



**CALIFORNIA  
ENERGY COMMISSION**



California Energy Commission  
Clean Transportation Program

## **FINAL PROJECT REPORT**

# **Electrical Measurement Standards for Electric Vehicle Charging**

**Prepared for: California Energy Commission**

**Prepared by: California Department of Food and Agriculture,  
Division of Measurement Standards**



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# California Energy Commission

Kevin Schnepf, Environmental Program Manager I

**Primary Author**

California Department of Food and Agriculture  
6790 Florin Perkins Road, Suite 100  
Sacramento, CA 95828  
(916) 229-3000

**Contract Number: CEC-600-15-010**

Sharon Purewal

**Commission Agreement Manager**

Mark Wenzel

**Office Manager**

**ADVANCED VEHICLE INFRASTRUCTURE**

Hannon Rasool

**Deputy Director**

**FUELS AND TRANSPORTATION**

Drew Bohan

**Executive Director**

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- ChargePoint
- Tesla
- EVgo
- Advent Designs/Tesco
- Sacramento Municipal Utility District
- Southern California Edison
- San Diego Gas and Electric
- Pacific Gas and Electric

# PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the California Energy Commission allocate up to \$20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about \$100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the California Energy Commission's annual Clean Transportation Program Investment Plan Update. To establish standards and specifications for commercial measurement of electricity for fueling light-duty electric vehicles and to assist with analysis and implementation of specific topics including commercial electric vehicle supply equipment and infrastructure planning, the California Energy Commission issued 600-15-010 on May 23, 2016.

# ABSTRACT

The expansion of electricity as a zero-emission transportation fuel in California requires the development of a reliable network of publicly accessible commercial charging stations capable of safe and accurate fueling of electric vehicles. Prior to full-scale commercialization, devices used in commercial transactions must undergo type evaluation testing to assure that the measuring device is accurate; repeatable; designed to operate in the conditions it will be exposed to; cannot be used to defraud customers and communicates a fair and accurate accounting of all measurements and charges to the customer. For type evaluation to occur, there must be enforceable standards in the form of tolerances and specifications for the device in question. Prior to establishing tolerances and specifications, there must be established primary reference standards to which a device can be tested and compared to. Electric vehicle supply equipment is experiencing a strong expansion into commercialization, device specifications and tolerances, and test procedures need to be fully developed to support an equitable and consistent marketplace that fosters adoption of zero emission vehicle technology. The California Department of Food and Agriculture, Division of Measurement Standards is responsible for the establishment and oversight of specifications and tolerances for commercial weighing and measuring devices in the state. The Department of Measurement Standards State Metrology Laboratory maintains the standards of measurement: length; mass; time; volume; temperature; and alternating current electrical power used to ensure that all devices provide accurate and traceable measurements for their respective units of measure. A primary standard is needed with the operating range necessary for calibrating and testing electric vehicle supply equipment measurements to traceable and known values for both alternating current and direct current power. Field standards used to test installed equipment on-site that is calibrated to the primary standard are needed to support and maintain a reliable and robust statewide commercial electric vehicle fueling network. Finally, specifications and tolerances for electric vehicle supply equipment developed by the National Conference on Weights and Measures must be adopted for successful commercialization of the electric vehicle fueling market.

**Keywords:** California Department of Food and Agriculture, electric vehicle supply equipment, electric vehicle, direct current, alternating current

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# TABLE OF CONTENTS

	Page
Acknowledgements .....	i
Preface .....	ii
Abstract .....	iii
Table of Contents .....	v
List of Figures .....	v
Executive Summary .....	1
CHAPTER 1: Commercialization of Electric Vehicle Charging Infrastructure Background .....	3
CHAPTER 2: Actions and Reports .....	5
2.1 Electric Vehicle Supply Equipment Measurement Standards Report .....	5
2.2 Field Test Equipment Fabricator Work Report .....	6
CHAPTER 3: Conclusion.....	10
Glossary.....	1

## LIST OF FIGURES

	Page
Figure 1: Field Standards for Testing Installed Electric Vehicle Supply Equipment.....	7
Figure 2: Primary Library Standard Installed in the Metrology Laboratory .....	8





# EXECUTIVE SUMMARY

## Background

The California Air Resources Board's zero-emission vehicle regulation requires that by the year 2025, 15 percent of all vehicles produced and delivered for sale in California must be zero-emission vehicles. California leads the nation in its long-term transportation strategy to reduce pollution and greenhouse gas emissions by adopting alternative fuel vehicles and zero-emission technologies. Widespread public adoption of light-duty battery electric vehicles is intended to be a major component of the transition to zero-emission vehicles. Accordingly, an aggressive expansion of commercial fueling infrastructure is needed to meet the state's goals for adoption of low-emission hybrid electric and zero-emission battery electric vehicles.

The California Department of Food and Agriculture is mandated by the California Business and Professions Code Division 5, Chapter 2, § 12107 to adopt requirements for commercial weighing and measuring devices used in California. Many commercial transactions are based on weight, volume, length, or count of products bought and sold. Common commercial weighing and measuring devices include grocery and deli scales, taximeters, and retail gasoline meters at service stations.

An electric charging station, when used to transfer electricity to a vehicle for a fee, becomes a commercial measuring device. The Business and Professions Code § 12500.5 requires that weighing and measuring devices be approved by the California Department of Food and Agriculture before they may legally be used for commercial sales. The responsibility for evaluating and approving weighing and measuring devices is assigned to California Department of Food and Agriculture's Division of Measurement Standards. Commercial weighing and measuring devices are approved by the Division through a process known as "type evaluation."

Assembly Bill 631 (Ma, Statutes of 2011, Chapter 480) amended Public Utilities Code § 216(i) to clarify that the ownership, control, operation, or management of a facility that supplies electricity to the public only for use to charge light-duty plug-in electric vehicles), as defined, does not make the corporation or person a public utility. Therefore, it is the responsibility of the California Department of Food and Agriculture to establish the legal requirements for commercial sales of electricity to fuel light-duty vehicles. As the rollout of battery electric vehicles has already begun, there is an urgent need to develop the standards, specifications and test methods to validate commercial electric vehicle supply equipment.

## Actions

The execution of interagency agreement 600-15-010 between the California Energy Commission and the California Department of Food and Agriculture's Division of Measurement Standards initiated research into electrical energy measuring equipment. The Division of Measurement Standards' staff began researching existing and available electrical measurement technology and the current state of electric vehicle supply equipment designs. Research incorporated consultation with national experts in areas of electrical equipment design, electrical power measurement, electrical safety, and metering technology including representatives from Argonne National Labs; Fluke Analytical Research; Radian Corporation; National Electrical Manufacturers Association; National Institute of Standards and Technology's Office of Weights and Measures; members of the United States National Working Group on Electric Vehicle Supply Equipment formed by the National Conference on Weights and

Measures; Advent Designs/Tesco; ChargePoint; Tesla; EVgo; and many technical experts from municipal and investor owned utilities.

This extensive consultative research approach was a successful iterative process that led to the Division of Measurement Standards developing the design specifications and performance requirements for laboratory and field standards essential to safely, accurately, and reliably test electric vehicle supply equipment. The design specifications, performance requirements, and user interfaces developed by the California Department of Food and Agriculture staff were then submitted for technical review and vetted by multiple industry and national experts. The Division of Measurement Standards included the finalized design specifications in a Request for Proposal for competitive bidding for the design, fabrication, delivery and installation of primary and field standards for testing electric vehicle supply equipment.

## **Conclusion**

The California Department of Food and Agriculture's Division of Measurement Standards has acquired the requisite field and primary standards to test and evaluate commercial electric vehicle supply equipment design types. Testing and evaluating of electric vehicle supply equipment will allow approved devices to be installed and used commercially for fueling light-duty plug-in hybrid and battery electric vehicles. A major barrier for commercial electric vehicle supply equipment compliance with Business and Professions Code § 12500.5 has been removed. The Division of Measurement Standards can begin training county weights and measures officials on electric vehicle supply equipment testing and evaluation procedures. The Division can now utilize the primary standard for electrical measurement to calibrate and certify field standards used for evaluating installed electric vehicle supply equipment. The newly acquired standards will be used to further refine and update the National Institute of Standards and Technology's Examination Procedure Outline for Electric Vehicle Supply Equipment (Examination Procedure Outline 30).

California will continue to lead the nation in its long-term transportation strategy to reduce pollution and greenhouse gas emissions by adopting alternatively fueled vehicles and zero-emission technologies. Additionally, an open, transparent, and competitive marketplace for commercial fueling of electric vehicles will be a foundational pillar supporting the state's goals for widespread adoption of low-emission hybrid electric and zero-emission battery electric vehicles.

# CHAPTER 1:

## Commercialization of Electric Vehicle Charging Infrastructure Background

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California faces continuing challenges in achieving clean air and an adequate and sustainable energy supply and set the following goals:

- A reduction in greenhouse gas emissions to 80 percent below 1990 levels by 2050
- A decrease in petroleum fuels usage to 15 percent below 2003 levels by 2020
- An increase in the use of alternative transportation fuels to 20 percent of all fuel consumed by 2020 and 30 percent by 2030
- A reduction of emissions of nitrogen oxides to 80 percent of 2010 levels by 2023 to meet current federal ozone standards
- A statewide increase to 1.5 million zero-emission vehicles by 2025 and by 2030

New technologies and new approaches in many areas are needed to meet these challenges. The California Energy Commission's Clean Transportation Program supports innovation in the transportation sector. This program was established by Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) and subsequent amendments. The development of reliable electric vehicle fueling infrastructure is one of the efforts supported by this program.

Governor Brown's Executive Order B-16-12 orders all state agencies to support and facilitate the rapid commercialization of zero-emission vehicles in California. This order includes a goal for the development of infrastructure supporting up to one million zero-emission vehicles in the state by 2020 and 1.5 million by 2025.

Governor Brown's Executive Order B-30-15 establishes a new interim greenhouse gas emissions target reduction of 40 percent below 1990 levels by 2030 and directs all agencies to implement measures to meet this target. By replacing petroleum-fueled vehicles on the state's highways, zero-emission vehicles reduce tailpipe emissions of greenhouse gases and improve the state's air quality.

Governor Brown's Executive Order B-48-18 orders a new target of putting five million zero-emission vehicles into operation on California highways by 2030. The Executive Order includes the installation of 250,000 commercial Level 2 electric vehicle supply equipment and 10,000 direct current fast charge electric vehicle supply equipment. The purpose of the order is to streamline and support electric vehicle supply equipment infrastructure.

The California Air Resources Board's zero-emission vehicle regulation requires that by the year 2025, 15 percent of all vehicles produced and delivered for sale in California be zero-emission vehicles. Existing state statutes and regulations adopted by the California Department of Food and Agriculture that govern the commercial sale of transportation fuels in California protect consumers and ensure a level playing field among competing businesses. Assembly Bill 631 (Ma, Statutes of 2011, Chapter 480) amended Public Utilities Code § 216(i) to clarify that the ownership, control, operation, or management of a facility that supplies electricity to the public only for use to charge light-duty plug-in electric vehicles, as defined, does not make the corporation or person a public utility. Therefore, it is the responsibility of the California Department of Food and Agriculture to establish the legal requirements for commercial sales of electricity to fuel light-duty vehicles.

Business and Professions Code § 12500.5 requires that the California Department of Food and Agriculture approve design types for all commercial weighing measuring devices prior to their use in the marketplace. The California Department of Food and Agriculture is also mandated by the California Business and Professions Code Division 5, Chapter 2, § 12107 to adopt requirements for commercial weighing and measuring devices used in California. As the rollout of battery electric vehicles has already begun, there is an urgent need to develop the standards, specifications, and test methods to validate commercial electric vehicle supply equipment.

# **CHAPTER 2:**

## **Actions and Reports**

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### **2.1 Electric Vehicle Supply Equipment Measurement Standards Report**

The execution of interagency agreement 600-15-010 initiated research into electrical energy measuring equipment. Staff began researching existing and available electrical measurement technology and the current state of electric vehicle supply equipment designs. Consultations with industry experts were initiated and have been maintained throughout the standards development process. Many consulting efforts were made with regional and national experts and electric vehicle supply equipment industry representatives including: Argonne National Labs; Fluke Analytical Research; Radian Corporation; National Electrical Manufacturers Association; National Institute of Standards and Technology Office of Weights and Measures; members of the United States National Working Group on Electric Vehicle Supply Equipment formed by National Institute of Standards and Technology; ChargePoint; Tesla; EVgo; Advent Designs/Tesco; and representatives from municipal and investor owned utilities. Early in the project, the technological landscape for electric vehicle supply equipment and associated measuring equipment was evolving rapidly. Pressures from competing electric vehicle supply equipment design concepts and varying connector designs from Asia and Europe were impacting the process to develop field and laboratory test equipment with broad application capability.

The Department of Measurement Standards staff then developed the design specifications and performance requirements for laboratory and field standards essential to safely, accurately, and reliably test electric vehicle supply equipment. The design specifications, performance requirements, and user interfaces developed by the Department of Measurement Standards were submitted for review and vetted by multiple industry and national experts in the fields of electrical measurement, standards development, equipment safety, and electrical safety. This iterative process led to the Department of Measurement Standards submitting a Request for Proposal for competitive bidding for the design, fabrication, delivery and installation of primary and field standards for testing electric vehicle supply equipment. The Request for Proposal was posted on January 24, 2017 and the contract was fully executed on May 11, 2017.

Training of the Department of Measurement Standards staff to ensure they possess the requisite knowledge for electric vehicle supply equipment testing was an early project priority. Two staff members were selected to attend electric meter school for training on the safe use and application of test standards for testing electrical dispensing and measurement systems. Electricity when used as motor vehicle fuel must be sold in units of kilowatt hours and electric meters are installed in electric vehicle supply equipment for measuring and quantifying the amount of energy provided. The Division of Measurement Standards staff members completed this training at the Northwest Meter School in Seattle, Washington in August 2016.

Newly trained staff then consulted with National Electrical Manufacturers Association and reviewed Occupational Health and Safety Administration requirements for laboratory safety and design requirements for the installation and operation of electrical energy testing and measuring equipment (primary and field standards). Electrical and safety requirements for the installation of electric vehicle supply equipment provided to the Division of Measurement Standards for evaluation of standards were established. These donated test devices were

instrumental in the evaluation and development of examination test procedures necessary for safely and effectively field testing installed commercial electric vehicle supply equipment.

During the contractor's fabrication phase of the primary lab standard, the Department of Measurement Standards staff conducted technical reviews and submitted recommended edits to Draft National Institute of Standards and Technology Examination Procedure Outline Number 30 - Examination Procedure Outline for Retail Electric Vehicle Fueling Systems. This document establishes the method and procedure for evaluating commercial electric vehicle supply equipment. It is the procedural document used by the Department of Measurement Standards evaluators and county weights and measure officials when testing electric vehicle supply equipment.

## **2.2 Field Test Equipment Fabricator Work Report**

Over the next year and a half of design and development by the contractor, the Department of Measurement Standards staff collaborated and reviewed each component of the design, updated performance specifications, and refined user interface and operability requirements with the contractor through weekly meetings and several on-site visits. As the design for standards began reaching the final stages before fabrication, safety protocols, power supply and space requirements for the Division of Measurement Standards metrology laboratory were established. The Division of Measurement Standards staff maintained regular updates with the contractor's fabrication progress through regular web-conferencing, teleconferencing, and email. Each phase of the fabrication was reviewed to ensure that the standards would provide essential functionality and meet contract requirements for performance.

To prepare for the installation of the primary laboratory standard, the Division of Measurement Standards submitted the laboratory electrical upgrade requirements and obtained bids to install the power supply and electrical outlets needed to operate electric vehicle supply equipment testing equipment and conduct National Institute of Standards and Technology traceable calibrations. The contract for electrical work to upgrade the Division of Measurement Standard's Metrology Laboratory was awarded in July 2017 with the needed power supply, circuitry, and outlets installation completed August 31, 2017.

The standards fabrication contractor delivered the first of two field standards to the Division of Measurement Standards in June 2018. Images of the field standards are provided in Figure 1. The contractor provided training to staff on the use the field standard and walked staff through the test procedure. Staff gained familiarity with the use of the field standard by connecting the device to the Division of Measurement Standard's electric vehicle supply equipment and conducting test measurements. Connection, activation, and measuring procedures were reviewed to establish that the field standard had met design requirements.

**Figure 1: Field Standards for Testing Installed Electric Vehicle Supply Equipment**



Source: California Department of Food and Agriculture Division of Measurement Standards

In October 2018, staff traveled to the contractor’s design and fabrication facility in Bristol, Pennsylvania to conduct an on-site assessment of the primary laboratory standard and review conformance to design specifications. Staff went through each component and its functionality with the contractor to approve the design and release it for shipping and installation at the Division of Measurement Standard’s laboratory in Sacramento. While evaluating the device at contractor’s location, staff received preliminary training on the use of the primary standard for measuring electrical energy and calibrating field standards.

Delivery and installation of the primary laboratory standard was completed on February 6, 2019. Images of the installed primary standard are provided in Figure 2. The Division of Measurement Standards staff received additional training from the contractor on February 8 – 9, 2019 at the Division of Measurement Standard’s Metrology Laboratory using the newly installed primary standard and provided field standards. The Division of Measurement Standards staff can now safely test and evaluate electric vehicle supply equipment for both alternating current and direct current power. Testing capabilities with the supplied standards include alternating current voltage from 90 to 250 volts and alternating current from 0.2 to 80 amps within 0.01 percent accuracy tolerance and direct current voltage from 60 to 300 volts and direct current from 0.5 to 100 amps with 0.02 percent accuracy tolerance.

**Figure 2: Primary Library Standard Installed in the Metrology Laboratory**



Source: California Department of Food and Agriculture Division of Measurement Standards

With the National Institute of Standards and Technology -traceable alternating current electrical measurement standards, trained staff, a working version of National Institute of Standards and Technology Examination Procedure Outline 30, and established type evaluation procedures, the Division of Measurement Standards can now successfully type evaluate commercial electric vehicle supply equipment. An open, transparent, and competitive marketplace for commercial fueling of electric vehicles can now be a foundational pillar



supporting the state's goals for adoption of low-emission hybrid electric and zero-emission vehicles.

## **CHAPTER 3:**

### **Conclusion**

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The California Department of Food and Agriculture's Division of Measurement Standards has acquired the requisite field and primary standards to test and evaluate commercial electric vehicle supply equipment design types. Testing and evaluating of electric vehicle supply equipment will allow approved devices to be installed and used commercially for fueling light-duty plug-in hybrid and battery electric vehicles. A major barrier for commercial electric vehicle supply equipment compliance with Business and Professions Code § 12500.5 has been removed. The Division of Measurement Standards can begin training county weights and measures officials on electric vehicle supply equipment testing and evaluation procedures. The Division can now utilize the primary standard for electrical measurement to calibrate and certify field standards used for evaluating installed electric vehicle supply equipment. The newly acquired standards will be used to further refine and update the National Institute of Standards and Technology's Examination Procedure Outline for Electric Vehicle Supply Equipment (Examination Procedure Outline 30).

California will continue to lead the nation in its long-term transportation strategy to reduce pollution and greenhouse gas emissions by adopting alternatively fueled vehicles and zero-emission technologies. Additionally, an open, transparent, and competitive marketplace for commercial fueling of electric vehicles will be a foundational pillar supporting the state's goals for widespread adoption of low-emission hybrid electric and zero-emission battery electric vehicles.

# GLOSSARY

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.