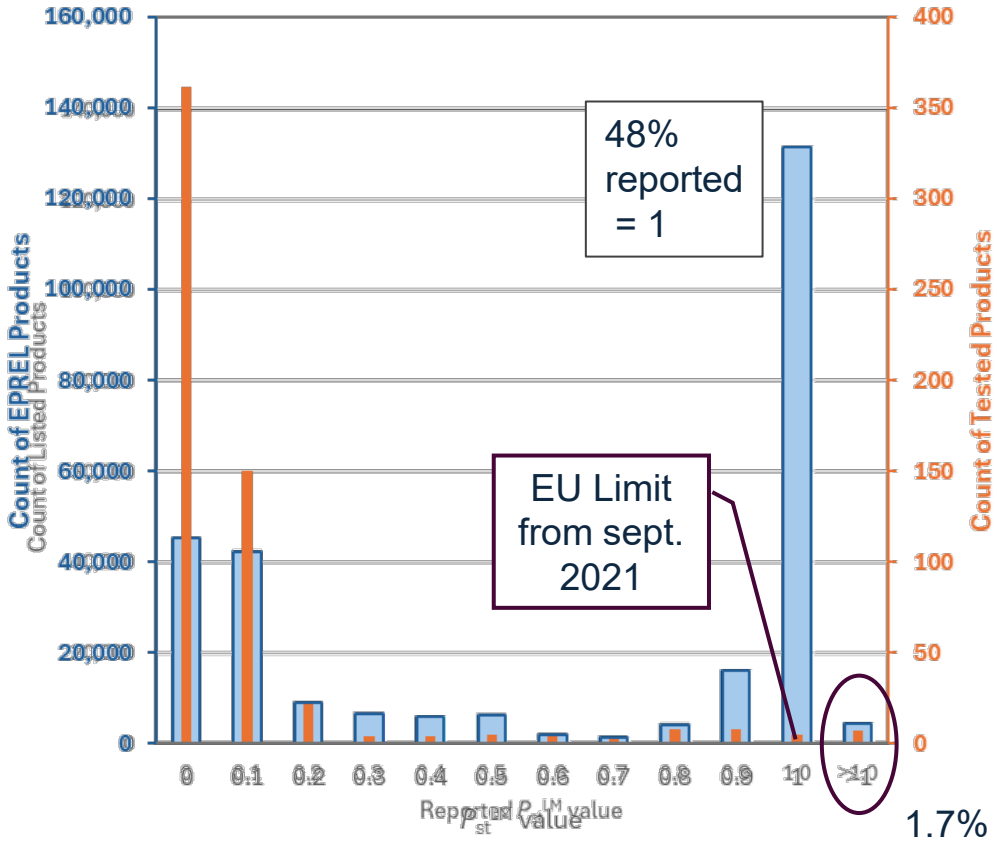
Data sources: **SSLC Platform database**

Measured data by member country laboratories and others:

- 500 LED lamps with measured values of P_{st}^{LM} and SVM, tested according to IEC technical reports
- Laboratories in Australia, Denmark, France, Sweden and the United Kingdom measured in the period between 2017 and 2024
- further 80 LED lamps tested at Aalto University in Finland in 2021 (products purchased in 2016 and 2021)

Reported and measured data

Distribution of P_{st}^{LM} values



P_{st}^{LM} = 1.0 is a value **above** the threshold of visibility, and actual threshold may be closer to 0.3-0.4 (Kucačka et al, 2025)

This is the subject of investigation in the upcoming TWINKLE project.

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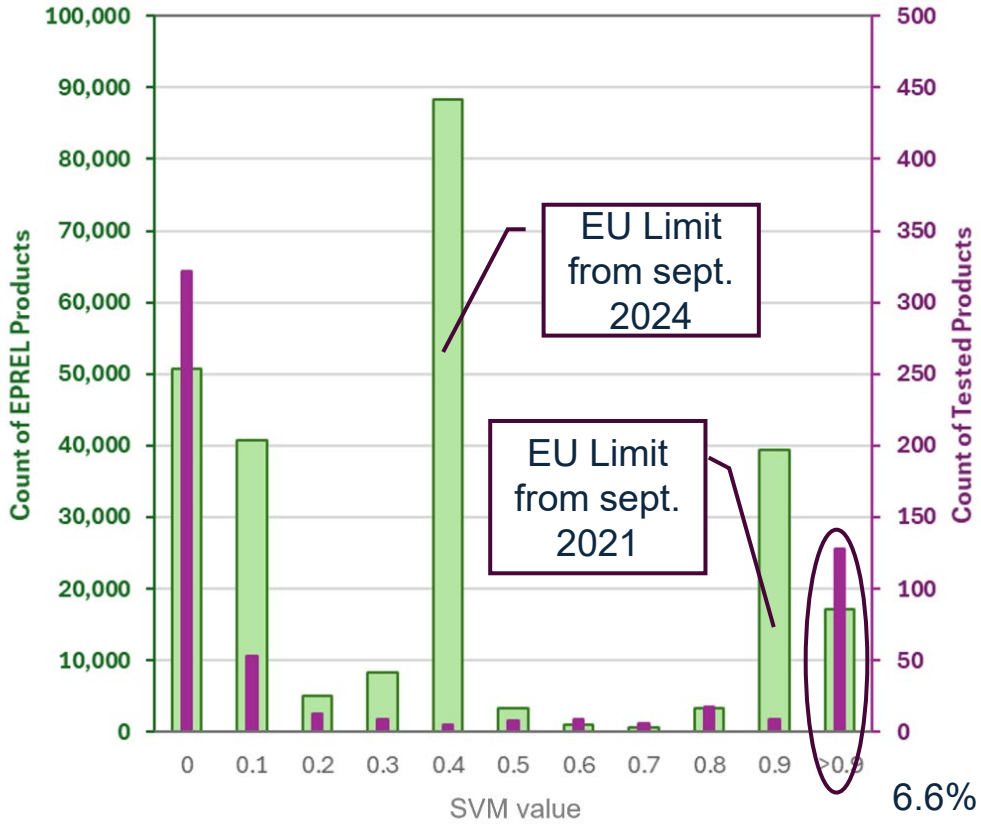
Reported and measured data

Distribution of *SVM* values

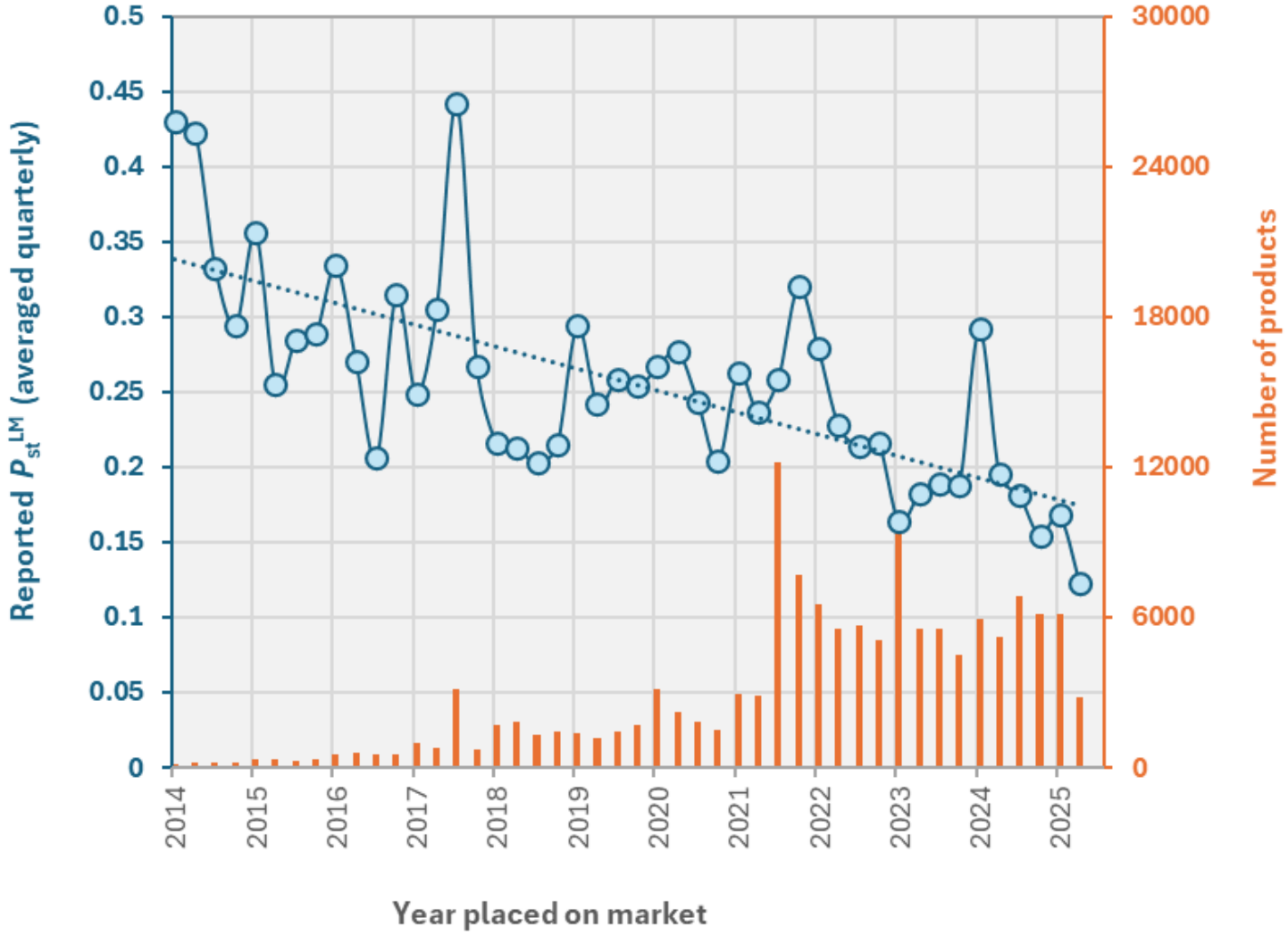


SVM values at the limit of 0.4 (or 0.9 up to September 2024) are retained for analysis.

Short term flicker index 2014-2025

Average quarterly values of P_{st}^{LM} and corresponding number of products entering the market (n=267,913)

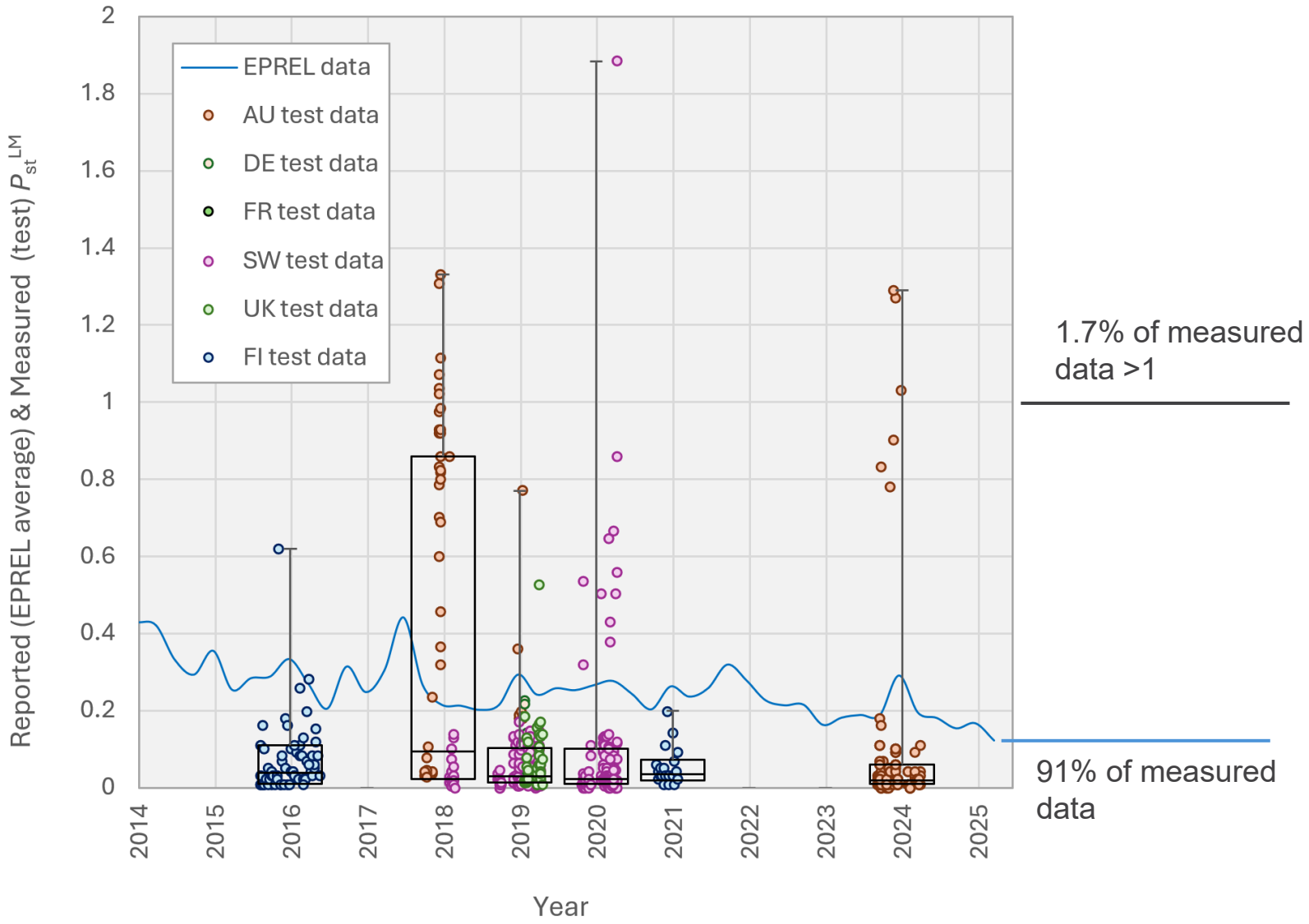
Removing values of 1 (n=137,265)



Short term flicker index 2014-2025

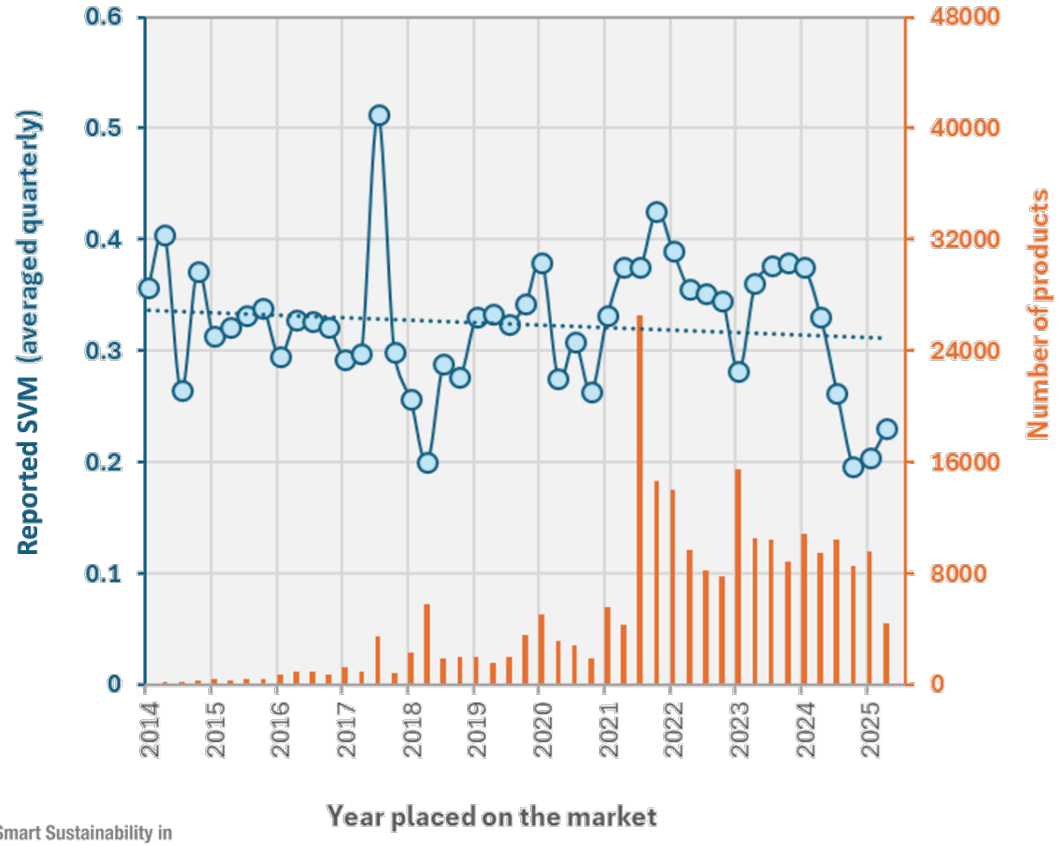
Quarterly average values of P_{st}^{LM}

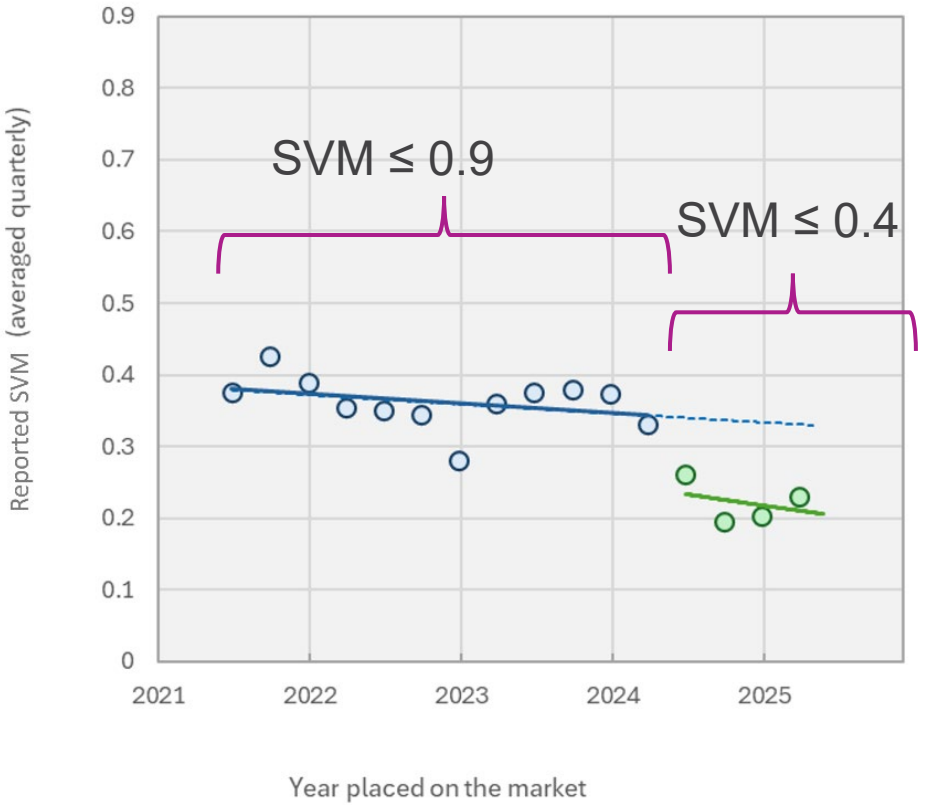
Overlayed with measured product data



SVM 2014-2025

Average quarterly values of SVM and corresponding number of products entering the market (n=236,133)

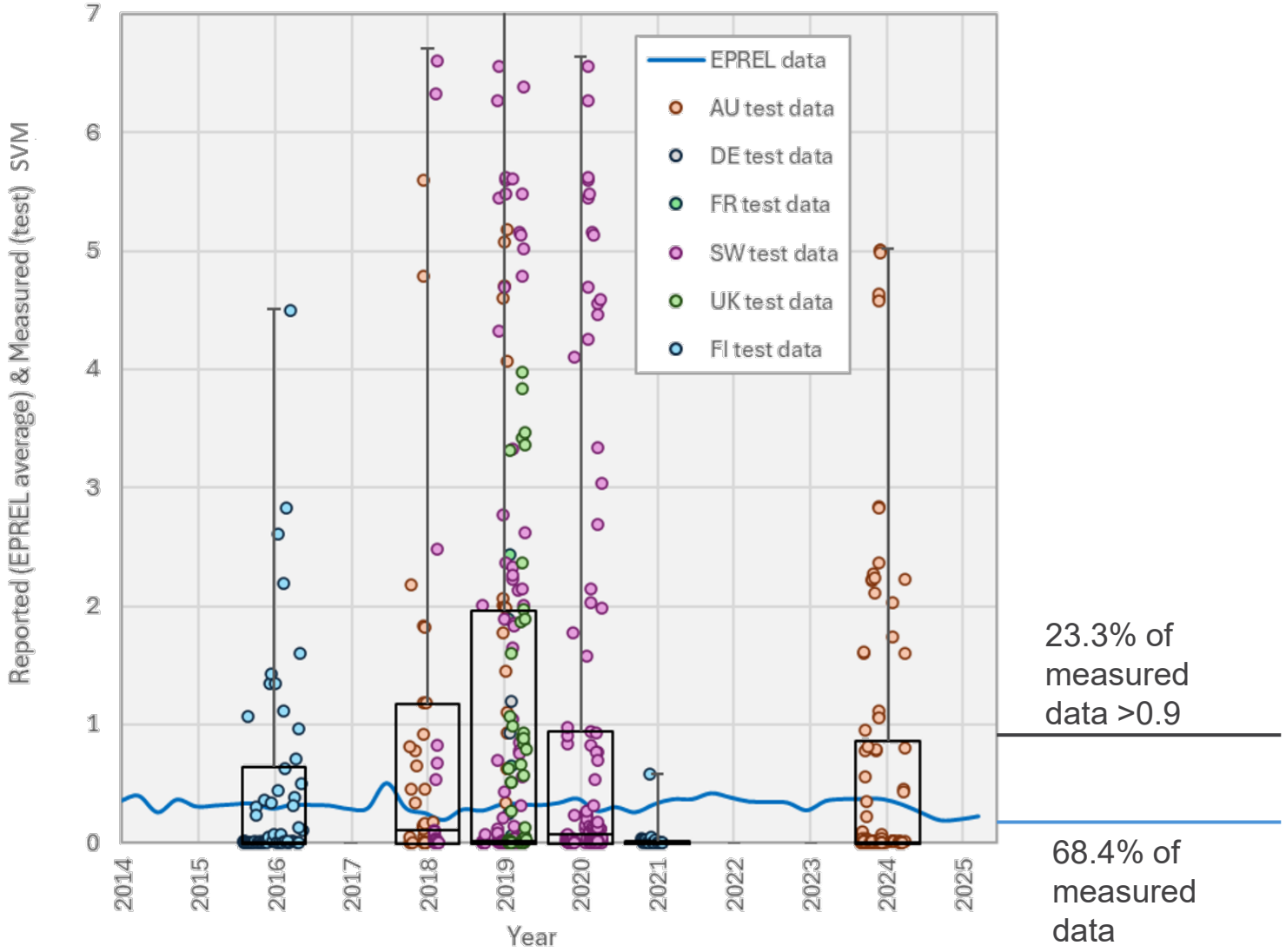




SVM 2014-2025

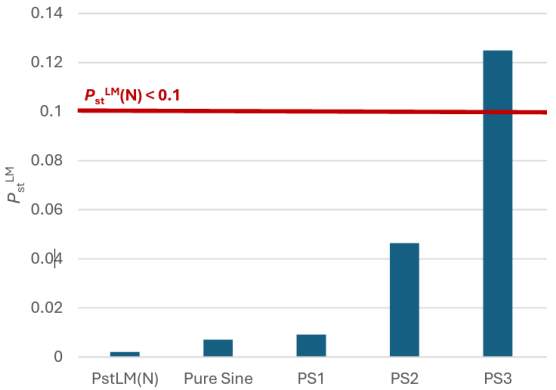
Quarterly average values of SVM

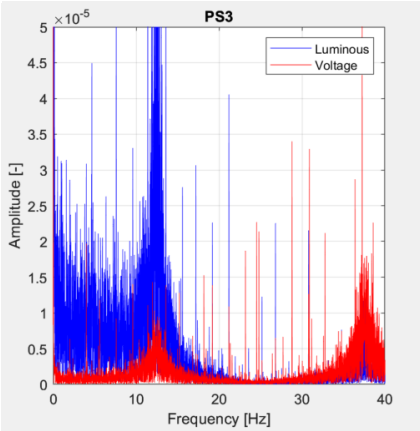
Overlayed with measured product data



*Issues with measurement of TLM metrics

- The SSLC Platform conducted an Interlaboratory Comparison (IC 2023) on TLM measurements (report due end of May 2026)
- Many participating laboratories measured consistently measured higher values (*i.e.*, had a positive bias) compared to the reference values of P_{st}^{LM} for the LED artefacts.
  - caused by the AC power supply used to operate the lamps
  - voltage waveform contained significant low frequency noise resulting in measured P_{st}^{LM} values of up to 0.2 to 0.3 for halogen lamps with an actual P_{st}^{LM} of 0.015





- not the case for the SVM measurement, where some values were found to be too low (negative bias) for some labs (due to specific filtering and power supply issues)
- Recommendations on performance specifications for power supplies to avoid a large influence on the measured P_{st}^{LM} value were published (link)

Conclusions

- From 2014 to 2025, observed decrease in average reported P_{st}^{LM} from > 0.3 to 0.2 *(after removing over-reported data, at P_{st}^{LM} = 1.0)*
- 90% of tested lamps in that period had P_{st}^{LM} below reported average, and only 1.7 % above limit
- General decrease in SVM over the whole time period *(improving performance trend potentially dampened by retained over-reported data)*
- In the reduced period from 2021 to 2025, the impact of change in regulation can be observed with a drop in the value of average reported SVM by 0.1 in September 2024
- 68% of the tested lamps had SVM below reported average, and 24.8% above the limit
- Considerations:
  - IC2023 shows many laboratories may have a lower limit of P_{st}^{LM} measurements in range of 0.2-0.3
  - Reported EPREL data may be prone to over-reporting, and it's difficult to separate product types (lamp/luminaire/module)

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Thank you for your attention

Questions are welcome