



Electric Vehicle Chargers



Prepared by Bill Hardy, TESCO

*For North Carolina Electric Meter School
Tuesday, June 27, 2017 at 2:45 p.m.*

Electric Vehicle Service Equipment

What is it all about?



INTRODUCTION

- EVSE Basics
- HB 44 Requirements
- Real World Testing



INTRODUCTION

- Basic Statistics
 - 30,221 Commercial Charging Spots
 - 371 Non-Tesla DC Rapid Charge Locations
 - 4,359 Tesla SuperChargers at 705 Locations
 - >500,000 pluggable electric vehicles in US

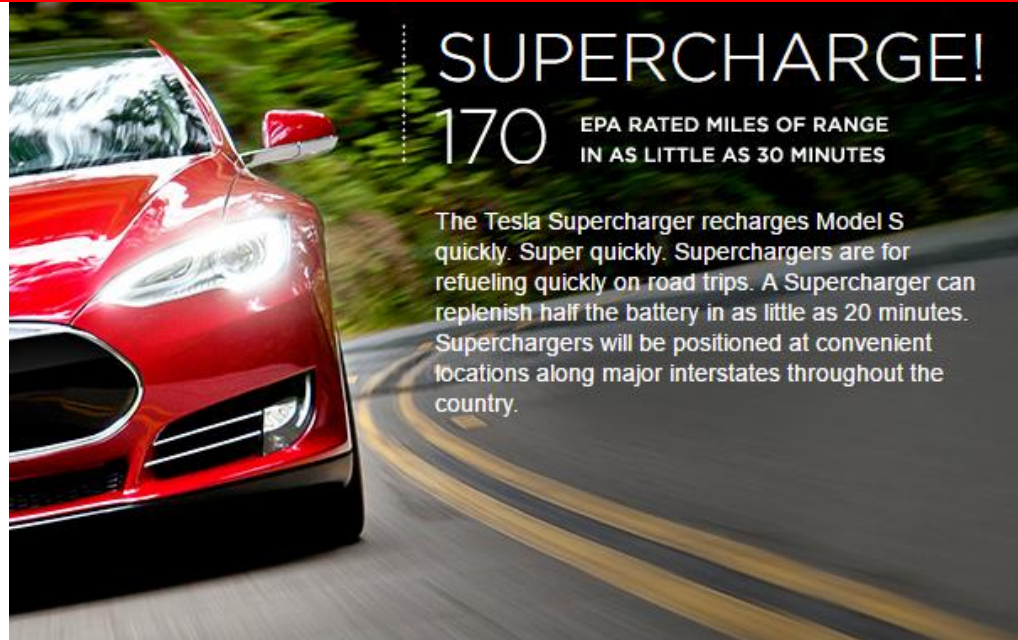


The EVSE Market

- **2015 - 15 Electric Vehicles on USGOV List**
 - **ONE HAS 100+ MILE RANGE, most < 50**
 - **ALL have AC Level 1 and 2 Capability**
 - ◆ maximum Charging Rate is 7.2 kW, many only 3.6kW
 - **Three Offer DC Rapid Charge**
 - **2018 – 24 Announced ALL ELECTRIC VEHICLES**
 - All have 120+ mile range
 - All have DC Rapid Charge (Most are J1772 Compatible)
- INFRASTRUCTURE IS ESSENTIAL TO MAKE THESE CARS SELL**



The EVSE Market



Over 300,000 Tesla Model X reserved at \$1,000 each in first three months.

EVERY major auto manufacturer has multiple models on 2018 introduction plans.



The EVSE Market

The White House
Office of the Press Secretary

July 21, 2016

For Immediate Release

July 21, 2016

FACT SHEET: Obama Administration Announces Federal and Private Sector Actions to Accelerate Electric Vehicle Adoption in the United States

The Obama Administration is taking responsible steps to combat climate change, increase access to clean energy technologies, and reduce our dependence on oil. That is why, today, on the heels of the United States Department of Energy's (DOE) first-ever **Sustainable Transportation Summit**, the Administration is announcing an unprecedented set of actions from the Federal government, private



The EVSE Market

JULY 21

TSLA: 220.50 -7.99

White House unlocks \$4.5 billion for electric vehicle infrastructure and announces new EV programs

Fred Lambert - 3 days ago @FredericLambert

CHARGING STATION

EV INFRASTRUCTURE



42 Comments [Twitter](#) [Facebook](#) [Google](#) [Pinterest](#) [Reddit](#)



The EVSE Market

EV INTEGRATION

Southern California Utilities to Deploy 5,000 EV Chargers in First-of-Their-Kind Pilots

15,000



The country's biggest rate-based rollout of EV chargers targets apartments, commercial parking and grid integration.

by Jeff St. John
February 01, 2016



The EVSE Market

PG&E proposes EV charging infrastructure buildout

US power utility PG&E has submitted its proposal to the California Public Utilities Commission (CPUC) to increase EV charging stations in its service territory.

The proposed plan aims to boost the adoption of EVs to lower carbon emissions whilst relieving pressure on the national grid.

The utility is hoping that the programme will ensure that excess energy produced from renewable energy sources will be used and not become waste.

According to the Scientific American, the utility company plans to use \$160 million to install 7,600 EV charging stations within the next three years.

The programme will focus on increasing the number of EV charging stations with installation at workplaces and multi-family apartments.

Approximately 7,500 Level 2 charging ports and 100 direct-current fast chargers will be installed.

Level 2 charging stations able to fully charge an EV in four to eight hours, will be installed at workplaces and residential premises.

DC fast chargers which power EVs in 20 to 30 minutes will be installed near highways and shopping areas.

There are currently 5,000 charging stations in PG&E's service territory.

PG&E requests CPUC approval to install an



The EVSE Market

- UNIVERSAL DRIVERS
 - Auto Companies believe there are two major issues holding back electric vehicles
 - ◆ Range Anxiety
 - ◆ Cost to purchase compared to gas vehicles
 - Range Anxiety is resolved in several ways
 - ◆ Car has larger battery to extend range
 - ◆ Charging gets below 15 minutes per hundred miles
 - ◆ Wide spread availability of rapid charging stations



• UNIVERSAL DRIVERS

▪ Vehicle purchase cost

- ◆ Major part of vehicle cost is battery
- ◆ Battery costs are dropping very rapidly even as the battery capacity grows
- ◆ Efforts like the “Giga-Factory” and Chinese efforts promise to drive the price down further
- ◆ Giga-Factories just announced in Germany and Asia
- ◆ Examples:
 - Nissan Leaf was over \$40K now under \$30k
 - TESLA Model 3 is \$35,000



Electric Vehicle Adoption

▪ Cheap Gas ??

- ◆ Gas prices are very low now, but that has not slowed EV manufacturers plans for new model introductions
- ◆ Even at these prices EV fuel is 25% the cost of gas
- ◆ Certain urban areas may force wide scale adoption
- ◆ The probability that gas stays cheap forever is low

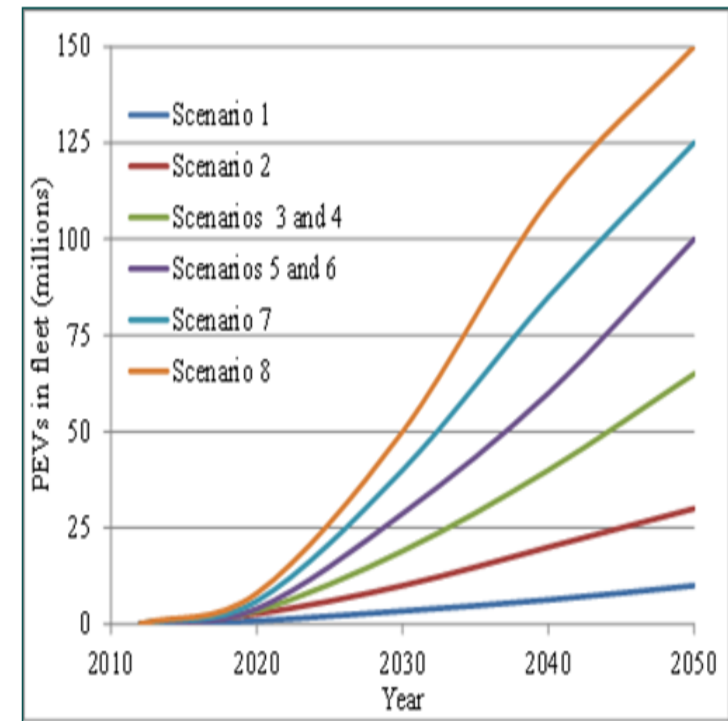
▪ Maintenance Costs

- ◆ Electric vehicles have almost no maintenance costs
- ◆ Lifetime ownership costs will be very low



• Electric Vehicle Adoption

- EV Economics overtake gas as lowest total cost to own and operate
- Maintenance Costs
 - ◆ Electric vehicles have almost no maintenance costs
 - ◆ Lifetime ownership costs will be very low



THE EVSE MARKET

- Vehicles Must Charge Quickly for Wide Scale Adoption
 - Typical miles per kWhr is 2.7 to 3.3
 - ◆ That is not likely to change much with technology improvements
- For a 100 mile range you need
 - 30 kWhr of charge
- A Tesla SuperCharger delivers 120 kW and can add 170 miles of range in 30 minutes.



THE EVSE MARKET

- Charge Times (hours)

Battery kWhr	AC Level 1 & 2			DC Fast Charge			
	1.92	7.2	19.2	50	120	200	400
10	3.65	0.97	0.36	0.14	0.06	0.04	0.02
20	7.29	1.94	0.73	0.28	0.12	0.07	0.04
40	14.58	3.89	1.46	0.56	0.23	0.14	0.07
60	21.88	5.83	2.19	0.84	0.35	0.21	0.11
80	29.17	7.78	2.92	1.12	0.47	0.28	0.14
90	32.81	8.75	3.28	1.26	0.53	0.32	0.16
100	36.46	9.72	3.65	1.40	0.58	0.35	0.18
110	40.10	10.69	4.01	1.54	0.64	0.39	0.19
120	43.75	11.67	4.38	1.68	0.70	0.42	0.21
Estimate based on 20% to 90% charge							
PHEV	EV80	EV100+			Happy Spot		



THE EVSE MARKET

- Fill the Tank Costs

COST TO FILLUP						
Price per kWhr	Energy (kWhr)					
	10	20	40	80	100	120
0.10	1.00	2.00	4.00	8.00	10.00	12.00
0.15	1.50	3.00	6.00	12.00	15.00	18.00
0.20	2.00	4.00	8.00	16.00	20.00	24.00
0.30	3.00	6.00	12.00	24.00	30.00	36.00
0.40	4.00	8.00	16.00	32.00	40.00	48.00
0.50	5.00	10.00	20.00	40.00	50.00	60.00
Charge at Home			Commercial Charging Station			



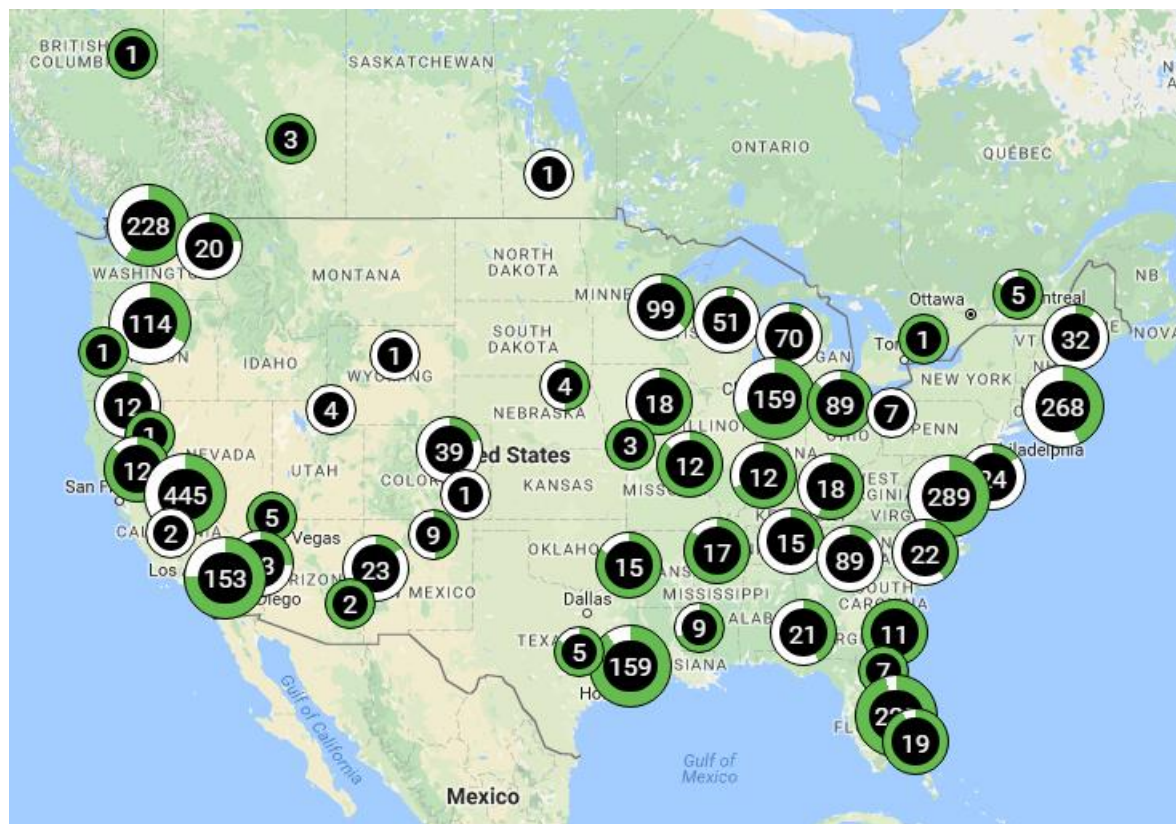
MULTIPLE STANDARDS IN USE

- **J1772 AC Level 1**
 - Primarily for home installation
 - 120 Volts at up to 16 Amps
 - Maximum Power Delivery (1.92 kW)
 - Typical time to charge
 - ◆ Pluggable Hybrid (3 – 5 hours, 0% to 100%)
 - ◆ EV 80 Mile Range (8 – 20 hours, 20% to 100%)
 - ◆ EV200 Mile Range (15 – 40 hours, 20% to 100%)
 - 5.6 miles per hour of charge



MULTIPLE STANDARDS IN USE

- J1772 AC Level 1 – Public Stations**



MULTIPLE STANDARDS IN USE

- **J1772 AC Level 2**

- Home and Commercial Installation
- 240 Volts at up to 80 Amps (30A and 50A most common)
 - ◆ Home 30A, Commercial 30A, 50A, 75A
- Maximum Power Delivery (19.2 kW)
- Typical time to charge
 - ◆ Pluggable Hybrid (0.5 – 1.5 hours, 0% to 100%)
 - ◆ EV 80 Mile Range (1.5 – 4 hours, 20% to 100%)
 - ◆ EV200 Mile Range (3.2 – 10 hours, 20% to 100%)



MULTIPLE STANDARDS IN USE

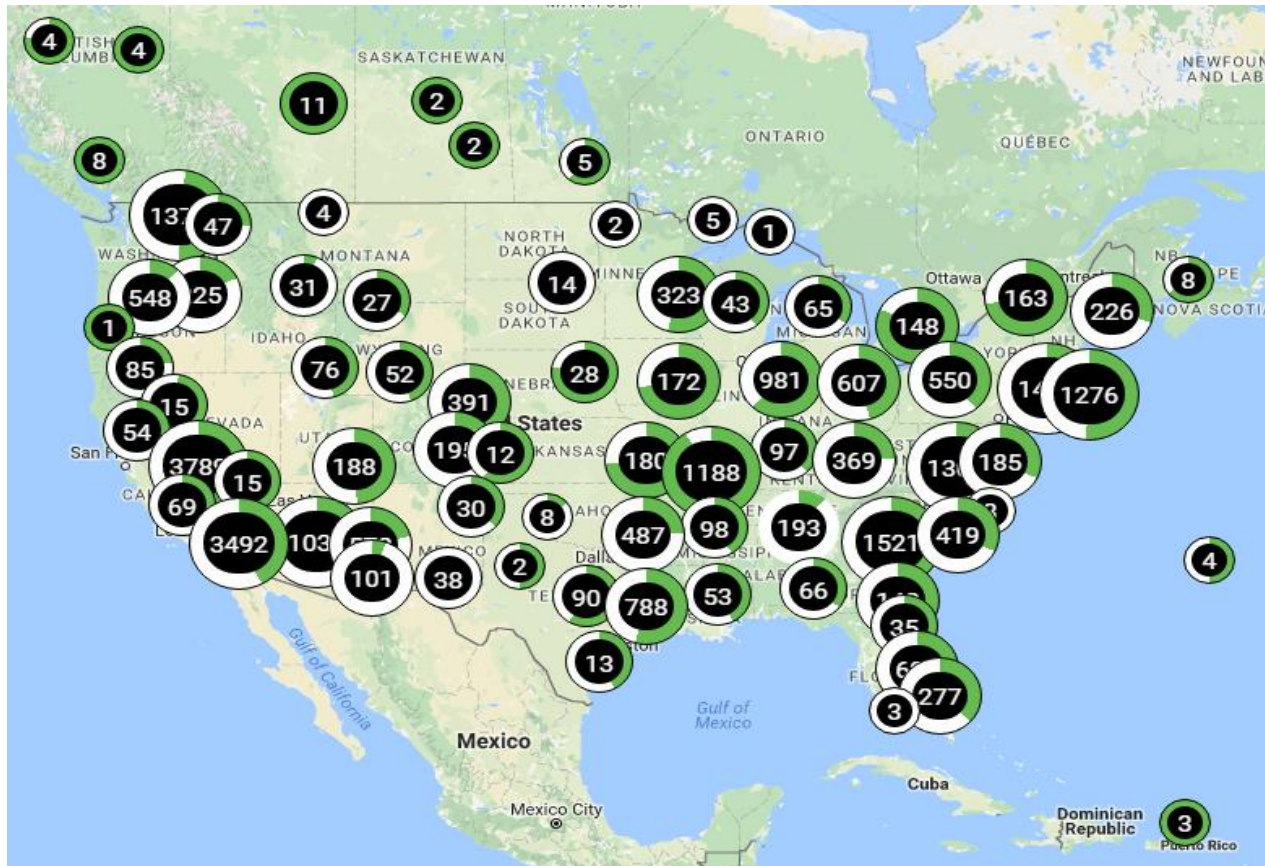
- **J1772 AC Level 2**

- ◆ 240V at up to 80A (19.2 kW) (56 miles per hour of charge)
- ◆ Most common is 32A (7.68 kW) (23 miles per hour of charge)
- Over 95% of commercial EVSEs are AC Level 2
- All current EV/PEV in US can use this type though some need adapters
- Stations cost \$3,000 - \$8,000



MULTIPLE STANDARDS IN USE

- **J1772 AC Level 2 - Public Stations**



MULTIPLE STANDARDS IN USE

- **J1772 DC Rapid Charge**
 - Commercial Installation
 - 200 to 600 Volts at up to 400 Amps (30A and 50A most common today)
 - ◆ Commercial 50kW, 100kW
 - Maximum Power Delivery (240 kW theoretical)
 - Typical time to charge
 - ◆ EV 80 Mile Range (0.3 – 1.5 hours, 10% to 80%)
 - ◆ EV200 Mile Range (0.3 – 1.5 hours, 10% to 80%)
 - At 50kW you get 150 miles per hour of charge



MULTIPLE STANDARDS IN USE

- **J1772 – 2016 for DC Level 2**
 - Uses Duo Connector
 - Only one connector for AC or DC
 - Very few presently installed in US
 - Will be standard for US and European manufacturers beginning in 2018 model year.



MULTIPLE STANDARDS IN USE

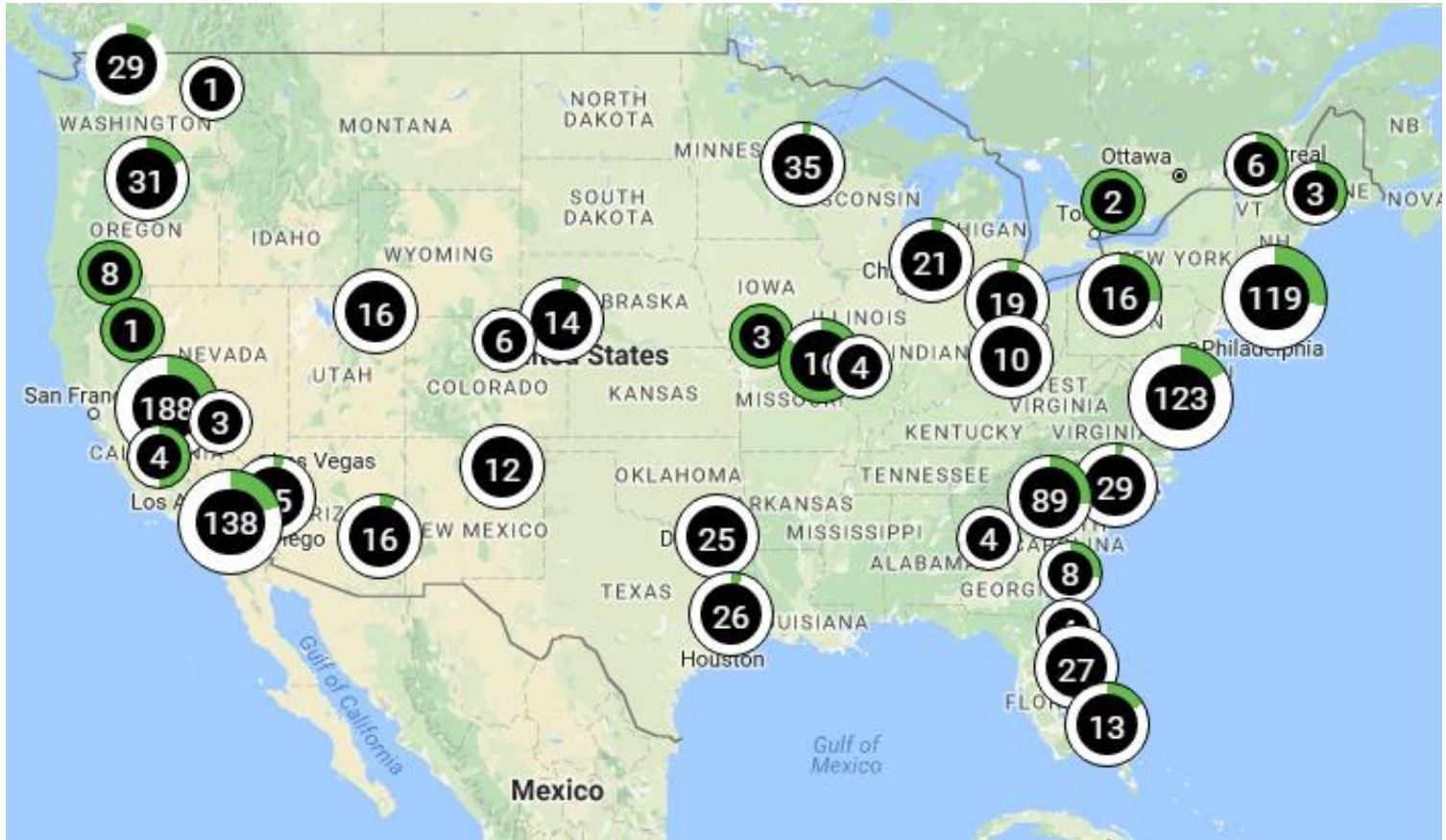
- **J1772- 2016 DC Level 2**

- Being installed at a rate of about 1 per every 100 AC Level 2
- Driving factor – Few current vehicles can use DC Fast Charge
 - ◆ Mainly Tesla and Nissan Leaf
 - ◆ These have their own free networks
- OVER 24 2018 models will have rapid charge capability
- Negative – Stations cost \$80,000 to \$120,000



MULTIPLE STANDARDS IN USE

- J1772 DC Level 2



EVSE BASICS

- **CHAdeMO**

- Originated in Japan but used World Wide
- First DC Rapid Charging Standard
- Cars which use this for DC need separate J1772 connector for AC
- Most US stations at Nissan dealerships
- Not clear if Japanese manufacturers will switch to new SAE J1772 DUO standard



EVSE BASICS

- CHAdeMO



EVSE BASICS

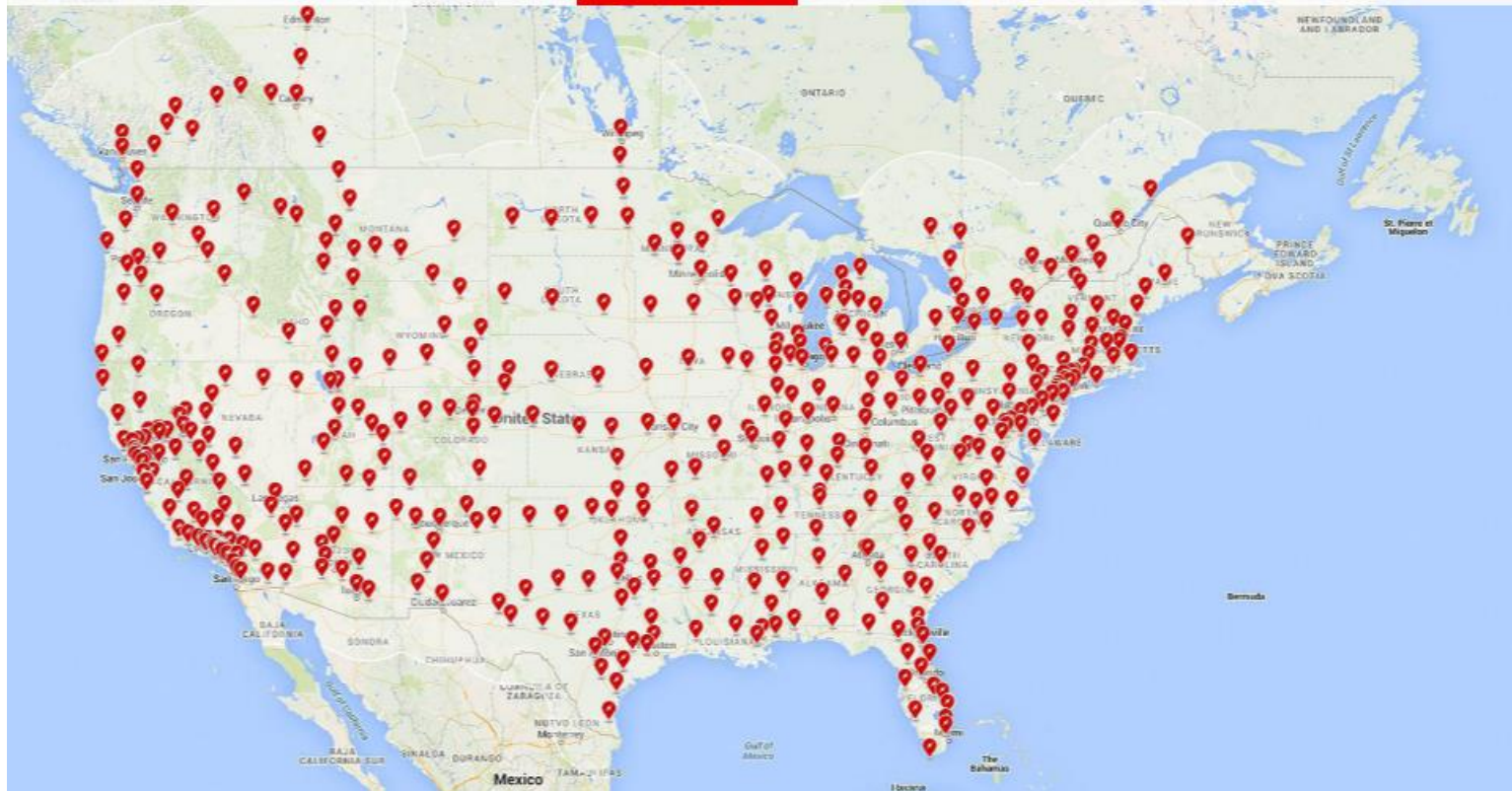
- **Tesla**

- Largest US DC Fast Charge Network
- Exclusive to Tesla Owners
- Today it is free, but will not be for Model 3 buyers
- Will it fall under W&M regulations???
- Protocol and hardware are proprietary
- Poses challenge for test equipment vendors



EVSE BASICS

- Tesla



MAJOR CHARGING NETWORKS

- **Aerovironment (AV)**
- **BLINK**
- **ChargePoint**
- **The Electric Circuit**
- **EVGO**
- **GE Wattstations**
- **GreenLots**
- **SEMAConnect**
- **Tesla**



REGULATORY BACKGROUND

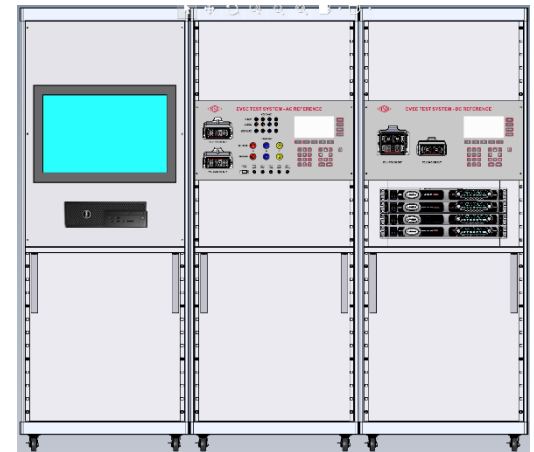
- **U.S. National Work Group - Electric Vehicle Fueling and Submetering**
 - Formed two years ago to develop HB44 standards for EVSE and submetering applications
 - Phase 1: EVSE Standard – Initial work completed July 2015
- **New Provisional Standard Approved in July 2015 Effective Jan 1, 2016**
 - HB44 Section 1.10 General Code
 - ◆ Several changes relevant to EVSE
 - HB44 Section 3.4 – Electric Vehicle Fueling Systems – Tentative Code
 - HB44 Section 5.5 – Timing Devices
 - ◆ Several changes relevant to EVSE



REGULATORY BACKGROUND

- **Additional New Standards in Process**
 - NIST Handbook 130 Examination Procedure for Retail Electric Vehicle Fueling Systems
 - ◆ This procedure is currently in development
 - ◆ A draft version is available from Juana Williams at NIST
 - NTEP PB14 Working Group
 - ◆ Establishing type test checklist

TESCO wins contract to build Primary Reference Standards and Type Test System for US NTEP Lab.



HB44 APPLICABILITY

- **A.1. General.** – This code applies to devices, accessories, and systems used for the measurement of electricity dispensed in vehicle fuel applications wherein a quantity determination or statement of measure is used wholly or partially as a basis for sale or upon which a charge for service is based.



HB44 APPLICABILITY

- **Exceptions-This code does not apply to:**
 - The use of any measure or measuring device owned, maintained, and used by a public utility or municipality only in connection with measuring electricity subject to the authority having jurisdiction such as the Public Utilities Commission.
 - Electric Vehicle Supply Equipment used solely for dispensing electrical energy in connection with operations in which the amount dispensed does not affect customer charges or compensation.
 - The wholesale delivery of electricity.



HB44 APPLICABILITY

- **Use Cases – NOT COVERED**
 - A store provides a free EVSE in its parking lot
 - A paid parking lot provides EVSEs for which there is no charge based on the amount of energy delivered
 - Tesla provides free charging services for owners
 - An organization charges a monthly fee for unlimited use of its network of EVSEs.



HB44 APPLICABILITY

- **Use Cases –COVERED**
 - ANY transaction which is based on the amount of energy delivered
 - Examples
 - ◆ An network of charge stations charges a monthly fee to belong AND a fee based on the amount of energy used
 - ◆ A EVSE charges for the amount of energy delivered
 - ◆ A parking lot charges for parking and EVSEs located in it also charge for the amount of energy delivered if used



HB44 - REQUIREMENTS

S.1.1. Electric Vehicle Supply Equipment (EVSE). – An EVSE used to charge electric vehicles shall be of the computing type and shall indicate the electrical energy, the unit price, and the total price of each transaction.

- EVSEs capable of applying multiple unit prices over the course of a single transaction shall also be capable of indicating the start and stop time, the total quantity of energy delivered, the unit price, and the total price for the quantity of energy delivered during each discrete phase corresponding to one of the multiple unit prices.



HB44 - REQUIREMENTS

- EVSEs capable of applying additional fees for time-based and other services shall also be capable of indicating the total time measured; the unit price(s) for the additional time based service(s); the total computed price(s) for the time measured; and the total transaction price, including the total price for the energy and all additional fees.



TEST TOLERANCES

- **No Load Test.** – An EVSE measuring system shall not register when no load is applied.
- **Starting Load.** – An EVSE measuring system shall register starting load test at a 0.5 ampere (A) load.



TYPE EVALUATION

- For type evaluation examinations, the acceptance tolerance values shall apply under the following conditions:
 - at any temperature, voltage, load, and power factor within the operating range of the EVSE, and
 - regardless of the influence factors in effect at the time of the conduct of the examination, and
 - for all quantities greater than the minimum measured quantity.



• **Process in EARLY stage of development**

1. Verify EVSE labeling meets requirements
2. Record all site information
3. Power on test equipment with load connected
4. Start test process on test equipment
5. Connect EVSE to test equipment
6. Determine maximum deliverable current (MDA) from CP signal
7. Set load to $\leq 10\%$ of MDA and perform the light load test



• Process in EARLY stage of development

8. Perform the light load test

- (a) This requires doing a charging cycle and at the conclusion of energy delivery comparing the total energy and price registered on the EVSE with that measured by the test equipment.

9. Record the test results

- (a) Repeat 8 & 9 multiple times for reproducibility test

10. Set load to >85% of MDA and perform the full load test

- (a) This requires doing a charging cycle and at the conclusion of energy delivery comparing the total energy and price registered on the EVSE with that measured by the test equipment.

11. Record the test results

- (a) Repeat 10 & 11 multiple times for reproducibility test





- **Process in EARLY stage of development**

12. Verify that after the final test that the display on the EVSE remains visible for at least 15 seconds

13. No Load Test (optional)

- (a) Test system must initiate a valid charging sequence without placing a load on the EVSE. No energy should be registered.
- (b) Not yet defined what “No” means or for how long the test should be performed



• Process in EARLY stage of development

14. Starting Load Test (optional)

- (a) Test system must initiate a valid charging sequence with a load of 0.5 amps.
- (b) Energy must be registered, not clear at this point what the accuracy requirement is, if any if 0.5 amps is less than 10% of MDA.





- **Process in EARLY stage of development**

- 15. Time Test (tbd)

- 16. RFI/EMI Test (tbd)

- 17. Zero-Setback Test

- a) On equipment activated with a single remote controller, activate one EVFS and check all others operated by the same controller to make certain they will not operate without activating the individual EVFS starting mechanism.



OUR TEST SOLUTIONS

T100 AC Level 1 & 2 to 32 Amps

T200 AC Level 1 & 2 to 75Amps



T400

AC Level 1 & 2 to 75 Amps

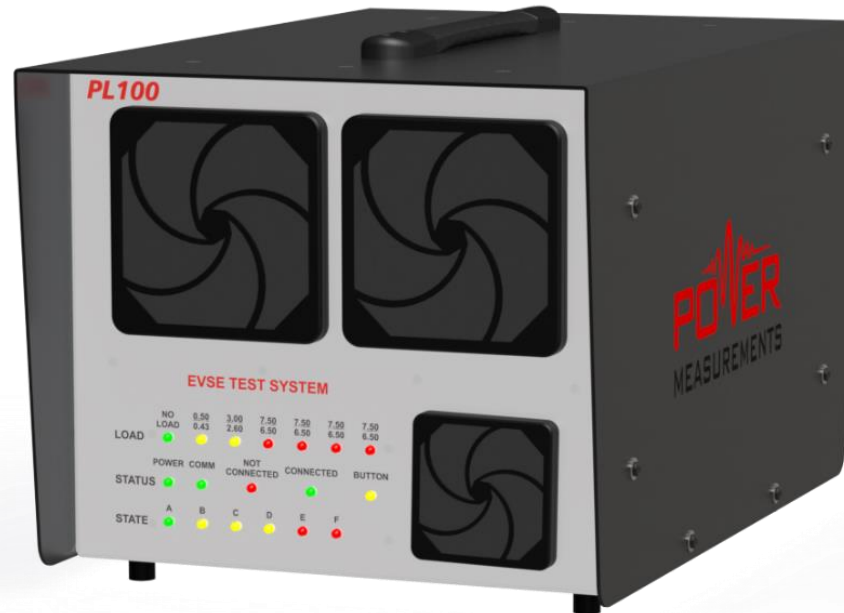
DC Level 2 to 75 Amps



OUR TEST SOLUTIONS

PL100 AC Level 1 & 2 to 32 Amps
PL200 200 AC Level 1 & 2 to 64 Amps

PL400
AC Level 1 & 2 to 64 Amps
DC Level 2 to 32 Amps



• TXXX EVSE TESTER

- Database driven

- ◆ Select a site and test
- ◆ Download all of your site data from your PC
- ◆ Locate site by GPS , ID or any other field

EVSE ID	Address
VA-00216-001-001	8297 Stonewall Shops Square
VA-23167-003-008	17562 Linton Hall Road
VA-23167-003-010	17562 Linton Hall Road
VA-23167-003-012	17562 Linton Hall Road
VA-34562-001-001	8386 Sudley Road
VA-34562-001-002	8386 Sudley Road
VA-34562-001-003	8386 Sudley Road
VA-34562-001-004	8386 Sudley Road

SEARCH:

POWER MEASUREMENTS **EDIT EVSE INFORMATION**

EVSE ID:

SITE NAME:

ADDRESS:

CITY: STATE:

MODEL: TEST PROCEDURE:

GPS:



SOLUTION

- **TXXX EVSE TESTER**
 - **Automated Operation**
 - ◆ **Create Test sequences which completely automate process**
 - ◆ **Testing is then a simple one click process**

The screenshot shows a software interface for configuring an EVSE test. It features a header with the 'POWER MEASUREMENTS' logo and the title 'TEST PROCEDURE'. Below the header, there are several configuration fields: 'EVSE ID' with a text input containing 'VA-23167-003-012'; 'TEST MODE' with three radio buttons for 'AUTO' (selected), 'ACTIVE', and 'PASSIVE'; 'KWh / TIME' with two input fields for 'KWh' (0.5) and 'TIME' (20 min); 'CURRENT' with three input fields for 'LL%' (10), 'HL%' (85), and 'NOM' (32); and 'TEST TO PERFORM' with six checked checkboxes: 'ACCURACY', 'PROX DIODE', 'EMERGENCY DISCONNECT', 'PROTOCOL', and 'CGFI'. At the bottom, there are two empty buttons and two buttons labeled 'CANCEL' and 'TEST'.



SOLUTION

- **TXXX EVSE TESTER**
 - **Simple Results**
 - ◆ **Process and Status During Testing**
 - ◆ **Easy entry of EVSE Displayed Results**

POWER MEASUREMENTS **FULL LOAD TEST**

STATUS : CHARGING

DESIRED LOAD 29.0 AMPS

EVSE CONTROL PILOT MAXIMUM 30.0 AMPS

ACTUAL TEST LOAD 29.02 AMPS

TEST STATUS PRESET 10:00 MIN 0.5 KWH
ACTUAL 4:23 MIN 0.318 KWH

START SHOW CANCEL SKIP

POWER MEASUREMENTS **FULL LOAD TEST RESULT**

	MEASURED	EVSE
KWh DELIVERED	0.765489	0.761
PRICE PER KWh		0.169
TOTAL PRICE	0.129	0.13
KWh ERROR (%)		0.58
PRICE ERROR (%)		0.78
PROTOCOL COMPLIANCE		WITHIN SPECS

SAVE RETEST MORE BACK TO MAIN

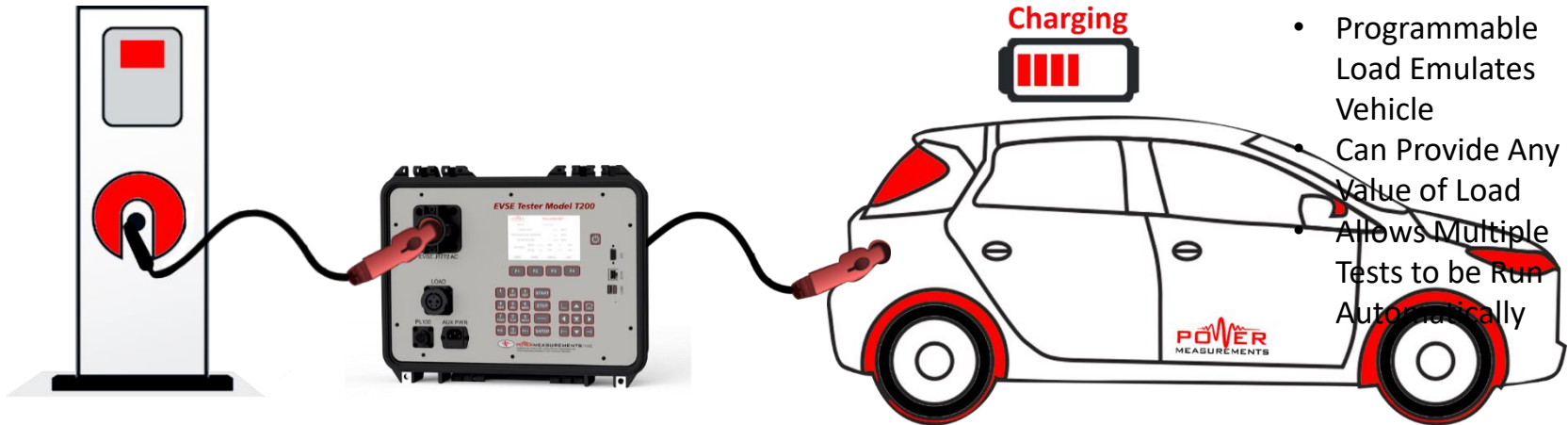


SOLUTION

- **TXXX EVSE TESTER**
 - **Fully Self Contained**
 - ◆ No PC or Smart Phone
 - ◆ Rugged Pelican Case
 - ◆ Run from internal battery, AUX AC or L1-L2 of EVSE
 - ◆ High Res Color display
 - ◆ Ethernet, USB, Serial
 - ◆ Built in GPS



Charging Station



- Programmable Load Emulates Vehicle
- Can Provide Any Value of Load
- Allows Multiple Tests to be Run Automatically

Electric Vehicle



- **Present Generation VERY difficult to test**
 - Devices may not display all HB44 parameters
 - Devices may require a transaction to start with removing the plug and end by replacing it
 - EVSEs require a account to charge, who pays
 - HB44 requires 6 to 10 tests, very slow if each requires a plug-unplug cycle.



• Industry working on a solution

- We need your help to make sure it works for you
- Issues are:
 - ◆ Need for universal authorization for inspectors
 - Must be secure
 - Access achieved through test equipment ????
 - ◆ Access to special test modes
 - Will these be acceptable to W&M
 - If these involve higher precision data access is that acceptable
 - ◆ Since energy can't be put back, who pays



Questions and Discussion



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This presentation can also be found under Meter Conferences and Schools on the TESCO website: www.tesco-advent.com

