# STRAIGHT FROM THE DEVICE

Accurate, self-reported energy data is a vital step along the path to successful connected lighting applications

By Jason Tuenge and Michael Poplawski

One of the potentially valuable features of connected lighting systems (CLS) is their ability to report their own energy use. Lighting energy use has typically been estimated simply as the multiple of nominal wattage and typical hours of operation, but with ever more dynamism in light levels, spectrum and adaptive lighting strategies, that simple calculation no longer serves.

CLS are among a growing number of energy data-producing devices in the built environment, but the value of generated data is often dependent on the level of accuracy needed for a specific use case. Manufacturers of data-producing devices, as well as end users with particularly stringent needs, may need to validate or characterize the reporting accuracy of the devices. This discussion provides best practices—based on a new Pacific Northwest National Laboratory (PNNL) study—for the calibration of energy-measuring devices, to help ensure that they deliver the data you need.

The accuracy of data-producing devices can be a function of design, component selection and manufacturing process. Validating or characterizing a device's reporting accuracy is typically done by comparing the data produced by a specific device or set of devices against measurements made by a reference instrument, which generally needs to be calibrated to establish and maintain its accuracy. While many commercial laboratories are accredited to perform such calibrations, their scopes of accreditation vary; as a result, a given laboratory may or may not be suitable for calibrating a particular instrument for specific reference-measurement uses. Calibration of energy-measuring equipment is particularly challenging because measurement accuracy can be affected by multiple interacting electrical parameters (e.g., frequency, voltage, current) and time.

Calibration essentially relates readings from the device being calibrated to some reference, capturing systematic error (bias) along with uncertainties. This information enables correction and caveating of subsequent readings from the calibrated device. Note that device adjustment to improve or restore trueness isn't assumed here; sometimes it isn't possible to simultaneously adjust for all calibration points, and sometimes there's simply no means of adjusting the device.

Some standards define calibration as including adjustment. ANSI C12.1-2014 defines "watthour-meter calibration" as adjustment to bring the percentage registration of the watthour meter to within specified limits. By contrast, it defines "calibration" as comparison of the indication of the instrument under test, or registration of the meter under test, with an appropriate standard. So whereas the generic definition in ANSI C12.1 doesn't include device adjustment, its definition specific to energy meters does.

The International Vocabulary of Metrology (VIM) is published by the International Bureau of Weights and Measures. It defines calibration as being distinct from, and a prerequisite for, both adjustment (a set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured) and verification (provision of objective evidence that a given item fulfills specified requirements). However, if at all possible, you probably should have the calibration lab adjust your device, lest you forget to correct data you've recorded from its indications later. It should also be noted that the VIM definition for calibration doesn't include certification that the device meets performance specifications (e.g., response time).

Finding suitable calibration laboratories is essential. International Laboratory Accreditation Co-operation (ILAC) Mutual Recognition Arrangement (MRA) signatories document each laboratory's calibration and measurement capabilities (CMCs) in its scope of accreditation. This document can be downloaded from the accrediting body's website or from the laboratory's website and serves as a menu of sorts to facilitate comparison of different laboratories. Scopes of accreditation have some implicit flexibility, and some scopes are explicitly flexible (for example, regarding range and conditions), but there is no flexibility regarding quantities or measurement principles. For example, if energy isn't specifically addressed in the scope, the laboratory isn't accredited to calibrate for it.

In our report, we identified only four U.S.-based labs that were accredited to calibrate energy-measuring equipment. The report reveals how terminology used in scopes of accreditation differs between labs, confounding the use of search tools. It also illustrates how, in addition to differences in terminology, differences in availability and organization of content in scopes of accreditation make evaluation and comparison difficult.

After you've found one or more scopes of accreditation that appear to meet your needs, it's important to develop specifications you can send to each laboratory for price quotes. The new PNNL report contains a tailorable specification template to inform and facilitate specification development. During this process, you may, for example, learn that one or more of the labs can't calibrate your particular device, perhaps due to incompatibility with the lab's calibration equipment.

The most basic specification element for calibration is a requirement that the lab be accredited by an ILAC MRA signatory, to relevant standards such as ISO/IEC 17025. This will, among other things, help to ensure apples-to-apples comparisons. Next, you want to make sure the lab's scope of accreditation includes each quantity of interest. For example, if you need calibration for active power, then a scope that only covers apparent power would probably be insufficient. You also want to be sure the lab is accredited for the type of calibration applicable to your device. For example, the lab should be accredited to source or generate AC energy if calibrating energy-measuring equipment, and should be accredited to measure AC energy if calibrating energy-sourcing equipment.

The range of quantity values for which the lab is accredited to calibrate should span the range of intended use for the device. For example, if AC power measurements using a power analyzer are expected to be in the range of 1 to 100 watts, a laboratory accredited to calibrate from 1 to 10 watts may not be suitable. However, ranges can deviate if the scope of accreditation is explicitly stated as being "flexible."

Similarly, the range of conditions for which the lab is accredited to calibrate should span the range of intended use for the device. For example, if AC power measurements using a power analyzer are expected to be made at AC source (voltage) frequencies ranging from 58 to 62 hertz, a laboratory only accredited to calibrate at 60 hertz may not be suitable.

Once you've identified multiple laboratories that appear to meet your other requirements, you can rank based on CMC uncertainty. The stated uncertainty for each CMC needs to be small enough to meet any requirements you may have established for accuracy. However, stated CMC uncertainties are best-case, so you should request predicted uncertainty for your particular device to avoid any unpleasant surprises.

The lab should understand the product (including complete make and model, as well as relevant accessories) and product configuration/settings to be used in calibration. Some labs may only be accredited to calibrate energy-measuring equipment using pulse input (which can facilitate or expedite calibration for energy) as a proxy for direct measurement. Scopes of accreditation typically do not explicitly state whether pulse input or pulse output are required, but user manuals may clarify relevant calibration equipment limitations.

Equipment range settings should be specified to reflect intended usage. If range settings are not optimized for resolution in practice, the device should be calibrated accordingly. Calibration interval should also be specified, so that it can be stated in the calibration report and thereby help in scheduling future recalibration. Appropriate value will depend on several factors, such as applicable requirements for accuracy as well as ratings for the device being calibrated (rated accuracy can be a function of time since last calibration). For guidance, see ANSI C12.1-2014, ILAC G24:2007 / OIML D 10:2007, NCSL International RP-1, etc.

Ultimately, measuring-equipment owners need to ensure that the calibration covers the instrument's intended use and that the laboratory is qualified to perform the calibration with sufficiently low uncertainty. The PNNL report offers further recommendations for other stakeholders. Calibration laboratories should clearly state scopes of accreditation and, for energy-measuring equipment, whether those instruments must emit pulse output in order to be calibrated. Scopes of accreditation should distinguish between active power and apparent power, and between calibration of devices that generate electrical quantities and those that measure them. Laboratories should harmonize terminology and the organization of content within scopes of accreditation to facilitate more-efficient review by potential customers. Website searches could also be facilitated by adding the text "USA" to scopes of accreditation for U.S. laboratories. In addition, ILAC MRA signatories should improve their website search tools and make content accessible via external search engines, to facilitate identification of suitable calibration laboratories.

For more details on this topic, including the tailorable specification template, download the full PNNL report *Specifying Calibration of Energy-Measuring Equipment* at *https://www.energy.gov/eere/ssl/downloads/specifying-calibration-energy-measuring-equipment*. ◎

**THE AUTHORS** | Jason Tuenge, Member IES, is a research engineer at PNNL, where his work supports the U.S. Department of Energy (DOE) Lighting R&D Program.

Michael Poplawski, Member IES, is a senior engineer at PNNL, where he primarily supports the DOE Lighting R&D Program.