# Session 6: Fundamentals of PEV (Plug-in Electric Vehicle) Charging Infrastructure

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*This presentation does not contain any proprietary, confidential, or otherwise restricted information*

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Idaho National Laboratory

# *Vehicle / Infrastructure Testing Experience*

- **Since 1994, benchmarked PEVs and chargers with data loggers in the field, and on closed test tracks and dynamometers**
  - **250 million test miles of data from 27,000 electric drive vehicles and 16,600 charging units**
  - **Telematics data logger systems used on 43,600 PEVs and charging units**
  - **EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC**
    - **4.2 million charge events, 124 million test miles. At one point, 1 million test miles every 5 days**

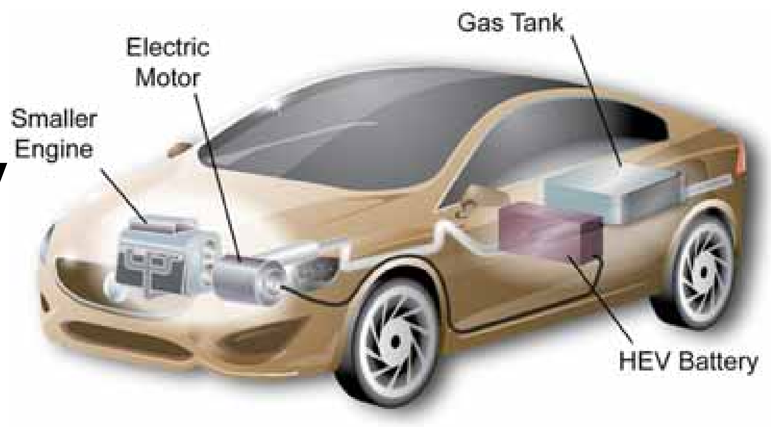
# *Areas of Concern with Transportation Oil Dependency – Long Term*

- **Energy security**
  - **Insufficient domestic supply of easily obtainable oil forces us to rely on imports**
  - **Global supply has reached "Peak Oil" (?)**
- **Global climate change**
  - **Tailpipe and smoke stack $CO_2$ emissions**
- **Economic stability**
  - **Unbalanced supply and demand affect all levels of the economy (global, national, personal)**

# *Light-Duty Vehicle Technology Summary*

- **ICE: Internal combustion engine vehicle**
  - **Gasoline, CNG or diesel fueled**
  - **No electric traction battery**

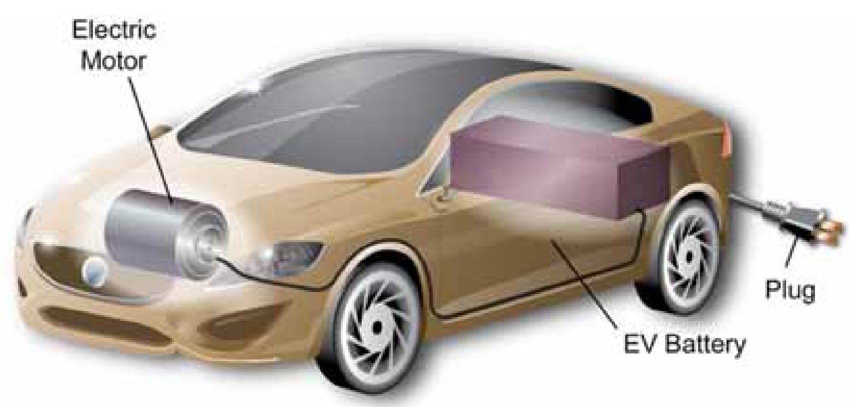

- **HEV: Hybrid electric vehicle**
  - **Gasoline fueled**
  - **Onboard energy sources gasoline and electricity**
  - **All energy originates from gasoline**
  - **Battery recovers braking energy and charged by the ICE**
  - **Electric motor provides propulsion assistance**



# *Vehicle Technology Summary*

- **PHEV: Plug-in hybrid electric vehicle**
  - **Gasoline & electricity fueled**
  - **Gasoline engine may not be used (All Electric Capable), or used in a Blended mode**
  - **When the battery is nearly empty, operates like a typical HEV**

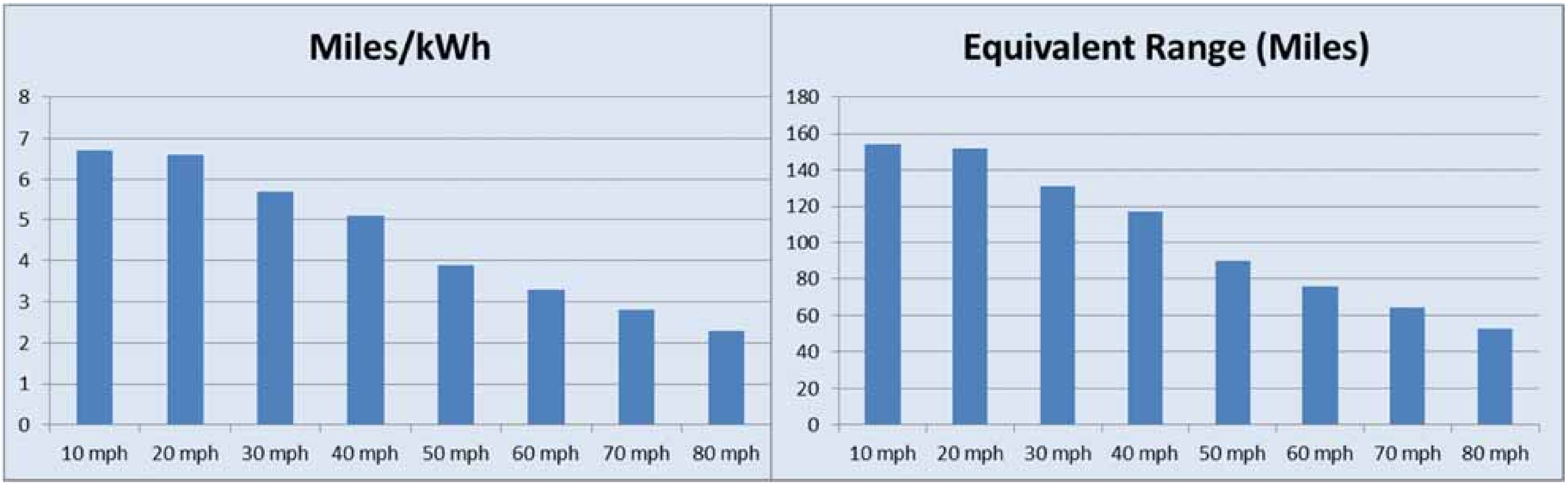

- **BEV: Battery electric vehicle**
  - **Electricity fueled**
  - **Electricity only onboard energy source**



# *Environmental and Speed Impacts on PEVs*

- All PEV ranges are impacted by:
  - Ambient temperatures,
  - Operating speed

- As an example: 2013 Ford Focus electric - dynamometer testing
  - UDDS at 72ºF = 4.1 miles / kW
  - UDDS at 20ºF = 1.7 miles / kW
- As an example: 2013 Ford Focus electric - Steady-State Speed (dyno) impact on efficiency and range



# EVSE Definition

- Electric vehicle supply equipment (EVSE)
  - A piece of equipment or device that allows a PEV to be safely connected to the grid
  - It is not a charger
  - It provides electricity to the PEV's on-board power electronics and on-board charger
  - Fleets, public access and residential locations

# *DCFC Definition*

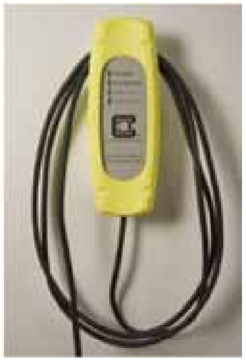
- **Direct Current Fast Charger (DCFC)**
  - **It is a charger that sites off-board the vehicle and it converts AC grid energy to DC vehicle energy**
  - **Larger and more expansive than EVSE, but it charges a PEV much faster**
  - **Provides electricity directly to the vehicle's battery**
  - **Requires sophisticated DCFC-to-PEV communication**
  - **Fleets and public access**

## *Charging Definitions*

- AC EVSE (on-board vehicle charger)
  - Level 1: 120V AC (up to 16 Amps, ~ 1.92 kW Max)
  - Level 2: 240V AC (up to 80 Amps, ~ 20 kW Max)
  - Level 3: > 20kW
  - Most PEVs have onboard chargers that operate at 3.3 or 6.6 kW
- DCFC Charging (uses off-board vehicle charger)
  - Level 1: Up to 20 kW
  - Level 2: Up to 80kW (type of DCFC in use today)
  - Level 3: >80kW (proposed)

## *Level 1 Charging Level*

- PEV charged by plugging into 120 V electrical outlets
- Charge Times (general approximation)
  - BEV: 14 hours (20 kWh battery) to 39 hours (56 kWh battery)
  - PHEV: 2 to 10 hours (depends on battery size)
  - As BEV battery packs grow in size, Level 1 may not be suitable for future charging
  - Consider sizing EVSE for future batteries
- Portable cord set that must utilize a UL approved SAE J1772 vehicle connector, GFCI, and otherwise meet NEC 625 requirements



## *Level 2 Charging Level*

- **Most common method for PEV charging**
- **Charge times (general approximation)**
  - **20 kWh BEV battery 3 hours (at 6.6 kW) to 56 kWh battery in 8.5 hours (at 6.6k kW)**
  - **PHEV 1 to 5 hours (at 3.3 kW)**
- **Suited better than Level 1 for charging today's larger battery packs and the future's even larger battery packs**
- **AC energy transfer to the onboard charger**
- **Permanently attached wall box, GFCI, some vehicle communication, UL approved, NEC 625 requirements and SAE standards, including J1772 connector:**






# *DC Fast Charger (DCFC)*

- For Navy PEVs, two DCFC technologies exist
  - Japanese CHAdeMO protocol connector
  - SAE standard connector
  - They are not compatible. The DCFC technology must match the PEV charge port
  - Some DCFC contain both technologies in the same unit
- Charge Times are dependant on battery size
  - 20 kWh BEV 50% recharge in at least 20 minutes and 80% recharge in at least 30-40 minutes
  - Charge times dependant on charger / battery relative sizing and temperatures
  - Not used for PHEVs due to small relative battery sizes
  - Common use: fleets, intercity grid pattern, or travel routes between cities in commercial settings
  - Off-board charger (high cost, large volume and weight)

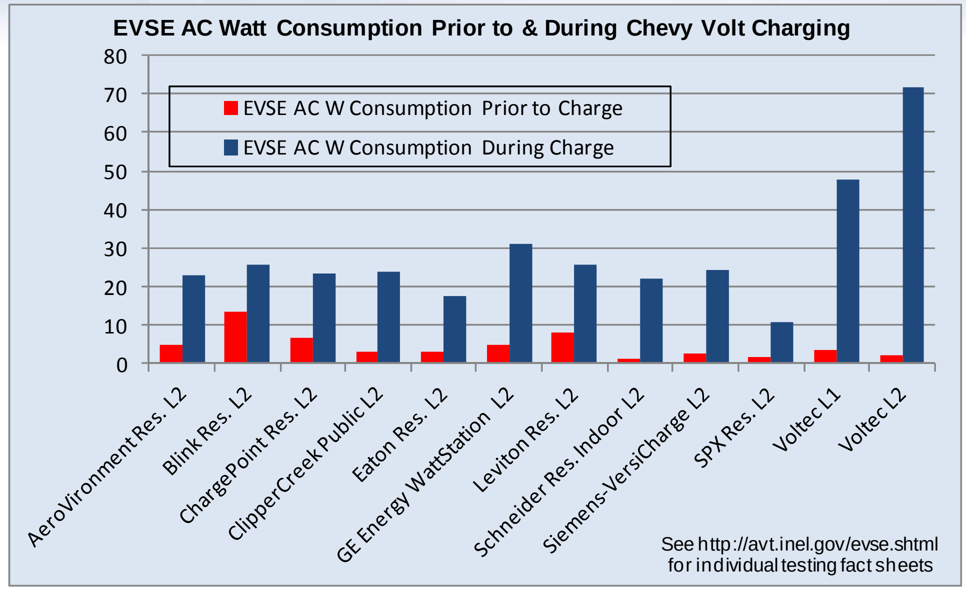
# DCFC Capable Vehicles

- **DCFC Capable (all BEVs)**
  - **BMW i3 – CCS (SAE Combo Connector Standard)**
  - **Chevrolet Spark – CCS**
  - **Mitsubishi i-MiEV – CHAdeMO**
  - **Nissan Leaf – CHAdeMO**
  - **Kia Soul – CHAdeMO**
  - **Other OEMs may offer**

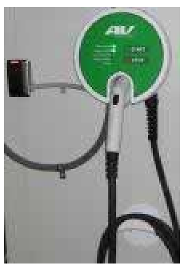
- **EVSE Level 2 Capable**
  - **Above BEVs and all other BEVs and PHEVs**
- **EVSE Level 1 Capable**
  - **All BEVs and PHEVs**

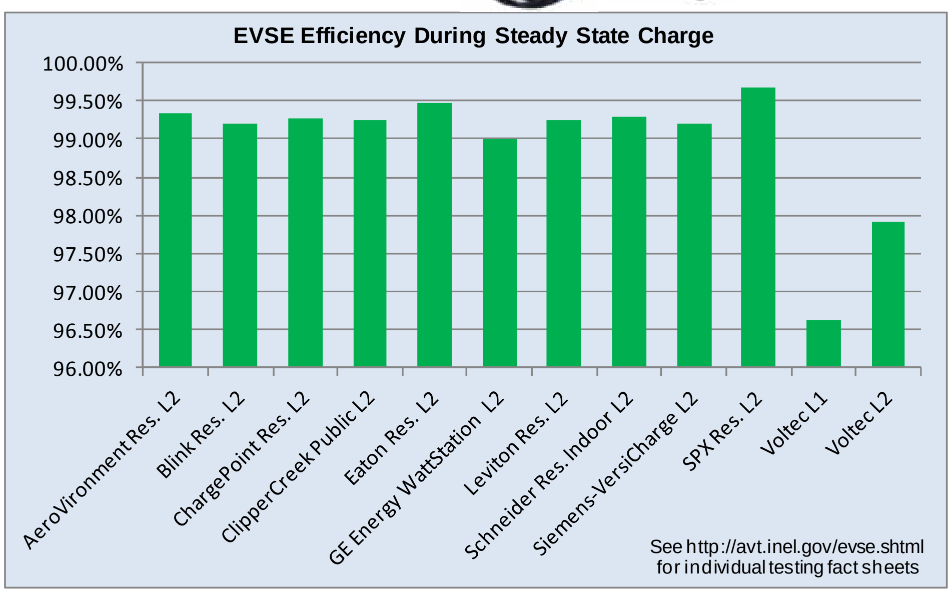
# *Level 2 EVSE Testing*

- **99%+ efficiency**
- **AC energy consumption at rest and during Volt Charging benchmarked**











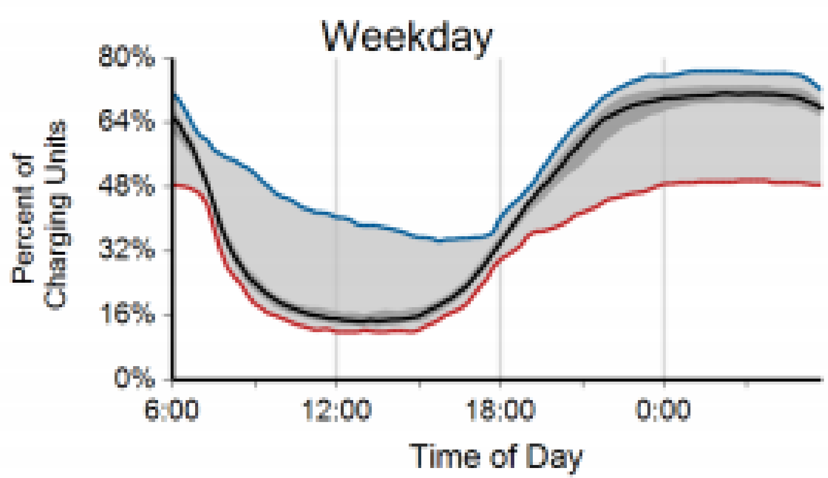
- **Most EVSE consume 13 W or less at rest**
- **Power use tied to features**
- **Most EVSE under 30 W during charge**

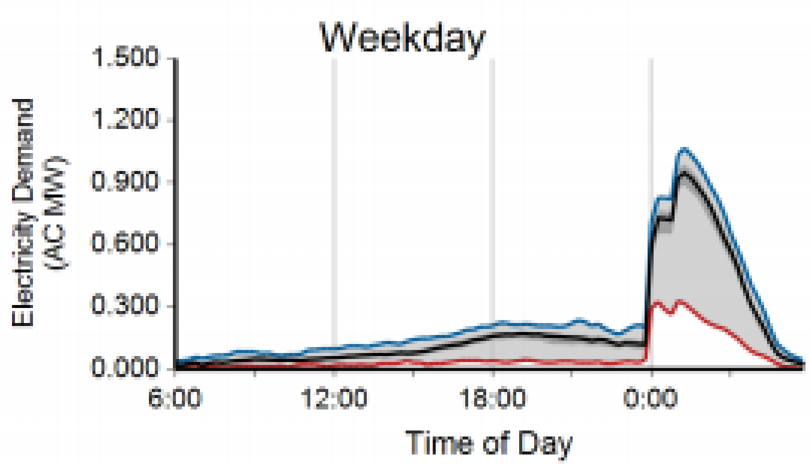
# DCFC Testing

- 9% to 86% increase battery state-of-charge in 32 minutes
- 88.7% Overall charge efficiency (480VAC to ESS DC)
- 53.1 AC kW peak grid power
- 47.1 DC kW peak charge power to the Leaf
- 15.0 Grid AC kWh and 13.3 DC kWh delivered to the Leaf
- Used a Hasetec DCFC for testing

# *Time-of-Use (TOU) Charging*

- TOU electricity rates and other considerations may require charging starts hours after connection times
- Smart EVSE should have charge time controls
- Most PEVs have charge time controls
- Charging start times can be controlled either way
- In the EV Projects' San Diego region, TOU was available
  - Left graph shows connection times
  - Right graph shows charging start times



# *Time-of-Use (TOU) Charging*

- **Delayed charging start times can be as simple as pushing a button 1, 2, 3, or 4 times**
- **Or, programing the vehicle or EVSE by drivers**


# *Charging Infrastructure Summary*

- time to charge from 20%
- AC Level 1
  - 1.4 kW, 2 to 39 hours
  - 120V/15-20A outlet typical
  - Typically portable

- AC Level 2
  - 3.3 and 6.6 kW, 1 to 8.5 hours
  - 240V/20-40A outlet typical
  - Fixed location

- DC Level 2 (DC Fast Charge)
  - 50 kW, 30 to 40 minutes
  - 480 V, 3-phase (industrial power)
  - Large, fixed location, $$$


- Plan for future PEVs, with possibly larger battery packs

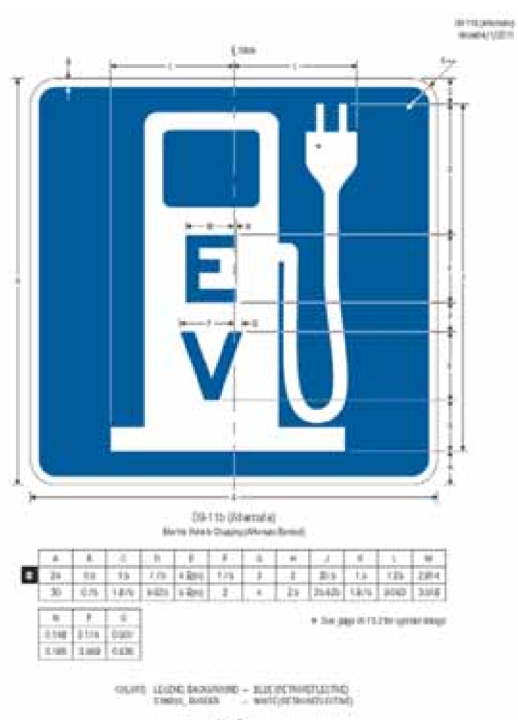
# *Additional Slides*

# *Site Considerations*

- **Geographic Coverage / Planning**
- **Local attraction(s)**
- **Proper charger level for location**
- **ADA Requirements**
- **Lighting / Security**
- **Signage**
- **Access**
- **Local Permitting Authority**

# Signage Examples






# *Fixing America's Surface Transportation (FAST) Act*

- **With the recent passage of the FAST Act, Federal agencies will have greater flexibility in providing EV charging services for their employees.**
- **FAST authorizes GSA and other Federal agencies to install and operate EV charging stations for privately owned vehicles in parking areas used by Federal employees, and allows the collection of fees to recover these costs**
- **The Executive Branch has started a working group**

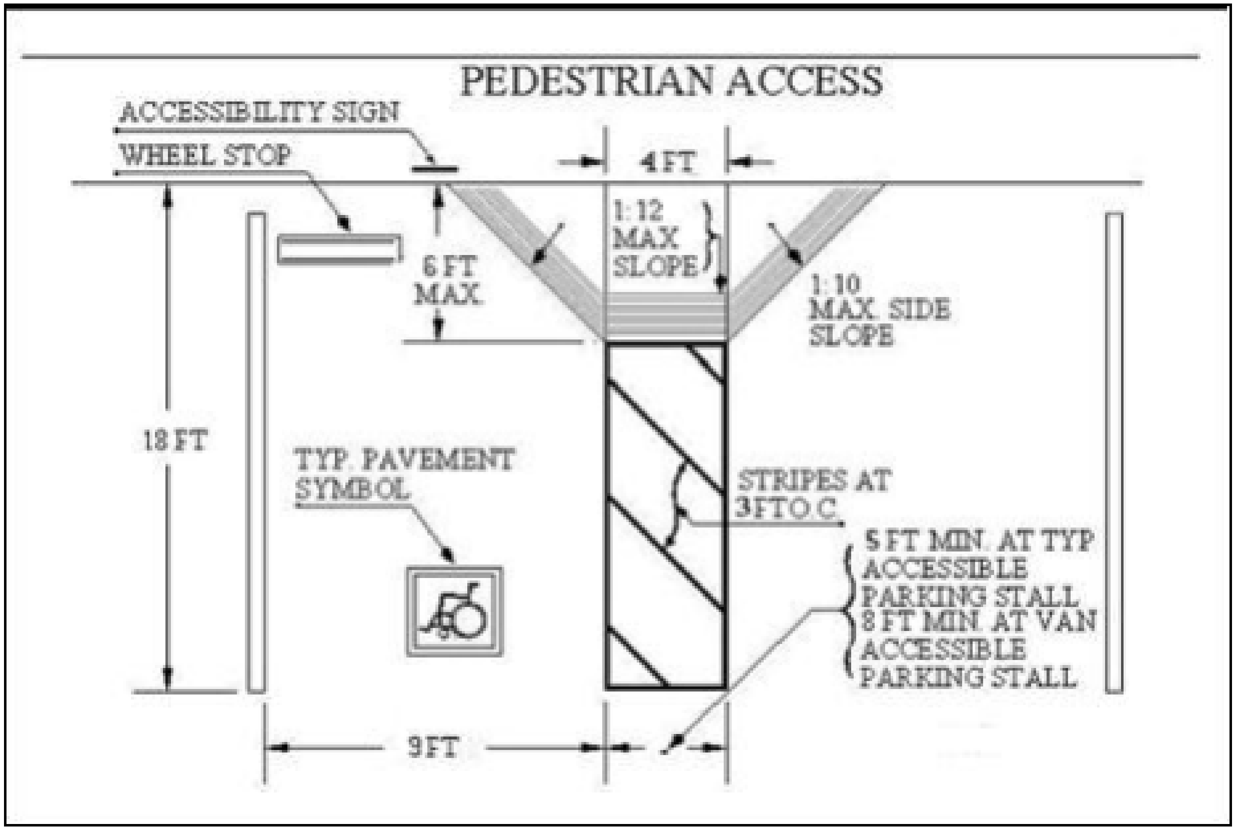
# Parking Bollards?


# Disabled Parking Considerations

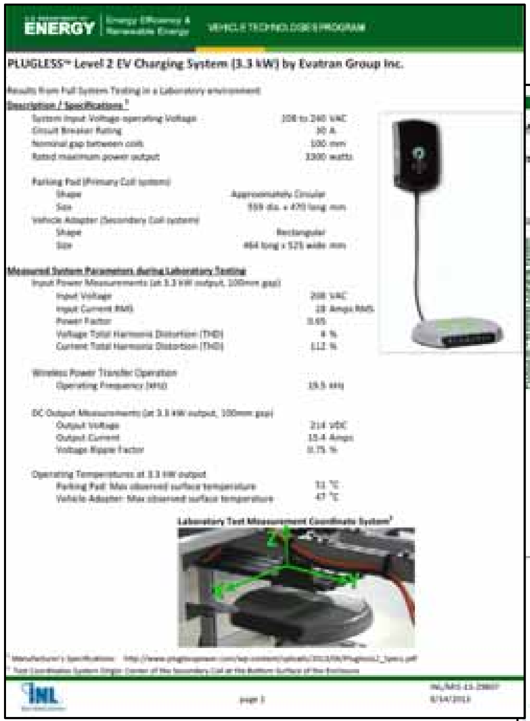
- **Recommendations to enable persons with disabilities to have access to a charging station per ADA and IBC (International Building Code):**
  - **An accessible space is required to park, exit vehicle and access the EVSE. The accessible charging station space should be 96" wide 60" wide access aisle similar to a standard ADA space**
  - **Operable controls within 48" front and side reach range; and a 30" x 48" clear floor space is required**
- **If an accessible EVSE is located at a site with other amenities, such as a coffee shop, the space needs to be connected by a minimum 36" wide accessible route to the entry of the building. Maximum 1:20 (5%) running slope and 1:48 (2%) cross slope**

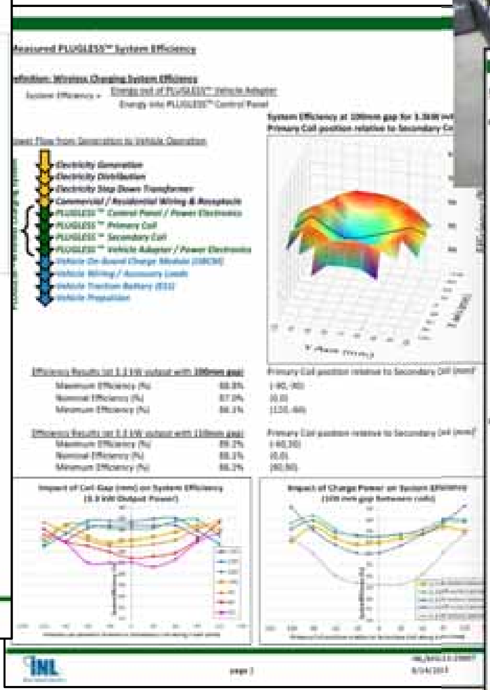
# Disabled Parking Considerations

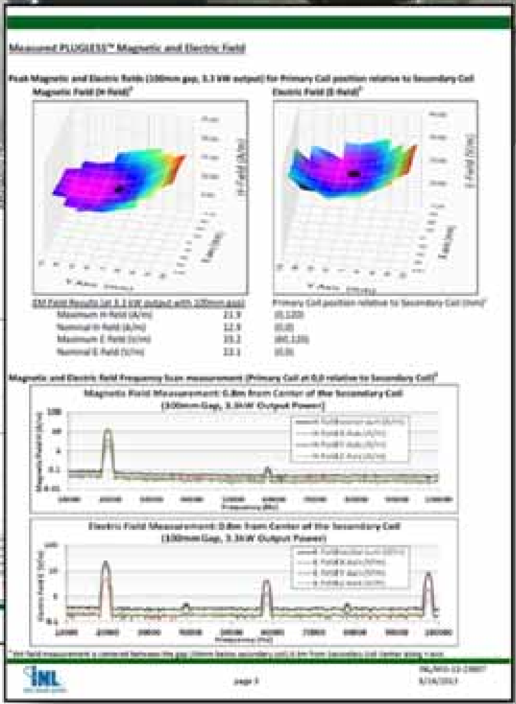
- **In general, for every 25 parking spaces, one parking space should be accessible. For every six parking spaces that are accessible, one parking space should be van accessible**
- **See:**
  **http://avt.inel.gov/pdf/EVProj/EVProjectAccessibilityAtPublicEVChargingLocations.pdf**



# *Wireless Power Transfer Brief Discussion*


**http://avt.inel.gov/evse.shtml**

# *Additional Information*

**For publications and general PEV and charging infrastructure information, visit http://avt.inl.gov**