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Early findings from Power over Ethernet (PoE) lighting studies

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Why study PoE?

- One of many connected lighting systems
  - Energy savings potential
  - Key new features (e.g., energy reporting)
- Manufacturers investing in the technology
- Uncertainty and confusion
  - System energy use
  - Energy reporting accuracy
  - Industry standards and test methods in progress

Completed PoE studies

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- *PoE Lighting System Energy Reporting Study, Part 1*
  - February 2017
  - Provides background on various PoE technologies and architectures, existing standards and specifications, and recommendations for characterizing and reporting energy consumption
- *Connected Lighting Systems Efficiency Study — PoE Cable Energy Losses, Part 1*
  - November 2017
  - Exploratory testing to quantify energy losses in different types of PoE cabling and verify the usefulness of recently published industry recommended practices for PoE lighting applications

https://www.energy.gov/eere/ssl/connected-lighting-systems

PoE system energy reporting

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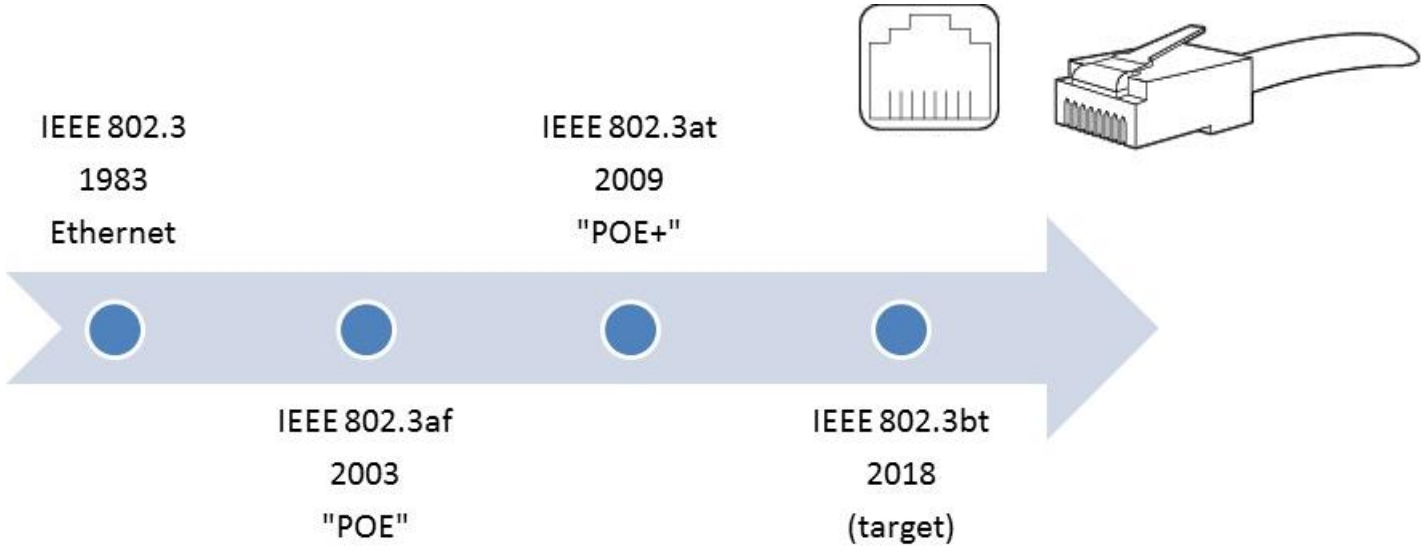
- Research questions
  - How prevalent is energy use reporting in commercially-marketed PoE devices and systems?
  - How is energy use being reported in PoE lighting systems?
  - Is energy loss in PoE cables and connections being reported?
  - What energy reporting performance are PoE lighting manufacturers claiming?
  - Which existing test setups, test methods, and performance classes appear suitable for PoE lighting?
  - What differences among PoE lighting systems (e.g., physical, logical) might need to be addressed?
  - What have prior studies found regarding the energy reporting accuracy of PoE lighting systems?

PoE system energy reporting

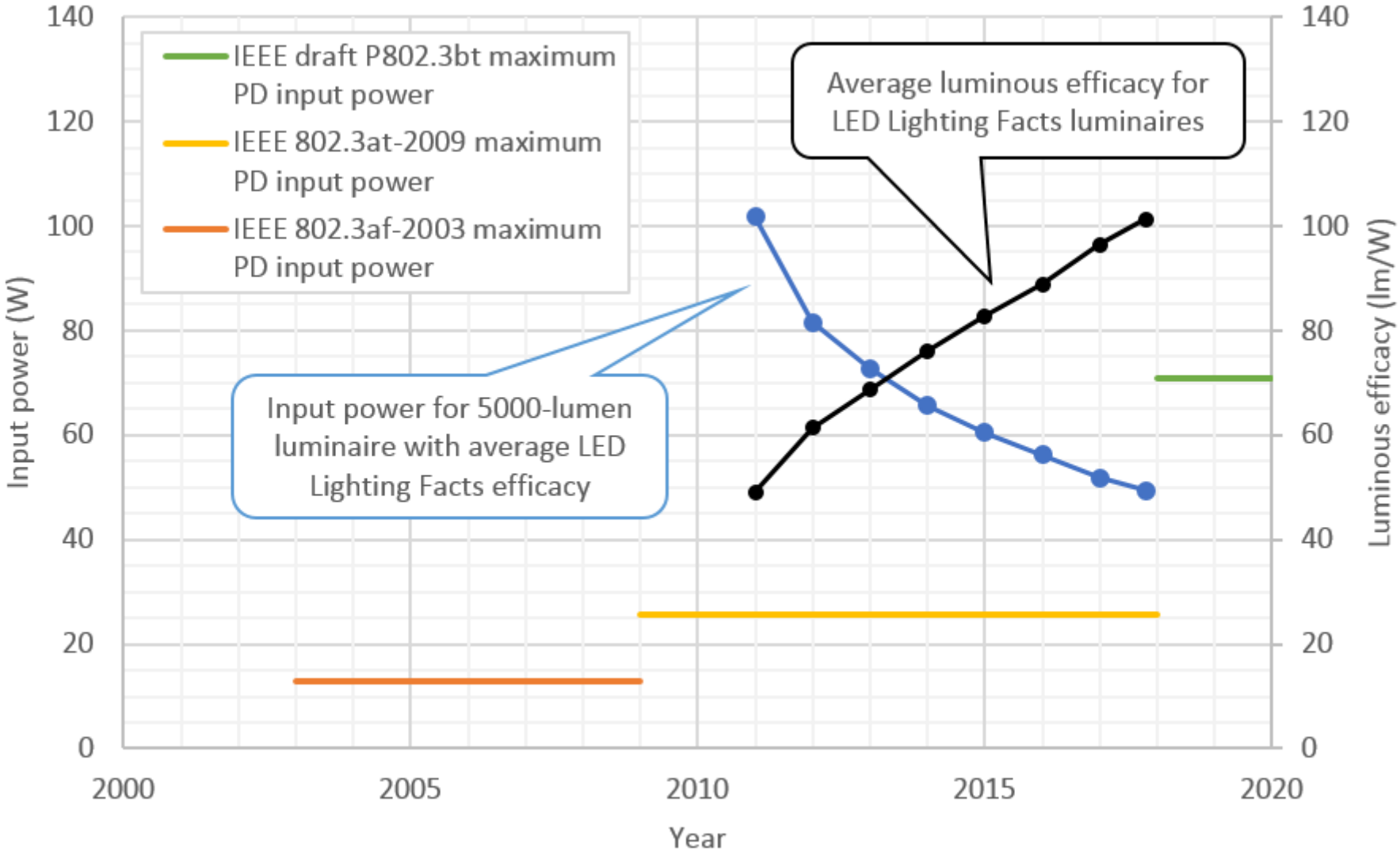
- Power over Ethernet (PoE)
  - Power and communication over an Ethernet cable, also referred to as local area network (LAN) cable or Category cable
    - 8-conductor cable with RJ45 “plug” connectors
    - Powered device (PD) sinks power from one of multiple power sourcing equipment (PSE) “jacks” in a PoE switch



PoE system energy reporting

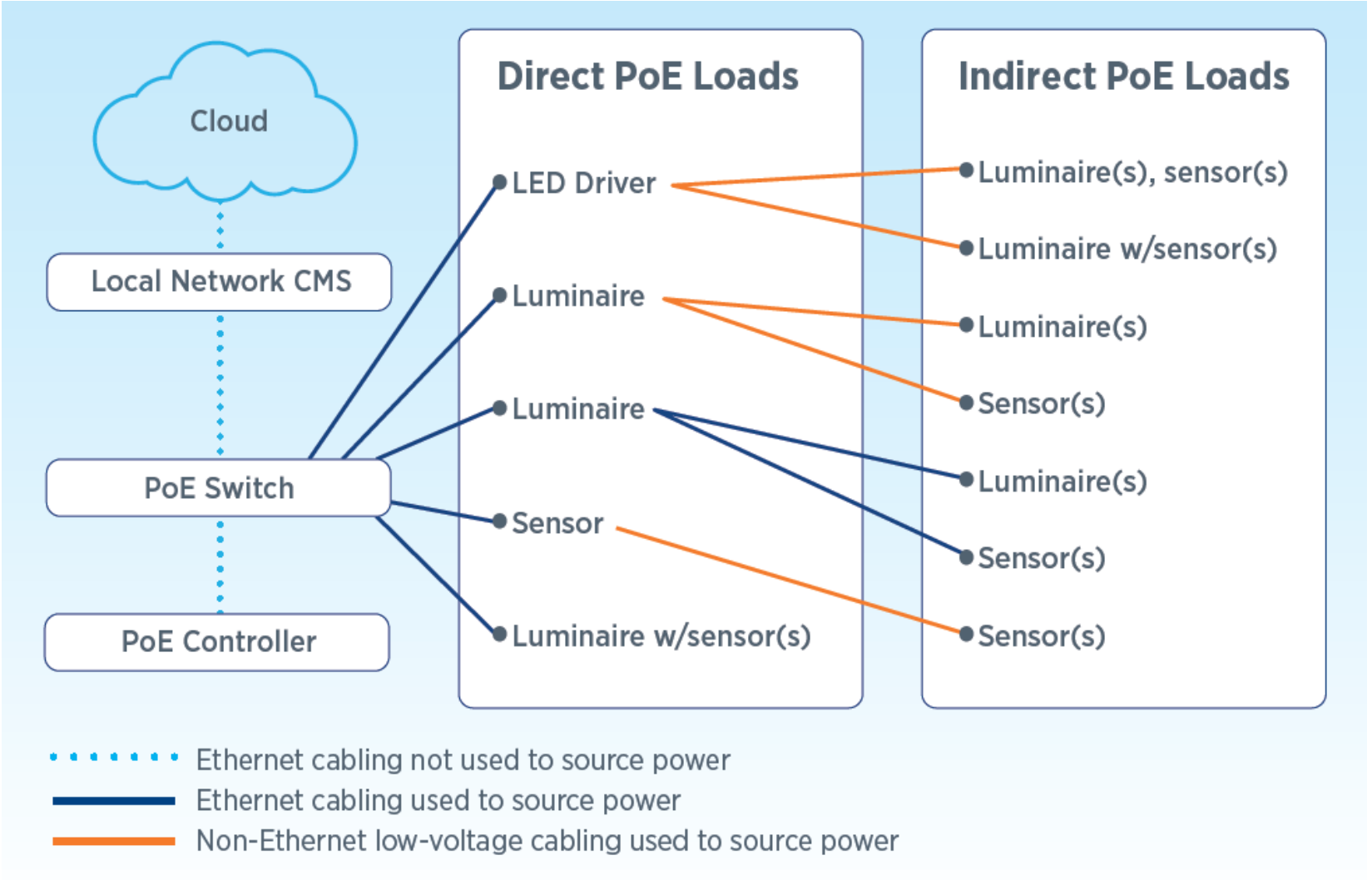
- Institute of Electrical and Electronics Engineers (IEEE)
  - 802.3af-2003 Type 1 PSE output ≤ 15.4 W
  - 802.3at-2009 Type 2 PSE output ≤ 30 W
  - Draft P802.3bt PSE Types 3 (60 W) and 4 (100 W)
    - Will use all 4 (rather than just 2) pairs of conductors to source power
- Cisco
  - Inline Power (ILP) PSE output ≤ 7 W in 2000
  - Enhanced POE PSE output ≤ 20 W in 2008
  - Universal POE (UPOE) PSE output ≤ 60 W in 2011
- HDBaseT Alliance and IEEE 1911
  - Power over HDBaseT (POH) PSE output ≤ 100 W in 2011
  - Silvertel Ultra PoE and Microsemi
- Some PSEs capable of > 100 W
  - Silvertel Ultimate PoE and Linear LTPoE++

PoE system energy reporting



PoE system energy reporting

- PoE system
  - PoE switch
  - PoE loads
    - Direct and/or indirect
    - Gateways/drivers, luminaires, sensors
  - PoE controller
    - Required for some systems
    - Physically connected to PoE switch for communication
    - Typically does not sink or source PoE



PoE system energy reporting

- Selected findings and recommendations
  - Some minimum required detail describing energy reporting capabilities should be developed by manufacturers and technology providers
  - Develop standards or specifications describing test setups, test methods, and performance classes suitable for characterizing energy reporting performance claims so that competing claims can be compared
  - DOE is considering a study to characterize the impact of cable and connector losses on example PoE system architectures, and verify that the recommended practices in ANSI C137 achieve their stated goal
  - DOE is considering studies characterizing the reporting accuracy and precision of multiple commercially-marketed PoE lighting devices and systems comprising one or more possible PoE system architectures

PoE cable energy losses

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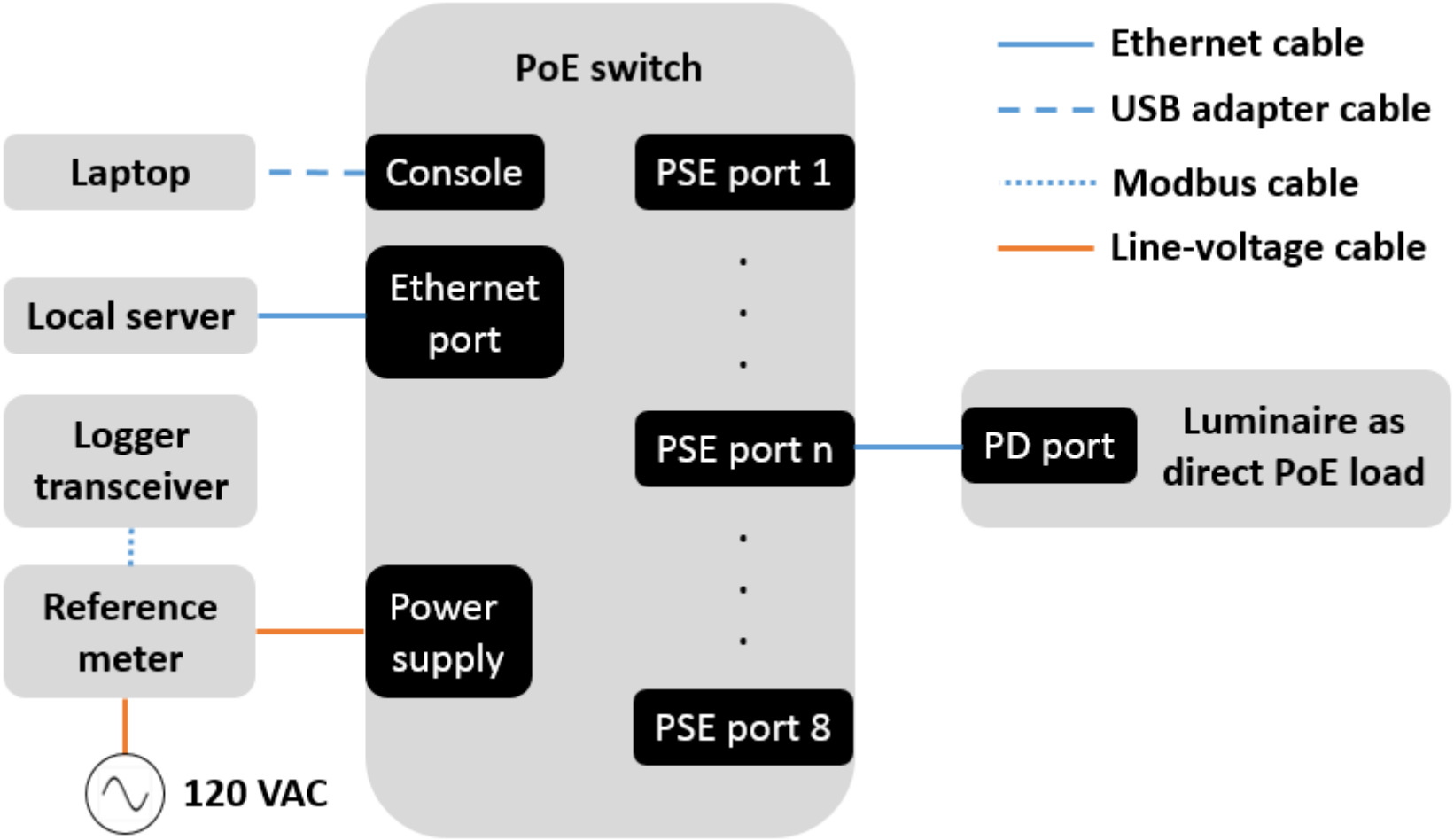
- Research questions
  - To what extent do power losses vary between models of cable differing in AWG, Category, fire rating, shielding, or manufacturer?
  - Is ANSI C137.3 guidance effective in limiting power losses to less than 5% in 50 m cable from PSE to PD?
  - What is the range of maximum and nominal DCR values claimed for relevant Ethernet cables, and how does this compare with standard values?
  - Can cable power losses be determined from values reported by PSE or PD?
  - What have prior studies found regarding PoE cable energy losses?

PoE cable energy losses

- Test setup implementation



PoE cable energy losses

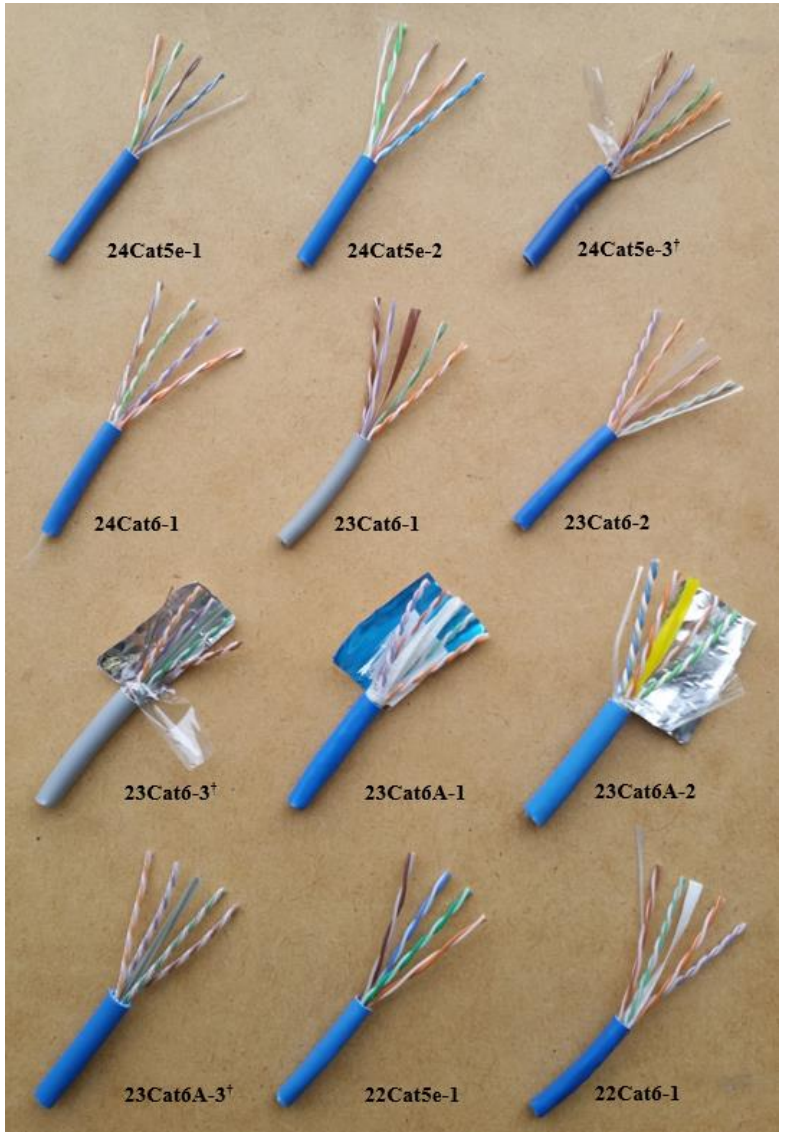
- Test setup implementation

PoE cable energy losses

- Set of cables acquired for testing
  - Labels for three products removed from testing are marked with a dagger (†) symbol

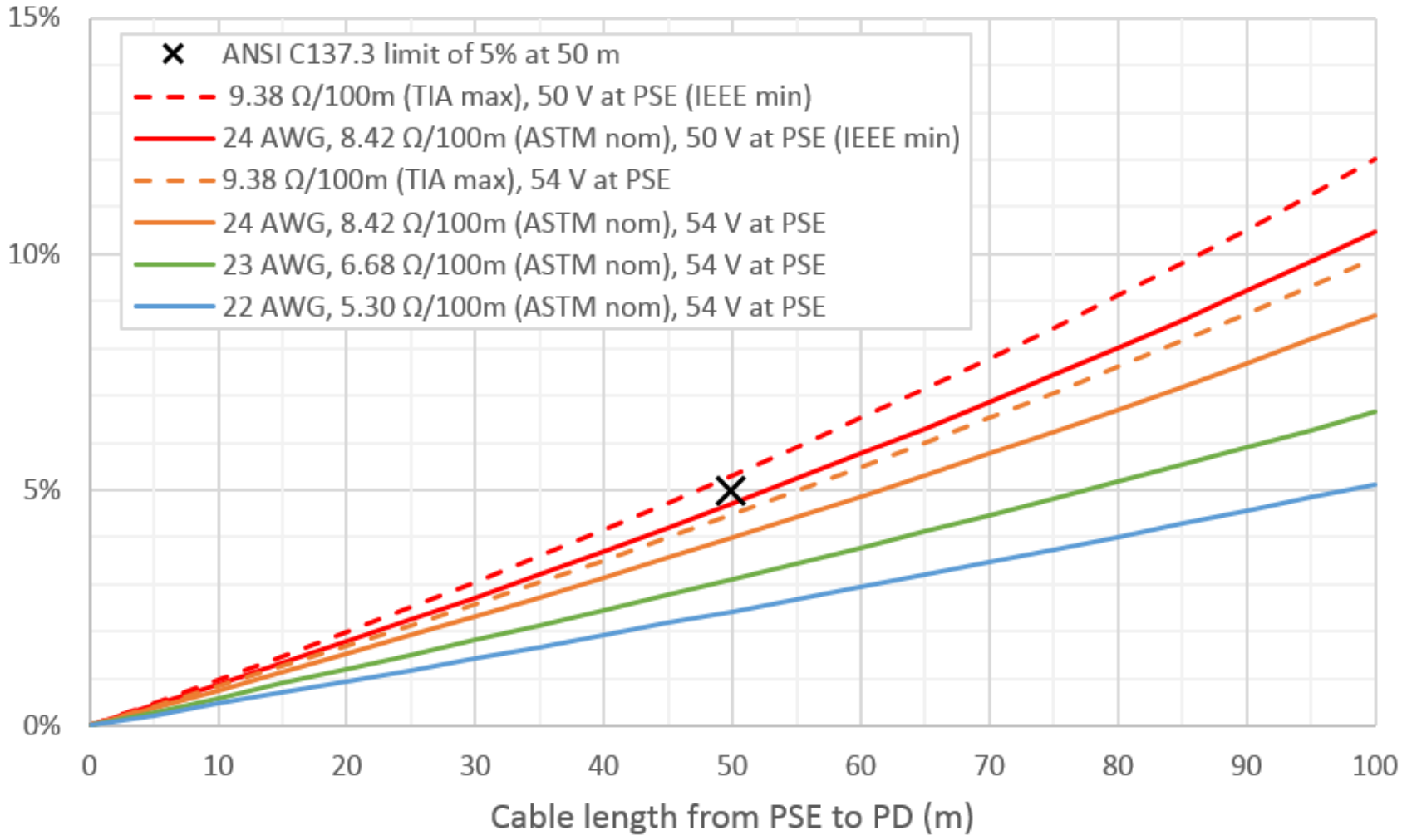
Test ID	AWG	Category	Shielding	Fire Rating	Rated Conductor DCR
24Cat5e-1	24	5e	U/UTP	CMP	≤ 9.38 Ω / 100 m
24Cat5e-2	24	5e	U/UTP	CMP	≤ 9.38 Ω / 100 m
24Cat5e-3	24	5e	F/UTP	CMP	≤ 9.38 Ω / 100 m
24Cat6-1	24	6	UTP	CMP	≤ 9.38 Ω / 100 m
23Cat6-1	23	6	U/UTP	CMP	≤ 8.00 Ω / 100 m
23Cat6-2	23	6	U/UTP	CMP	7.0 Ω / 100 m
23Cat6-3	23	6	F/UTP	CMP	≤ 9.38 Ω / 100 m
23Cat6A-1	23	6A	U/UTP	CMP	< 9.38 Ω / 100 m
23Cat6A-2	23	6A	UTP	CMR	≤ 9.38 Ω / 100 m
23Cat6A-3	23	6A	U/UTP	CMP	≤ 7.61 Ω / 100 m
22Cat5e-1	22	5e	U/UTP	CMP	Not stated*
22Cat6-1	22	6	U/UTP	CMP	6.5 Ω / 100 m

* Cutsheet referenced ANSI/TIA-568-C.2 and ANSI/ICEA S-90-661-2012.



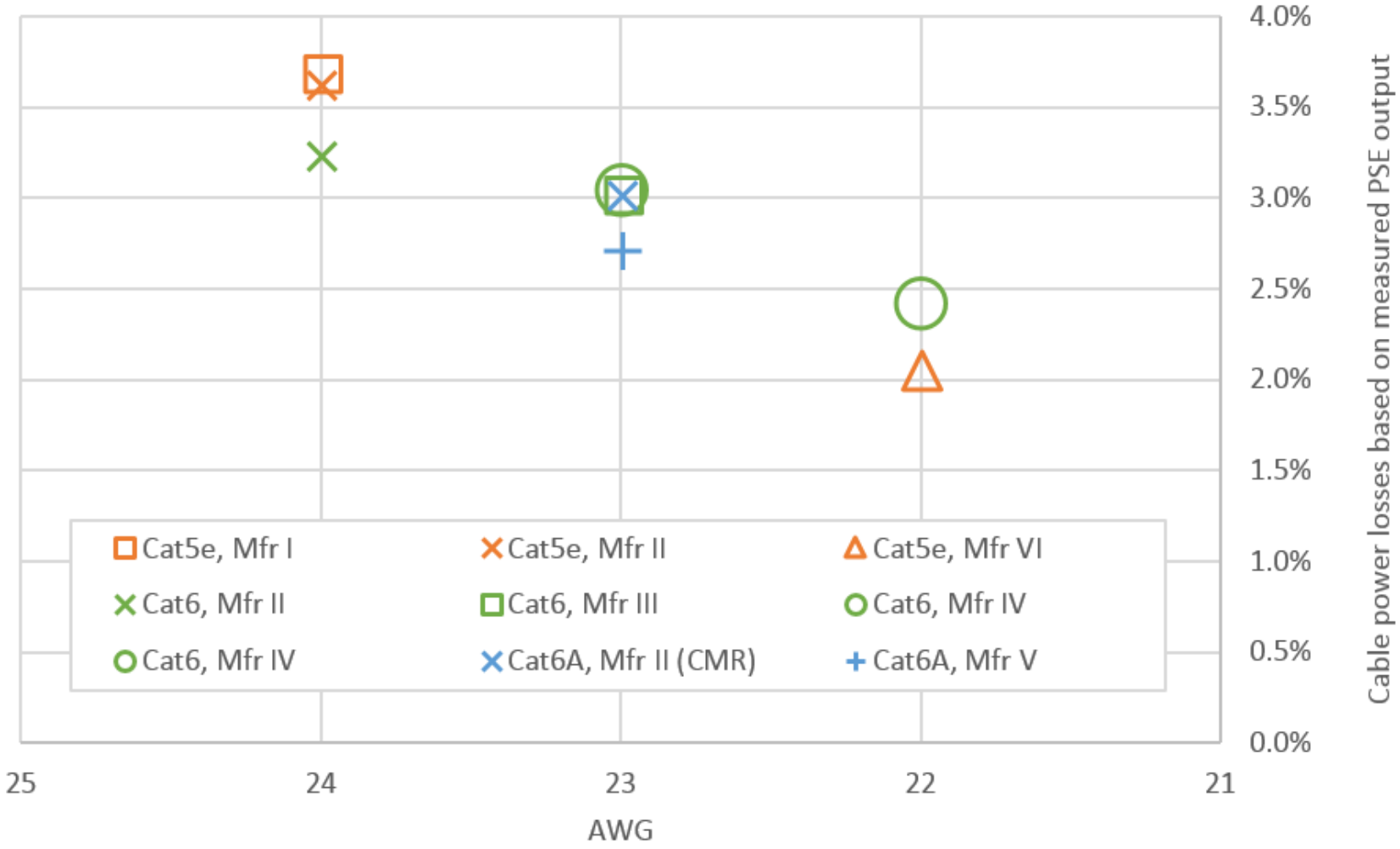
PoE cable energy losses

- Range of expected cable losses for 51 W PD at 20°C ambient



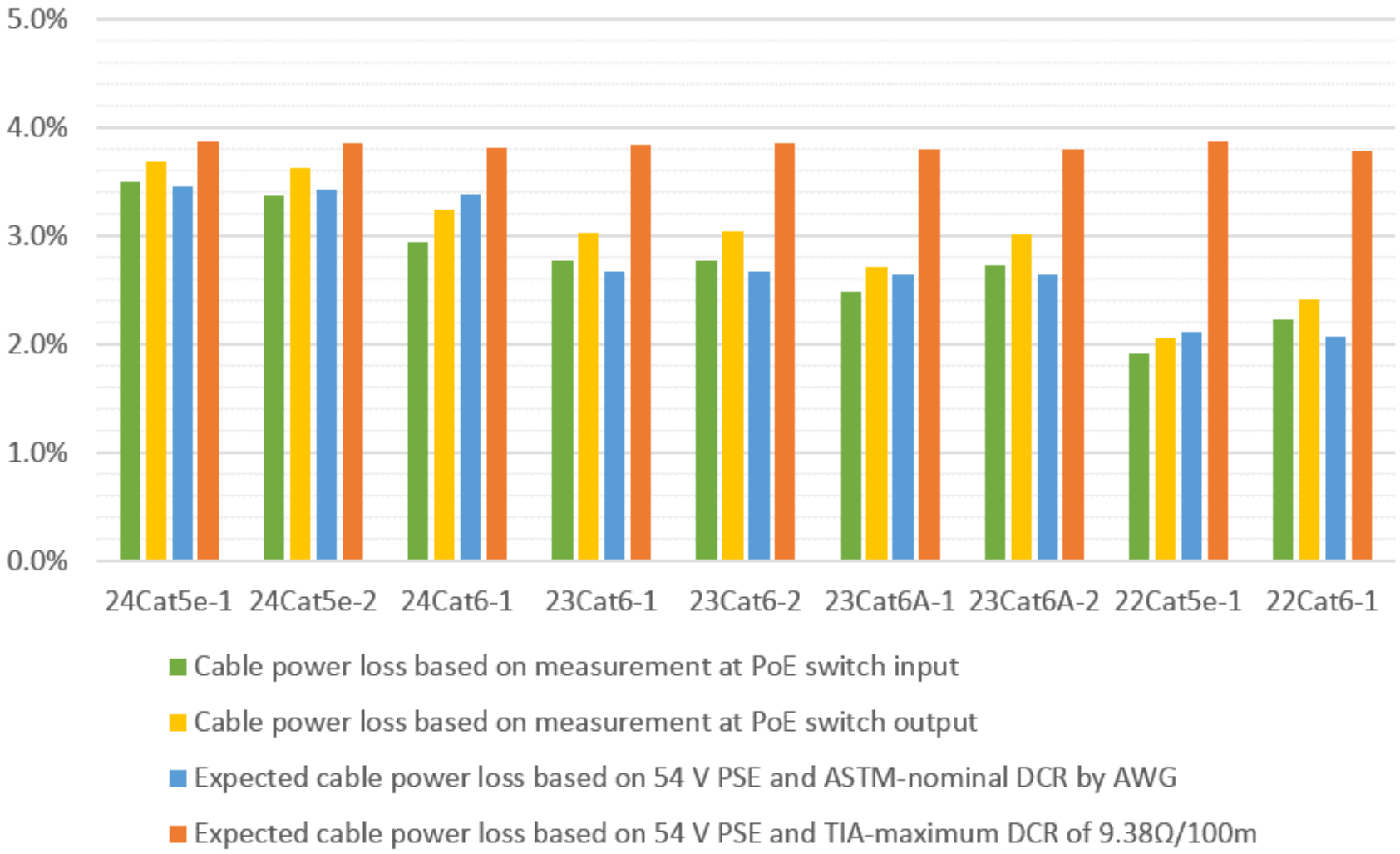
PoE cable energy losses

- Impact of cable selection on power losses with luminaire A as PD



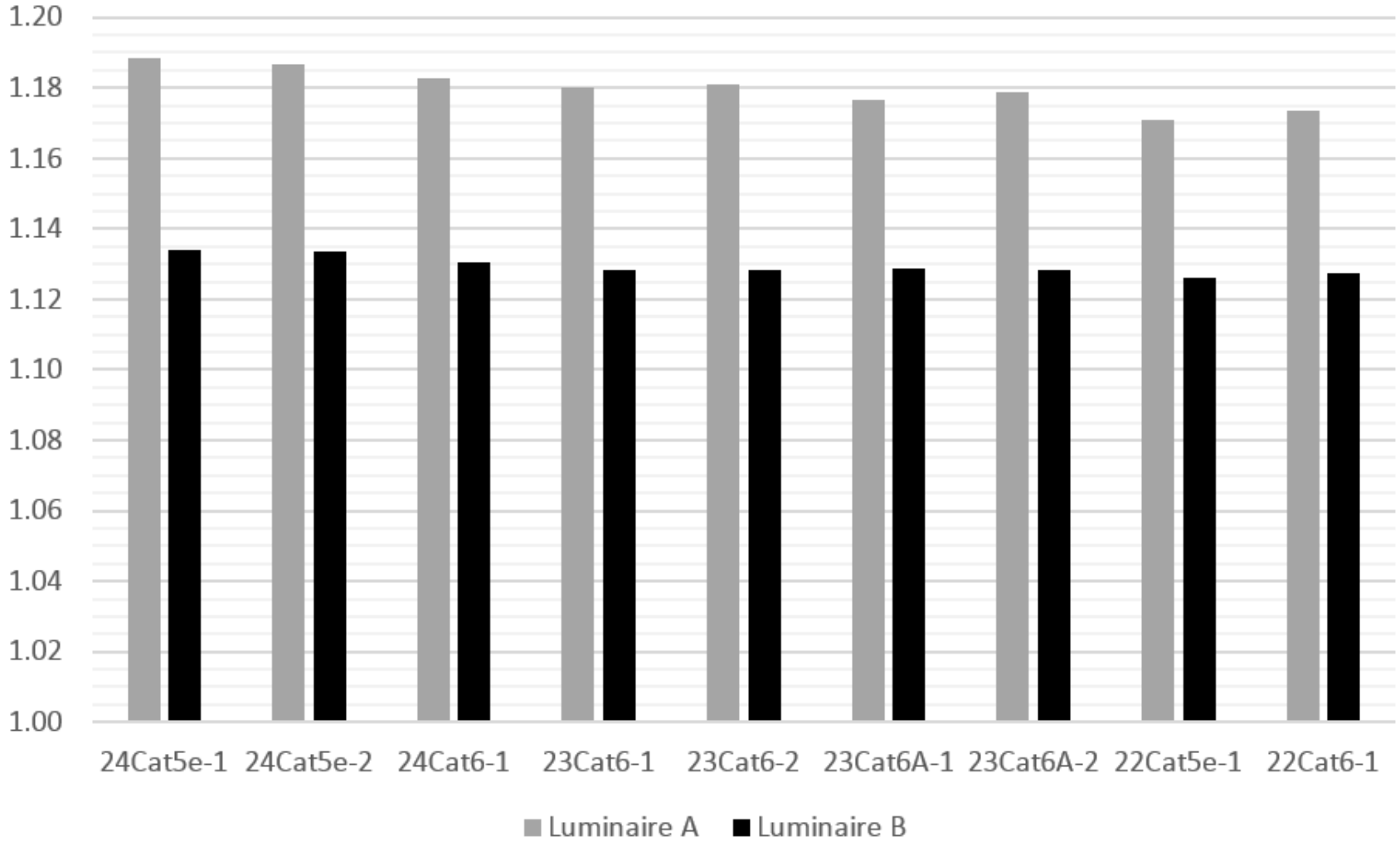
PoE cable energy losses

- Expected vs. calculated 50 m cable losses with luminaire A as PD



PoE cable energy losses

- System power (including PoE switch and 49 m cables) relative to input power for luminaires
  - A (4 x 44 W), and
  - B (7 x 51 W)



PoE cable energy losses

- Recommendations
  - PoE lighting system designers should specify that minimum American Wire Gauge (AWG) must be per ANSI C137.3 guidance, or specify minimum AWG directly if even lower losses are desired
  - PoE lighting system designers/suppliers/installers should publish statistics on PoE cable lengths used for each project (e.g., minimum, maximum, mean, median), along with information on each model used (e.g., wire gauge, Category, fire rating, shielding)
  - Manufacturers of PoE switches or PoE lighting loads that are not compliant with IEEE 802.3 should very clearly state this in datasheets and other product documentation and consider redesigning so these products can be certified compliant in the future; to prevent damage and other issues that can arise from incompatibility, buyers and specifiers should consider using products independently certified (e.g., by the Ethernet Alliance) as IEEE PoE compliant
  - Manufacturers of Ethernet cables and connectors (RJ45 plugs) should publish lists of compatible cabling products or parameters relevant to compatibility
  - Ethernet cable manufacturers should publish rated DCR values specific to each product
  - PoE switch manufacturers should state measurement accuracy for switch-reported PSE output power in product documentation, and PSE output voltage should be reported by the PoE switch

PoE cable energy losses

- Next steps
  - Ideas under consideration for a follow-up study of PoE cabling efficiency
    - Characterization of additional models of a given cable type (Category 6A)
    - Characterization of cable types not yet tested (e.g., shielded, Category 7+)
    - Characterization of the impact of cable installation variables (e.g., bundling)
    - Improvement of the test setup (e.g., PSE/PD emulators with power measurement capability)
  - Ideas under consideration for other studies that explore the impact of device selection or varying system use on system energy performance for PoE or other connected lighting systems
    - Characterization of the effect of PoE switch selection on PoE system energy efficiency
    - Characterization of the effect of different connected lighting system architectures (e.g., direct or indirect PoE loads from different manufacturers) on system energy efficiency
    - Characterization of the effect of different connected lighting system use cases (e.g., varying in network traffic) on system energy efficiency

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Q&A