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Trusted and Accurate Metrology for Electric Vehicle Supply Equipment (EVSE) in China

NIM has developed metrological methods and tools for an integrated EVSE supervision framework that combines SI-traceable EVSE testing, online performance evaluation, and risk-matched follow-up to support reliable charging services, sustainable infrastructure, clean urban transport, and the low-carbon transition

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The Challenge

China has built the world's largest EV charging infrastructure network. According to the National Energy Administration of China, by the end of March 2026, the total number of electric vehicle charging facilities, counted by charging connectors or charging guns, exceeded 21 million. Among them, public connectors numbered approximately 4.9 million, and private connectors exceeded 16 million. In this case, connector-level statistics describes the scale of the infrastructure, while electric vehicle supply equipment (EVSE) refers to the legal metrology-relevant equipment, metering channel, or transaction measurement function used in commercial or trade-settlement transactions.

For users, the EVSE is both a terminal for delivering an energy service and a legal metrology instrument. The measured electricity directly determines the amount the user pays. Accurate and trustworthy measurement is therefore essential not only for consumer protection and fair trade, but also for building confidence in charging services and sustaining electric mobility through clean, low-carbon urban transportation services.

The scale of deployment creates a measurement management challenge: millions of distributed and networked EVSE units used for trade settlement must continue to measure accurately after installation, software updates, maintenance, and long service periods. The specific risks are not only ordinary measurement drift, but also parameter tampering, hidden software functions or backdoors, data manipulation, and a mismatch between metered energy and billing data. Therefore, metrological control must maintain SI-traceable measurement for electric energy (kWh), voltage, current, power, time, and accumulated energy under dynamic charging conditions, while also ensuring well-documented digital metering records within an appropriate quality infrastructure (QI).

Three main challenges exist for the reliable and efficient operation of EVSE infrastructure, for which metrology plays a significant role.

Firstly, the accurate operation of EVSEs must be verified through trusted, legal metrology procedures and standards.¹ Because EVSE is digital and networked, the risks mentioned above may arise, which would potentially affect fair billing for consumers and weaken end-user confidence

¹ State Administration for Market Regulation (China), JJG 1148-2022 AC Charge Spots for Electric Vehicles(for Trial Implementation); JJG 1149-2022 Off-board Chargers for Electric Vehicles(for Trial Implementation); JJG 1192-2023 Calibrator of Off-board Chargers for Electric Vehicles; JJG 1193-2023 Calibrator of AC Charging Piles for Electric Vehicles.

Secondly, the accuracy of the energy delivered by an EVSE requires calibration with metrologically traceable, accurate measurement standards. Energy and power measurement must be traceable to SI-based national standards and must remain valid under AC, DC, high-power DC fast-charging, and supercharging conditions. High-power DC fast-charging EVSEs may reach 1500 V and hundreds of amperes. Existing and commercially available validation equipment may not cover future charging conditions, posing challenges for both testing instrumentation and the calibration standards required for metrological traceability.

Thirdly, the inspection of EVSE infrastructure requires risk- and cost-matched considerations. Practical field-based EVSE verification experience indicates that routine on-site verifications may cost about RMB 500 and take between 20 and 40 minutes per EVSE connector, making a complete one-by-one field verification difficult to scale. Given that millions of connectors already exist and are expected to expand further, this poses a high prospective cost for maintaining adequate verification of EVSE specifications through a conventional inspection scheme alone.

The objective is not to unconditionally reduce metrological control. Rather, it is to align the level and cost of metrological verification with the measured risk of potential fraud, so that targeted resources can be allocated to locations that deliver the most public value. Conversely, relying only on a fixed periodic verification cycle, for example, a three-year interval, may miss drift or abnormal behaviour between verifications; online evaluation results can help identify where earlier follow-up is needed.

The Solution

The National Institute of Metrology (NIM), together with regulators, local metrology institutes and industrial partners, provided metrological technical support for the EVSE supervision framework led by the competent government authorities. NIM's work supported traceability, method development, validation, calibration and verification capability, online evaluation, and technical evidence for risk-based decision-making, but did not constitute direct administrative supervision or enforcement.

This framework combines trusted and accurate metrology with risk- and cost-matched supervision across pattern approval or type evaluation, initial verification, in-service online evaluation, and differentiated countermeasures. It is supported by an intelligent metrological supervision platform and multi-mode online metrological monitoring, as illustrated in **Figure 1**. NIM-related technical activities supporting this framework include field inspection experience, pilot validation, multi-mode algorithm research, high-power DC fast-charging and supercharging traceability, and data-reference demonstration work. **Table 1** maps these specific activities and timeframes to the main roles within the integrated framework without implying that NIM directly implements administrative supervision.

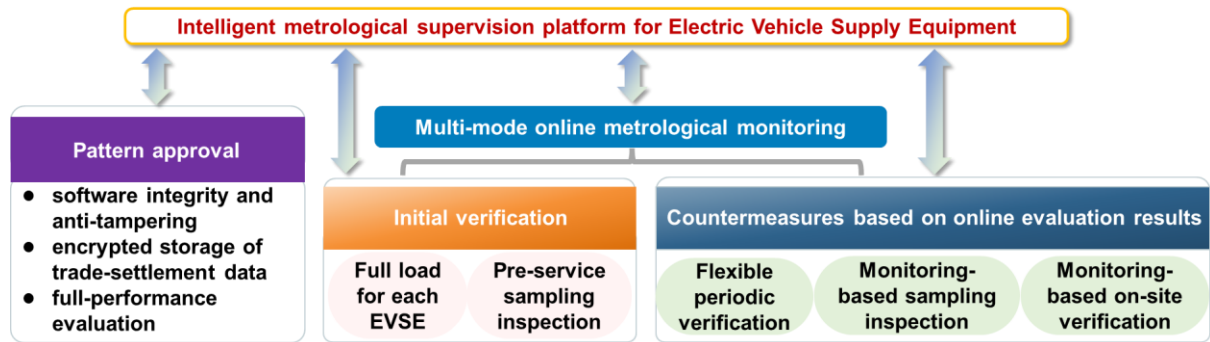


Figure 1. An overview of the integrated metrological supervision framework for EVSE.

Table 1. A timeframe and summary of NIM's metrological interventions supporting the EVSE framework.

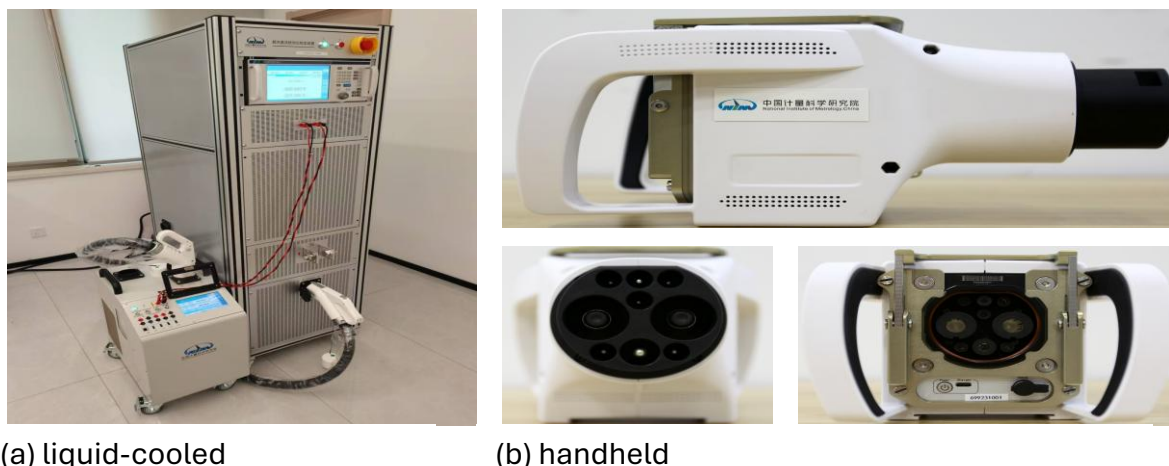
Timeframe	NIM-led metrology efforts	Main role in EVSE framework
2021	EVSE metrological inspection and technical support (Sanya location)	Field baseline and practical verification experience
2023	EVSE compulsory verification technical service (Beijing location)	Field workload and verification practice evidence
2023-2024	Online evaluation pilot and technical specification support	Energy-conservation online evaluation as part of NIM-supported follow-up confirmation route
2023-2027	NQI project on multi-mode EVSE metering error evaluation	Energy conservation, vehicle-EVSE interaction and method validation
2024	Quality-chain task on devices for supercharging metrological traceability standards	High-power traceability and dynamic energy testing
2025	Quality-chain work on supercharging metrological traceability data reference standards and demonstration	Factory-side verification, data records and mutual-recognition support

As part of the metrological intervention, NIM maintained SI-traceable electric energy standards and, since the 2024 quality-chain task of China's State Administration for Market Regulation on supercharging metrological traceability, developed suitable transfer instruments for high-power EVSE. NIM supported the EVSE traceability framework linking national electricity standards, AC and DC energy standards, verification devices, calibrators, and EVSE used for trade settlement (i.e. commercial transactions).

For supercharging, NIM developed two complementary field calibrators (see **Figure 2**): a liquid-cooled calibrator for high-current on-site testing up to 1500 V/800 A (**Figure 2a**, energy accuracy class 0.05), and a portable handheld calibrator for more flexible field checks up to 1000 V/800 A (**Figure 2b**, energy accuracy class 0.1). NIM also developed a verification device for these calibrators. The verification device supports up to 1500 V/1 kA (energy accuracy class 0.01) and includes a dynamic waveform testing component (energy accuracy class 0.02) with step, trapezoidal, and triangular signal generation. This capability is important because EV charging is an energy-integration process with time-varying voltage and current, not only a steady-state power measurement.

The initial verification of each EVSE unit combines full-load verification with pre-service sampling inspection. Remote intelligent verification cabins are controlled test bays containing load equipment, reference metering, communications, and data-security modules. They can be deployed either at the end of an EVSE production line or in a controlled pre-service testing environment. Newly manufactured EVSE can then be tested under full-load or simulated-load conditions, while data are encrypted, digitally signed and uploaded to a metrological data platform. This is not pattern (or type) approval; it is a factory-side or pre-service measurement assurance step that supports source quality control before equipment enters service.

Conventional on-site EVSE verification remains necessary, especially for high-risk or suspicious EVSE. However, intelligent online metrological monitoring can support the selection of appropriate countermeasures based on online evaluation results. NIM developed an online platform evaluation approach that uses an energy conservation method: the station-level input energy is compared with EVSE-reported output energy after accounting for losses and non-charging loads, and the results are then classified and used to guide any necessary follow-up countermeasures (see **Figure 3**). According to the results and considering the uncertainty level, the countermeasures (via verification or inspection) may include variable periodic verification, monitoring-based sampling inspection, or monitoring-based on-site verification.



NIM has collected data on national infrastructure statistics, practical field experience, NIM project tests, and method-validation results for this metrological intervention. Since 2021, the NIM-related work has included technical services and pilot studies, online energy-conservation evaluation, and NQI research on multi-mode EVSE metering error evaluation. Further, in 2024, NIM initiated a quality-chain project on EV supercharging metrological traceability, which is ongoing and includes the development of EVSE traceability data reference standards and demonstration applications.

The online evaluation route depends on both the suitability of the data and the calculation method. Before applying the energy-conservation evaluation, NIM checks the EVSE station topology, reliability of total-meter and charging-order data, time alignment, meter resolution, and, where available, the process data from the vehicle or EVSE. Any missing, low-resolution, or poorly synchronized data increases uncertainty and therefore triggers stricter sampling or field-based confirmation. Field validation of the energy-conservation method covered 8 stations and 98 EV charging connectors. Separately, simulation validation covered 50 stations, 1 000 EVSE units and 180 days of data across multiple simulation scenarios. The reported simulation results included a mean absolute error (MAE) of 0.32 %, and a root mean square error (RMSE) of 0.34 %.

In each scenario, overall accuracy (ACC) was defined as the proportion of all samples whose predicted metering status agreed with the reference status; the false-positive rate (FPR) was the proportion of truly compliant samples incorrectly flagged as out-of-tolerance; and the false-negative rate (FNR) was the proportion of truly out-of-tolerance samples incorrectly classified as compliant. The reported ACC, FPR and FNR of 99.7 %, 0.4 %, and 12.3 % respectively, are averages of the scenario-specific metrics. Because the proportions of compliant and out-of-tolerance samples varied among scenarios and the three metrics were averaged separately, these average values are not equivalent to metrics calculated from a single pooled confusion matrix. The results are summarized in **Table 2**.

A Quantifiable Impact

Within the broader NIM-related NQI research work, energy conservation, vehicle-EVSE interaction, remote metering modules, and remote verification calibrators were studied and presented in this case study as complementary technical routes. The vehicle-EVSE interaction method, for example, uses repeated charging records between vehicles and a small number of reference EVSE units that have either been verified or equipped with high-accuracy metering modules. These records can be used to characterize the vehicle as a transfer standard, which can then be used to compare EVSE units requiring verification. The integrated metrological EVSE monitoring framework can therefore accommodate different technical routes, while specific applications may select the route that best matches data availability, infrastructure conditions, and metrological risk.

Table 2. Evidence-based and data-quality indicators for this metrology intervention

Evidence Type	Supporting Data and/or Example	Use in this case study
National scale	21.481 million charging connectors by March 2026; 4.863 million public connectors ²	Defines the scale of the measurement challenge
Field baseline	Traditional on-site verification: approximately RMB 500 and 20-40 minutes per EVSE ³	Explains why risk-matched methods are needed
Supercharging metrological traceability	1500 V / 800 A field calibrator and 1500 V / 1 kA verification device ⁴	Shows high-power measurement capability
Field validation	Energy conservation method tested with 8 stations and 98 connectors ⁵	Provides practical validation evidence for the energy-conservation online evaluation route
Simulation validation	50 stations, 1000 EVSE units and 180 days of data; MAE 0.32 %, RMSE 0.34 %, accuracy 99.7 %, false alarm 0.4 %, missed detection 12.3 % ⁶	Evaluates algorithms as metrological methods

The SI-traceable standards and calibration devices, together with the verification and fieldable testing equipment, ensure accurate EVSE measurements in commercial transactions. One of the key results of this work is the integrated technical framework that supports trusted, accurate EVSE measurement and risk- and cost-matched supervision. The online EVSE infrastructure monitoring tool facilitates real-time evaluation of EVSE performance and accuracy estimation, enabling a holistic, data-driven decision process for how best to verify and inspect EVSE within municipalities across China.⁷

The broader impact of this EVSE framework is the expectation that these measurement devices are being adequately tested and evaluated for correctness; the resulting trust in this metrological process reduces the risk of fraud or manipulation and strengthens consumer confidence. Further, the SI-traceable calibration and verification processes not only underpin industrial quality but also promote fairness in routine EVSE trade settlements. The online evaluation process also identifies where abnormal metering may require differentiated countermeasures and facilitates the risk-matched use of verification resources, making supervision more scalable for large EVSE networks.

² National Energy Administration of China, EV charging infrastructure data, March 2026; source cited in NIM case-file materials. Public agency website: <https://www.nea.gov.cn/>

³ Xiao Zishang, NIM master thesis, 2025 (non-public NIM thesis/material used for method-validation data; available from NIM on request).

⁴ National Institute of Metrology (NIM), China, Supercharging metrological traceability project report, 2024 (internal project report; available from NIM on request).

⁵ Xiao Zishang, NIM master thesis, 2025 (non-public NIM thesis/material used for method-validation data; available from NIM on request).

⁶ Xiao Zishang, NIM master thesis, 2025 (non-public NIM thesis/material used for method-validation data; available from NIM on request).

⁷ National Institute of Metrology (NIM), China, Smart metrology and monitoring report, 2025 (internal technical report; available from NIM on request).

This framework is also aligned with the international direction represented by OIML G 22 and ongoing EVSE legal-metrology activities.⁸ For other countries or regions, the route can be adapted according to local scale and resources. In all cases, trustworthy EVSE charging depends on metrology-based traceability, secure and protected data, validated evaluation methods, and cooperation among metrology institutes, regulators, operators, and manufacturers.

As a key takeaway from this case study, EVSE metrological supervision at the national or policy level is best designed as a life-cycle system. This includes trusted design and software/data-security assessment at pattern approval or type evaluation, measurement accuracy and confirmation of metrological traceability at the initial verification step, and the flexibility to implement a range of countermeasures based on real-time evaluation results during in-service supervision. Further, digitalization does not replace metrology. A digital platform without metrologically traceable standards, data integrity, and uncertainty evaluation would lack the underlying trust and credibility. Conversely, conventional periodic verification alone cannot efficiently cover tens of millions of connectors.

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⁸ OIML Bulletin, Navigating the gap: Australia's experience in regulating electric vehicle supply equipment ahead of an OIML Recommendation, 2026, <https://www.oiml.org/en/publications/oiml-bulletin/2026-02/20260208>.