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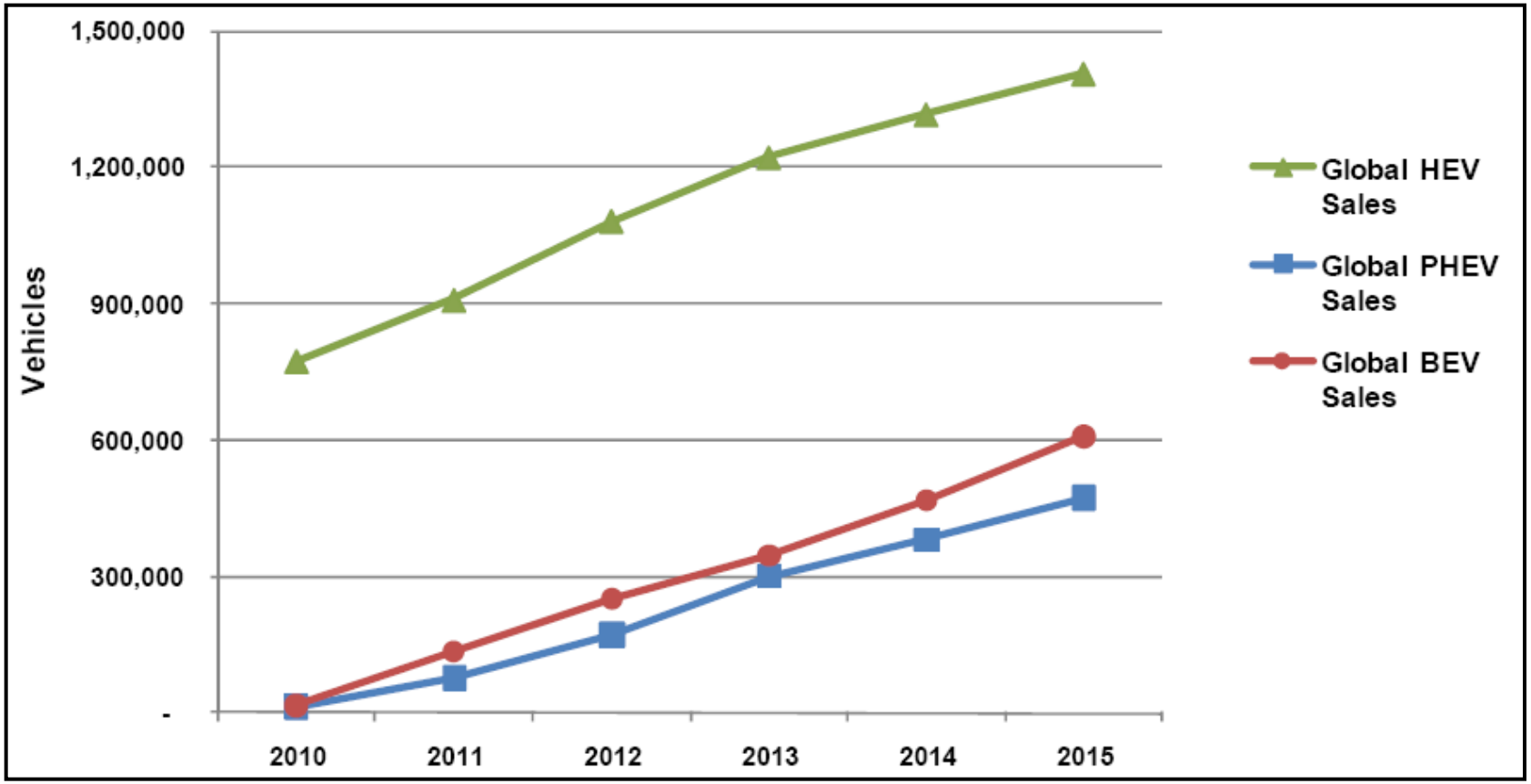
Electric Vehicle Infrastructure:
Getting Ready for the Perfect Electrical Storm

Mike Dixon, Eaton Corporation

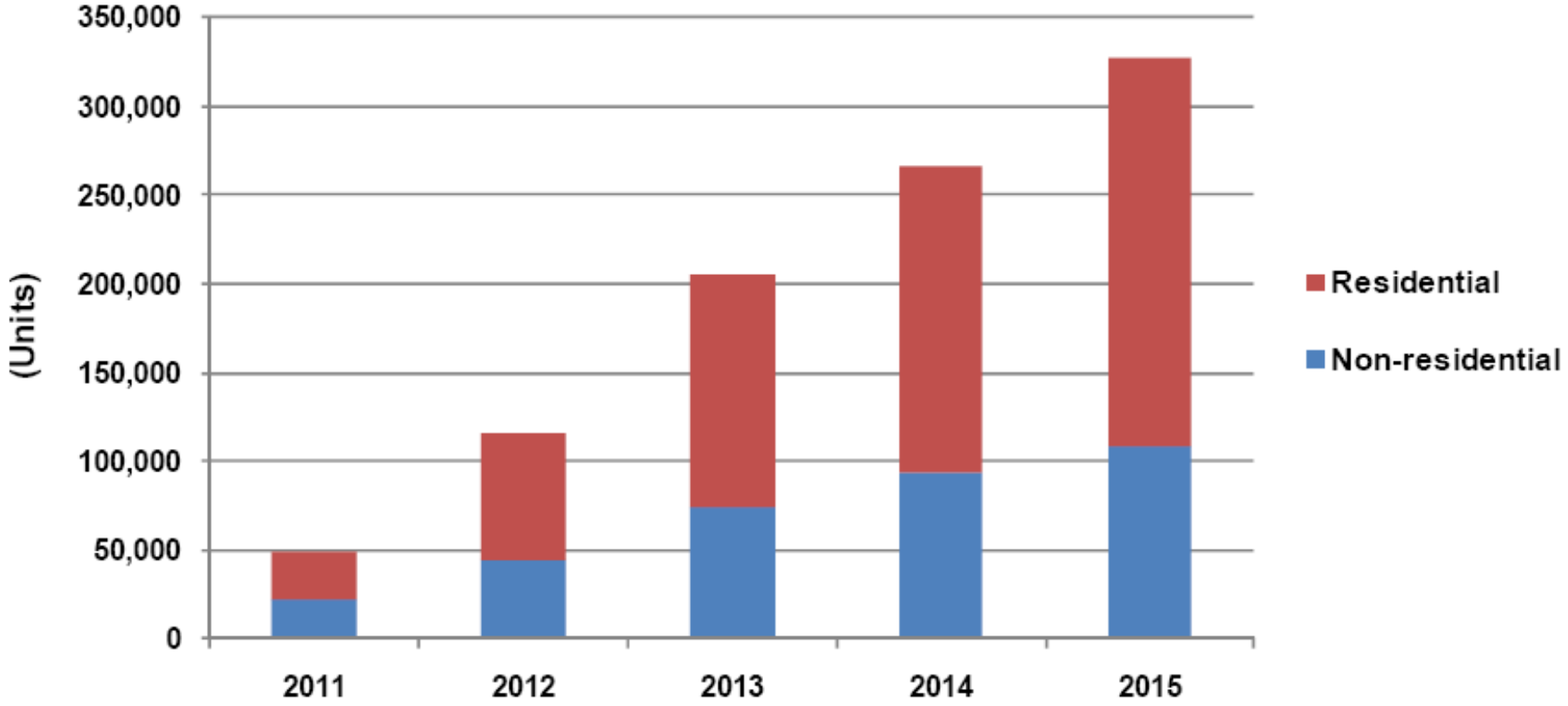
8 Aug 2011

Total Electrified Vehicle Sales, World Markets: 2010 - 2015



Source: Pike Research, Published 3Q 2010

Annual EV Charging Equipment Sales, United States: 2011-2015



Source: Pike Research, Published 3Q 2010

EVs On The Road

Nissan LEAF

Chevy Volt

Tesla Roadster

…And More To Come In The Future

Kia Venga

Mitsubishi i

Toyota Prius

Ford Focus

Honda Fit

BMW ActivE

What's What? Understanding Terminology

Hybrid Electric Vehicle

Plug-in Hybrid Electric Vehicle

Electric Vehicle or
Battery Electric Vehicle

Battery Information

- Lithium Ion (Li-ion)
  - ✓Other batteries (lead acid and nickel metal hydride) cannot match the weight-to-power ratio of Li-ion
  - ✓High nominal voltage (3V to 4V)
- Driving Range
  - ✓ Most EV's can only go about 40-100 miles before recharging
    - Most gasoline vehicles can go over 300 miles before refueling

How an EV Charges

- EVSE
  - ✓ Electric Vehicle Supply Equipment
  - ✓ General term used for all of the equipment used to supply electricity to the car
  - ✓ Eaton's EVSE is called 'Pow-R-Station'
- Can be found in residential, commercial or industrial settings

Understanding DC vs. AC

- Batteries store DC energy
- Two varieties of EVSE – DC & AC
- Two ways to fill a battery with DC energy
  - ✓ Push DC energy directly into a battery
  - ✓ Supply AC energy for the car to convert to DC

DC Charging Port

Goes directly to battery. DC EVSE is the battery charger.

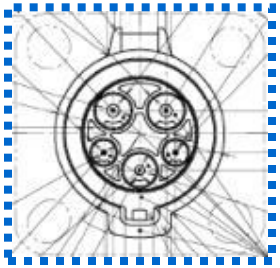
AC Charging Port

Goes to the on-car battery charger. AC EVSE is the most common type.

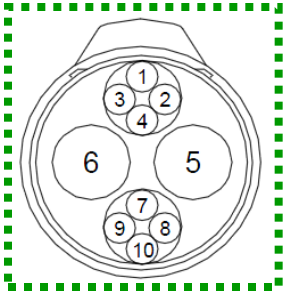
Nissan LEAF Charging Ports

EVSE Charging Levels

	Volts	Amps (up to)	kW	Current Eaton Offerings
AC Level 1	120Vac	20	2	✓
AC Level 2	240Vac	80	20	✓
AC Level 3	Undefined, likely 3-Phase			
DC Level 1	400Vdc	80	30	
DC Level 2	400Vdc	150	60	✓
DC Level 3	Undefined, high power			



J1772™ Connector for AC Charging



CHAdeMO Connector for DC Charging

Charging Levels Compared

- AC Level 1 (120 VAC, 20 amps)
  - \+ Convenient
  - \+ Economical
  - – Extended charging time
- DC Level 2 (400 VDC, 150 amps) alleviates range anxiety
  - \+ Convenient (when available)
  - \+ Fast
  - – Expensive
- The AC Level 2 (240VAC, 80 amps) = sweet spot
  - ± Moderate charge rate
  - ± Moderate cost
  - ± Moderate convenience

EV Charging Stations

Level 1	Level 2	DC Quick Charger

Level 1 and Level 2 EVSE
Applications- High Level of Versatility

- Single Family Homes
- Multi Family Homes
- University campuses
- Restaurants
- Airports
- Parking garages
- Municipalities
- Utility companies
- Shopping centers
- Corporate offices
- Hotels
- Truck stops

DC Level 2 EVSE
Applications

- Commercial and industrial gas stations
- Interstates corridors
- Municipalities
- Shopping centers
- Restaurants
- University campuses

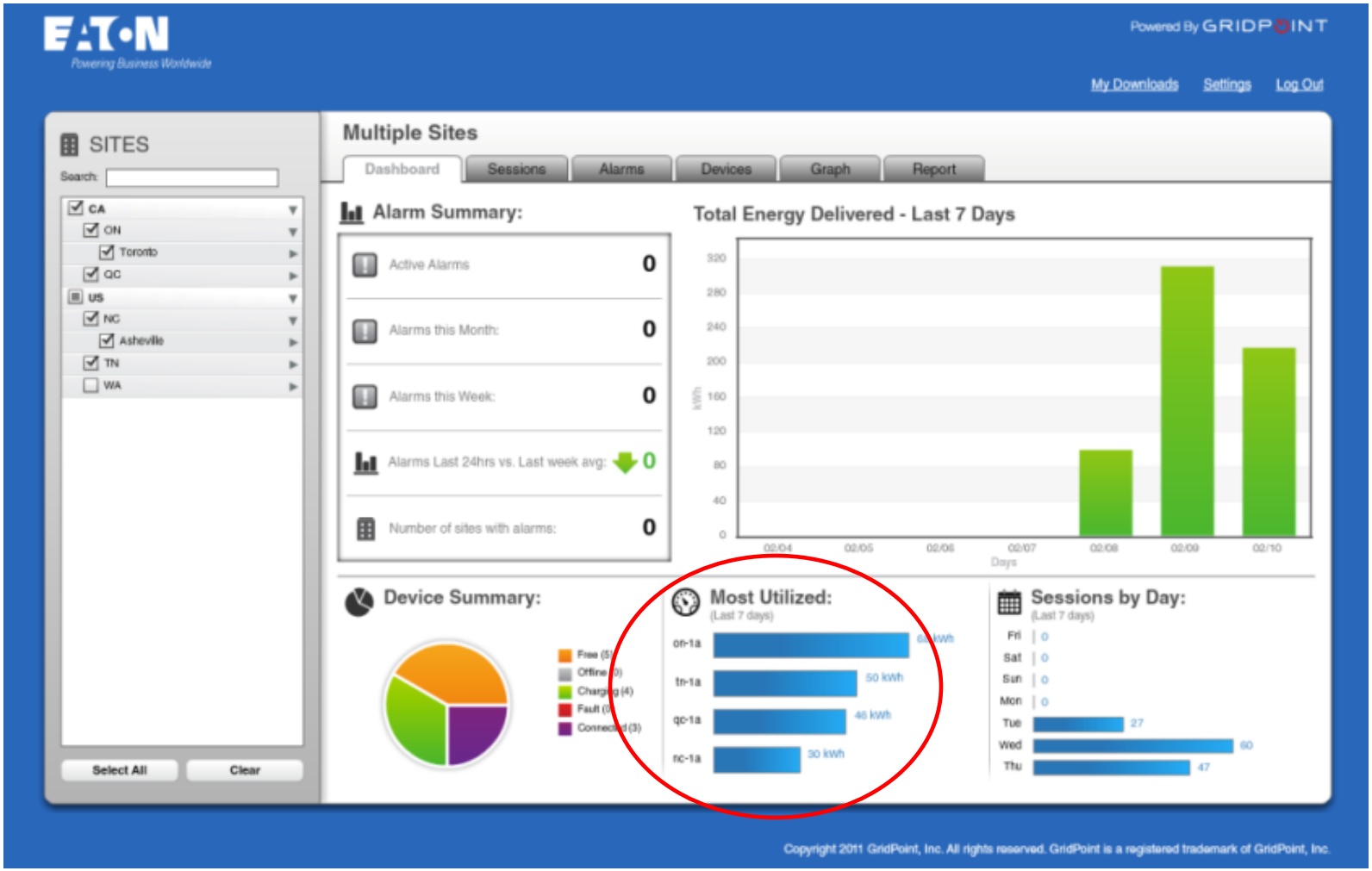
Communication Options

- Network manager (upgrade)
  - ✓ For managing multiple stations and sites
- Embedded webserver (standard)
  - ✓ For managing individual units
- Modbus RTU via RS-485 port (standard)
  - ✓ For integrating with building management system
- Modbus TCP/IP via RJ45 port (standard)
  - ✓ For integrating with building management system

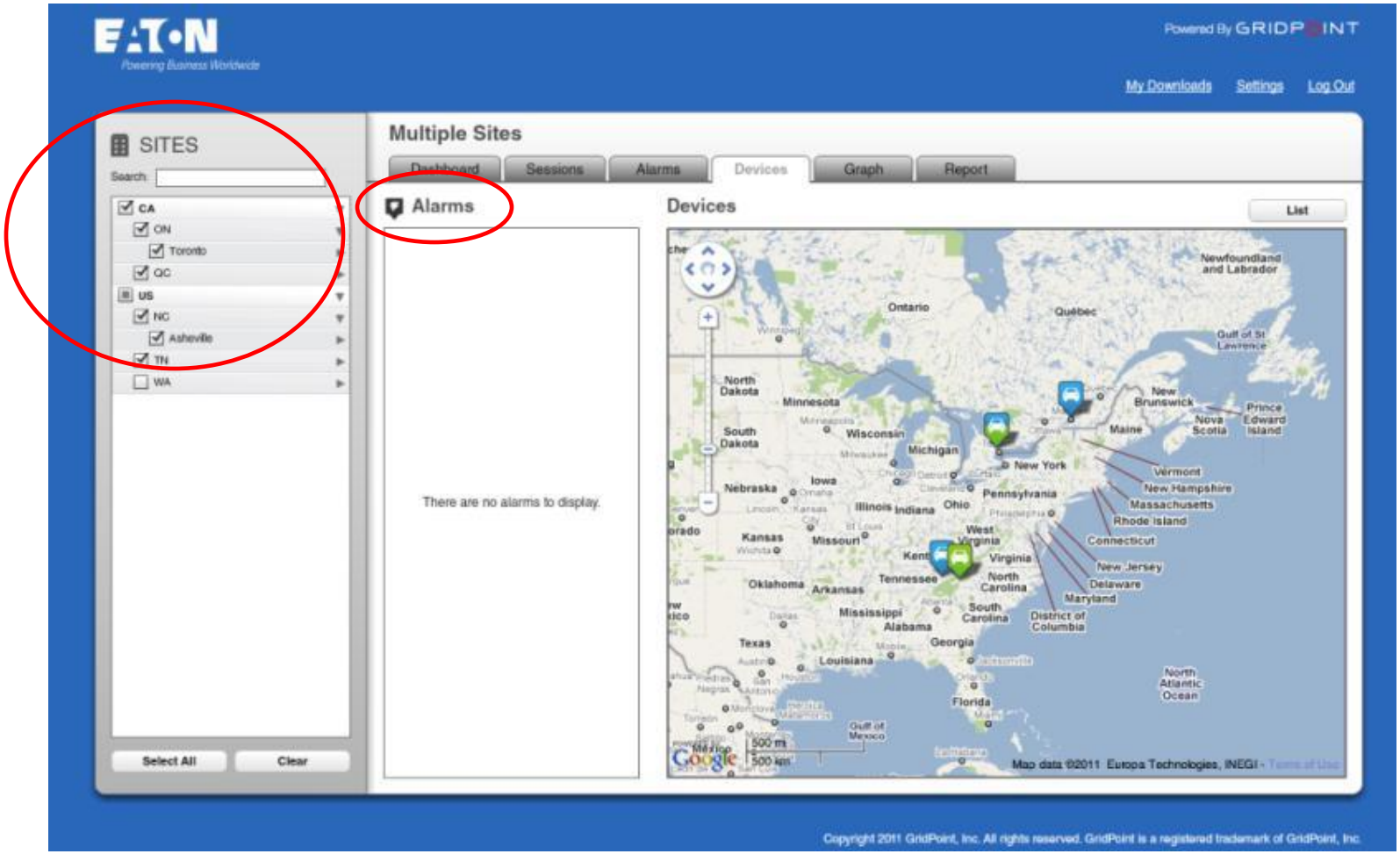
Network Manager

- Manage multiple installations simultaneously
- React to and prioritize key alerts and events
- Quickly digest aggregate system performance
- Check the status of charging stations
- Manage and control the timing and pace of vehicle charging
- Map charging station locations and statuses

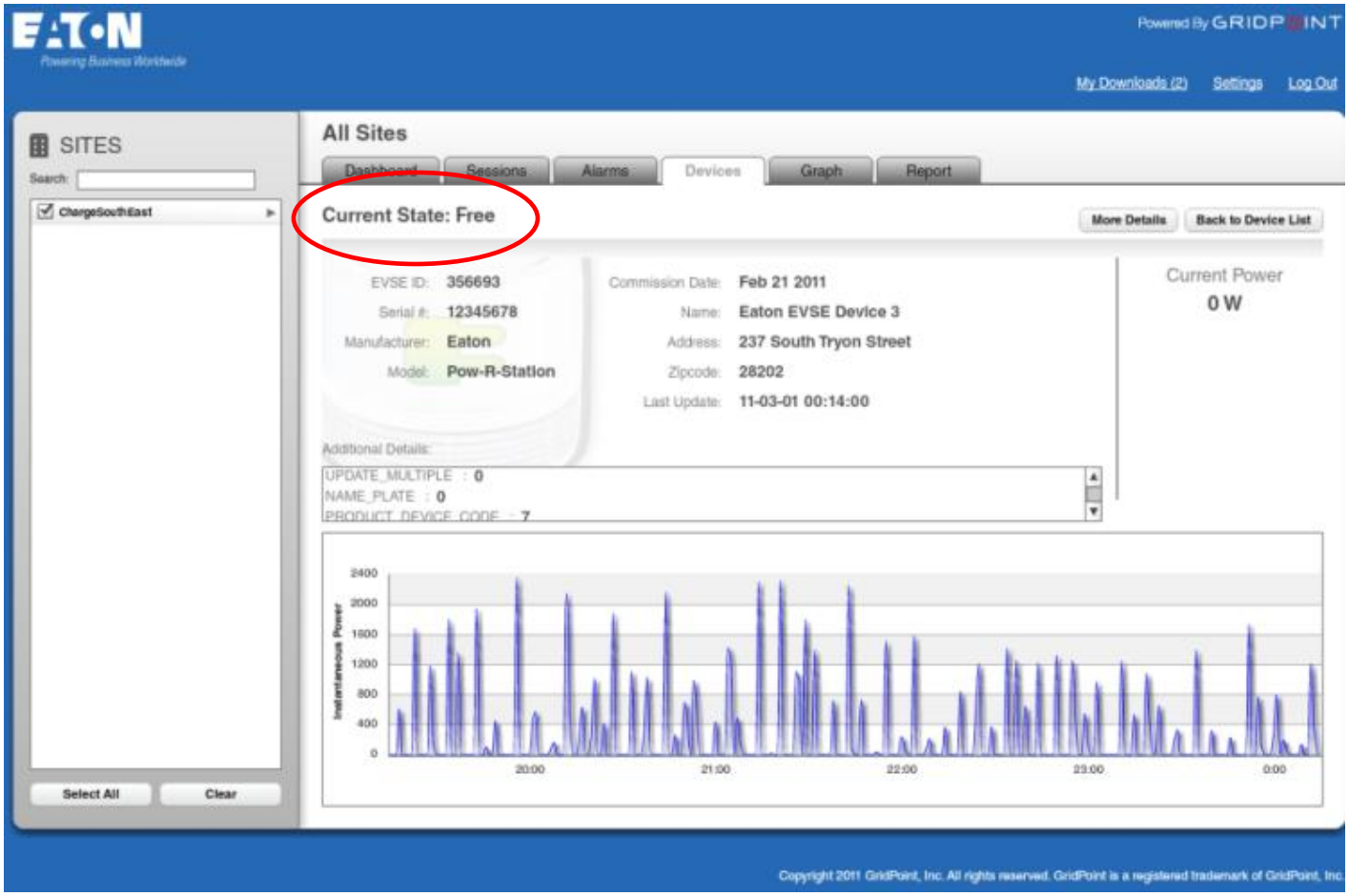
Network Manager



Network Manager



Network Manager



Site Evaluation and Installation

NFPA 70, Article 625

- NEC 2011
  - ✓ No change from NEC 2008
- Electrical conductors and equipment external to an EV
- Installation of equipment and devices related to electric vehicle charging

"Overcurrent protection for feeders and branch circuits supplying electric vehicle supply equipment shall be sized for continuous duty and shall have a rating of not less than 125 percent of the maximum load of the electric vehicle supply equipment."

- Article 625.21

NFPA 70, Article 625

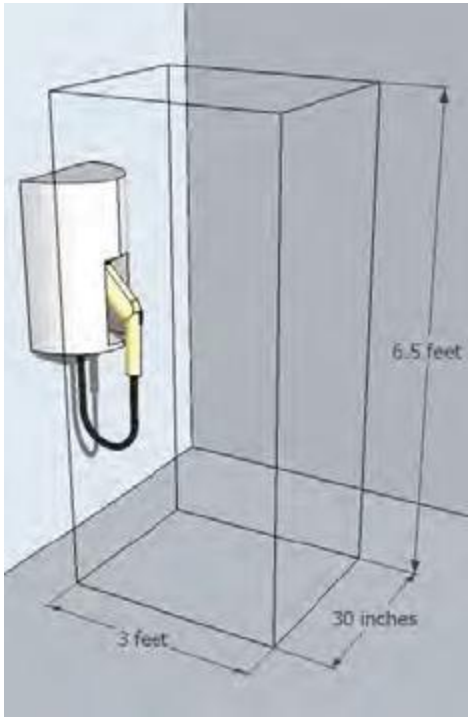
- Overcurrent protection for feeders and branch circuits
  - ✓ Sized for continuous duty
  - ✓ Rating of not less than 125% of the maximum load of the EVSE
- A load study of the location's electrical service may be needed to determine the availability of adequate electrical service

NFPA 70, Article 625

- Take the nameplate amperage rating of the Pow-R-Station, and multiply by 125% for the minimum upstream circuit protection needed
  - ✓ Typical for Level 2
    - 30 amp nameplate
    - 40 amp breaker
- Disconnect unneeded for Pow-R-Stations <60A
- Check the local jurisdiction for any other code requirements

General Requirements

- Connector Height
  - ✓ NEC Requirement: 24” to 48” from ground
  - ✓ Recommendation: 36” to 48” from ground
- Enclosure Height
  - ✓ Recommendation: Above 36”
- Space around enclosure
  - ✓ Width: 30”
  - ✓ Depth: 3’
  - ✓ Height: 6’6”



Site Evaluation
General Requirements

- Panel
  - ✓ Ensure panel is adequate for EVSE
  - ✓ Determine if upgrade is necessary
- Tripping Hazards
  - ✓ Avoid cord intersections with typical walking paths
  - ✓ Cord should not drape over/wrap around vehicle
  - ✓ Identify with signage in public locations

General Requirements

- Physical Damage Prevention
  - ✓ Placement out of the line of vehicle travel if possible
  - ✓ Wheel stop
  - ✓ Bollard
- Lighting
- ADA Accessibility- Public places

Site Evaluation
Cord Management

Damage Protection - Bollards

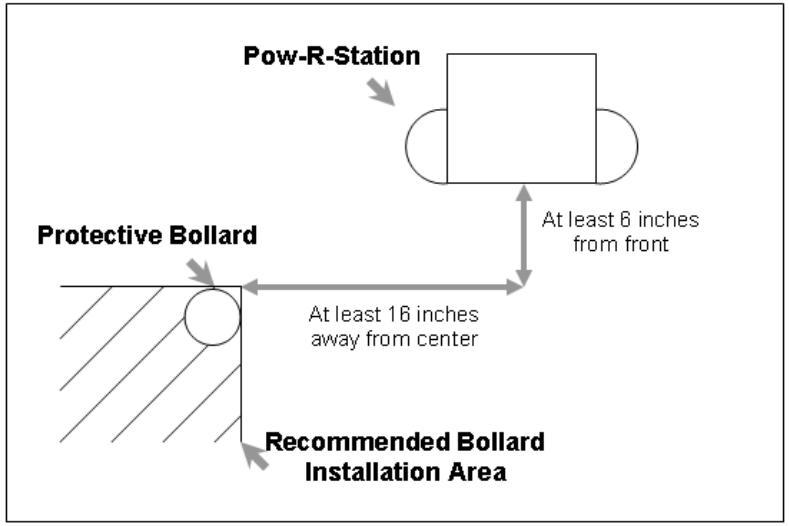


Figure 6: Protecting the Pow-R-Station with Bollards

Vehicle Inlet Locations

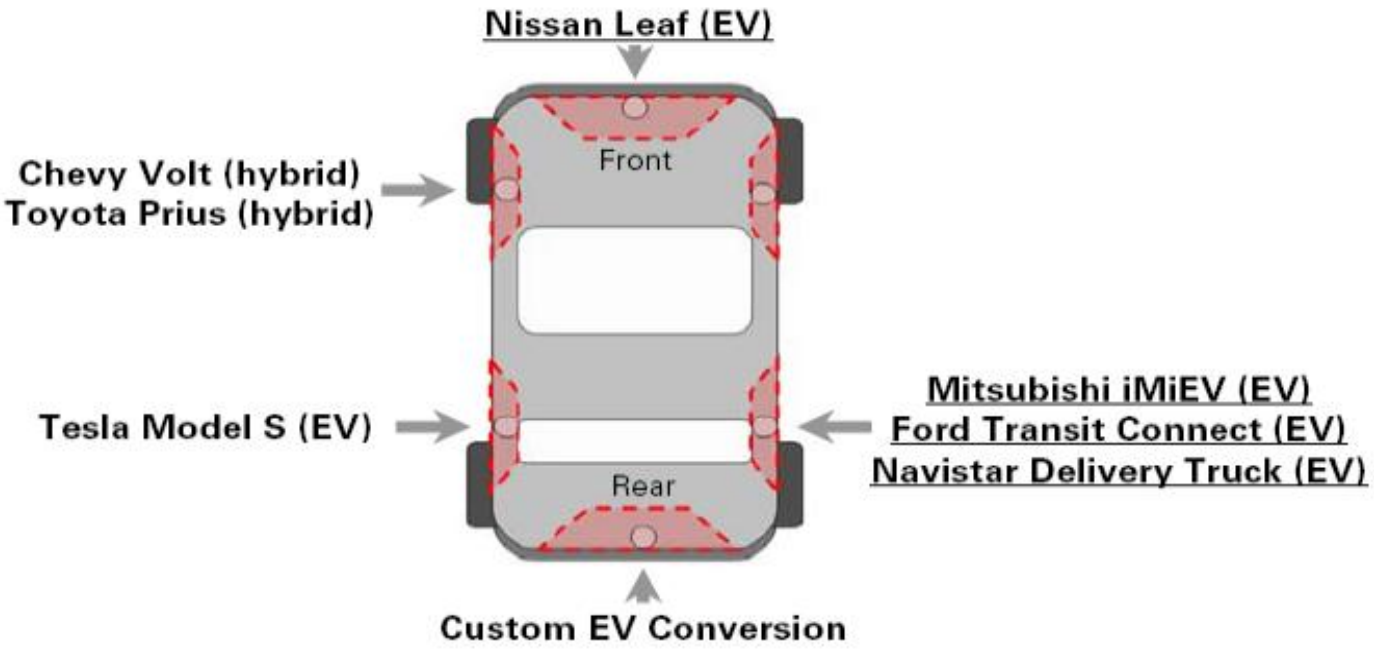


Image 1: Vehicle Inlet Locations Differ by Manufacturer

Locations of inlet vary based on vehicle.

Factors To Consider- Parking Decks

- Visibility
- Proximity to building entrance
- Proximity to power source
- Length of parking space
  - ✓ Must not shorten space below zoning requirement
  - ✓ Longer is preferred

Factors To Consider- Parking Decks

- Width of parking space
  - ✓ Wider is preferred
- Weather
  - ✓ Interior spaces reduce weather damage
- Available space
  - ✓ Floor
  - ✓ Walls
  - ✓ Ceiling

Factors To Consider- Parking Lots

- Visibility
- Proximity to building entrance
- Proximity to power source
- Existing infrastructure and landscaping
- Assume head-in parking for consistency

Factors To Consider- Parking Lots

- Length of parking space
  - ✓ Longer is preferred
  - ✓ Installation must not shorten space below zoning requirement
- Multiple cords (Level 1 Pedestal)
  - ✓ Direct access from each parking space to EVSE
- Width of parking space
  - ✓ Wider is preferred

Factors To Consider- On-Street Parking

- Visibility
- Proximity to power source
- Existing infrastructure and landscaping
- Available mounting spaces

Factors To Consider- On-Street Parking

- Pull-In
  - ✓ Front
  - ✓ Centered or between two spaces
- Parallel
  - ✓ Front third
  - ✓ Direction of traffic flow

It’s more than just an EVSE…It is an extension of the distribution system.

Some installations may be easy, but others may require service or equipment upgrades.

Utility → Meters → Loadcenters → Circuit Breakers → Disconnects → EVSE

Site evaluation is your opportunity to identify these needs.

Questions???

Mike Dixon, Eaton Corporation

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BACK UP CHARTS

EV Advantages vs. ICE

- Improved fuel economy
  - ✓ Electric motors convert 75% of the chemical energy from the batteries to power the wheels
    - ICEs only covert 20% of the energy stored in gasoline
- Lower emissions while driving
  - ✓ Emit no tailpipe pollutants
- Quieter ride, smooth operation and stronger acceleration
- Requires less maintenance than ICEs

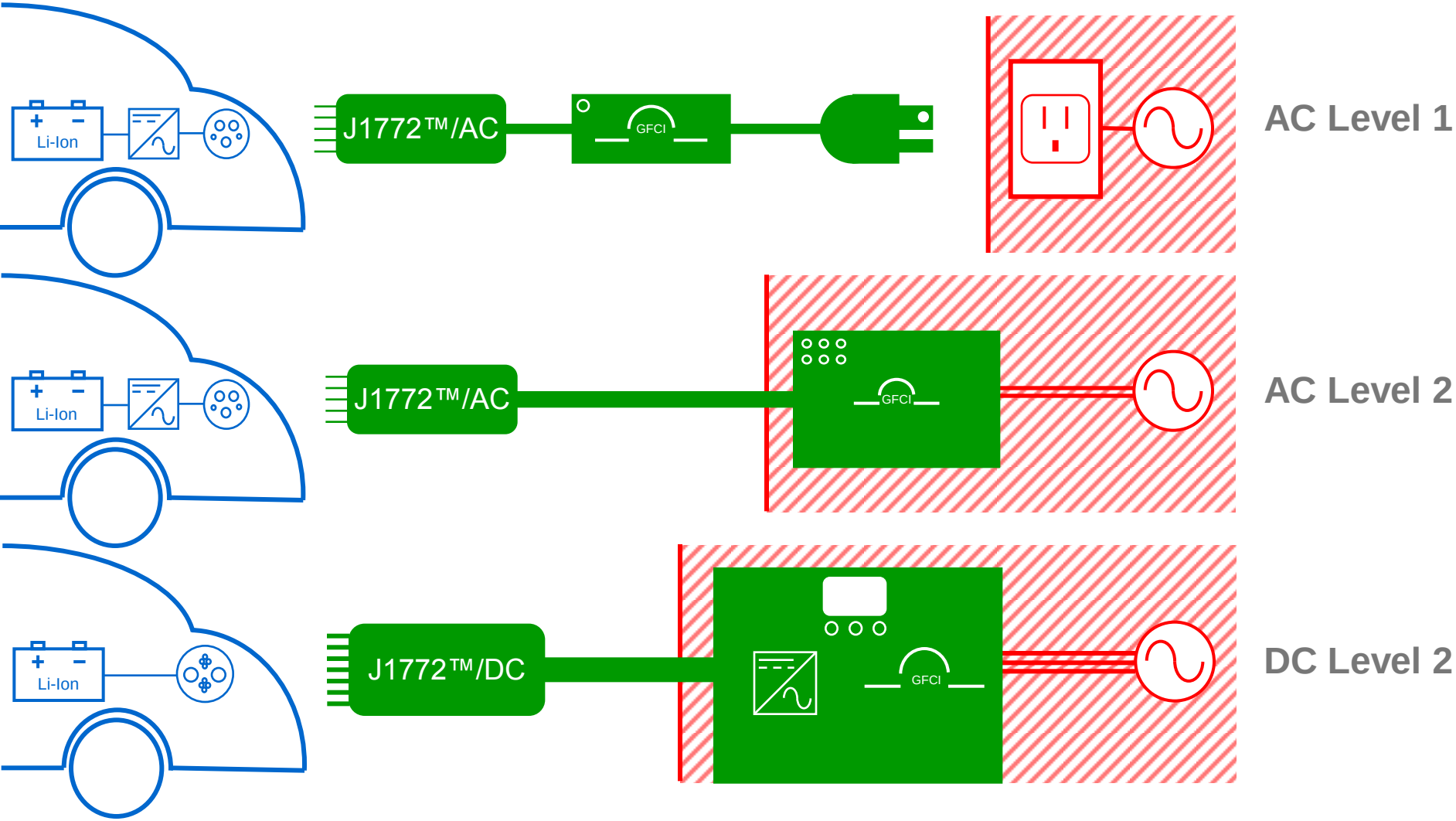
Basic Definitions

- Pilot
  - ✓ The handshake signal through the J1772 connector
  - ✓ Signal tells vehicle and EVSE when they are ready to charge
  - ✓ Tells the vehicle the Available Line Current (ALC)
- Plug Session
  - ✓ The time while the EVSE is plugged into a vehicle
  - ✓ It starts by plugging in the J1772 connector and ends when unplugging the same connector
- Traction Battery
  - ✓ The large battery on a plug-in electric vehicle that is used to store and release energy for propulsion
  - ✓ Different than the 12V battery that is used to start the vehicle initially and run accessories such as the radio

J1772™ Connector for Charging EV's

The under-carriage of the Nissan LEAF contains the traction battery

Charging an EV
Vehicle, EVSE, and Premise Relationship



AC Bottleneck = Lesser of EVSE Output and Rectifier Max Charge Rate

Volts x Amps = Max EVSE Output

Capacity of Battery

				Leaf ('12)
			EV Range (miles)	100
			Capacity (kW h)	24
			Max Rate (kw)	6.6
V	**A**	**kW**		
120	12	1.4	AC L1	17
240	16	3.8	AC L2 - 16A	7
240	30	7.2	AC L2 - 30A	4
240	70	16.8	AC L2 - 70A	4
208	150	31.2	DC L2 - 208v	0.77
500	125	62.5	DC L2 - 500v	0.39

Max Rate AC-DC Rectifier Can Charge the Battery

$$\frac{\text{Battery Capacity}}{\text{Bottle Neck}} = \text{Hours to Charge}$$

DC = Limited By EVSE Output

Volts x Amps = Max EVSE Output

Capacity of Battery

				Leaf ('12)
			EV Range (miles)	100
			Capacity (kW h)	24
			Max Rate (kw)	6.6
V	**A**	**kW**		
120	12	1.4	AC L1	17
240	16	3.8	AC L2 - 16A	7
240	30	7.2	AC L2 - 30A	4
240	70	16.8	AC L2 - 70A	4
208	150	31.2	DC L2 - 208v	0.77
500	125	62.5	DC L2 - 500v	0.39

$$\frac{\textbf{Battery Capacity}}{\textbf{Max EVSE Output}} = \textbf{Hours to Charge}$$

How Fast Does It Charge? It Depends!

				Leaf ('11)	Leaf ('12)	Volt	Tesla	i-MiEV	Prius EV
			EV Range (miles)	100	100	40	200	75	10
			Capacity (kW h)	24	24	10.4	53	20	2.5
			Max Rate (kw)	3.3	6.6	3.3	16.5	3.3	3.3
V	**A**	**kW**		**Charge Time in Hours**					
120	12	1.4	AC L1	17	17	8	37	14	2
240	16	3.8	AC L2 - 16A	8	7	4	14	7	0.76
240	30	7.2	AC L2 - 30A	8	4	4	8	7	0.76
240	70	16.8	AC L2 - 70A	8	4	4	4	7	0.76
208	150	31.2	DC L2 - 208v	0.77	0.77	NA	1.7	0.65	NA
500	125	62.5	DC L2 - 500v	0.39	0.39	NA	0.85	0.32	NA

*** Estimates based on published / projected / or assumed specifications**

How Fast Does It Charge? It Depends!

	Leaf ('11)	Leaf ('12)	Volt	Tesla	i-MiEV	Prius EV
EV Range (miles)	100	100	40	200	75	10
Capacity (kW h)	24	24	10.4	53	20	2.5
Max Rate (kw)	3.3	6.6	3.3	16.5	3.3	3.3

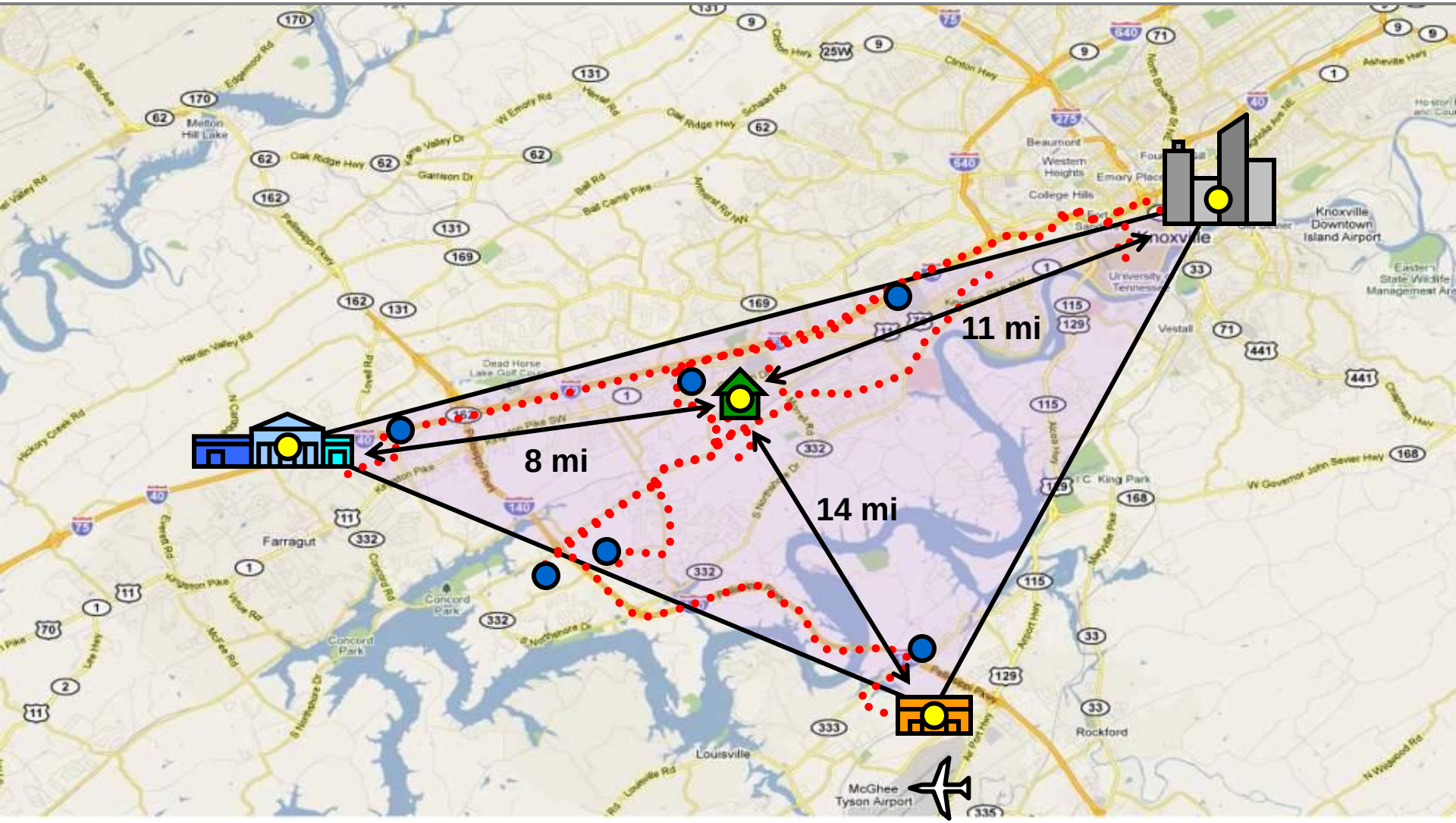
V	A	kW		Miles Charged Per Hour					
120	12	1.4	AC L1	5.9	5.9	5.0	5.4	5.4	5.0
240	16	3.8	AC L2 - 16A	12.5	14.3	10.0	14.3	10.7	13.2
240	30	7.2	AC L2 - 30A	12.5	25.0	10.0	25.0	10.7	13.2
240	70	16.8	AC L2 - 70A	12.5	25.0	10.0	50.0	10.7	13.2
208	150	31.2	DC L2 - 208v	129.9	129.9	NA	117.6	115.4	NA
500	125	62.5	DC L2 - 500v	256.4	256.4	NA	235.3	234.4	NA

*** Estimates based on published / projected / or assumed specifications**

Level 2 and DC Level 2 EVSE
User Safety

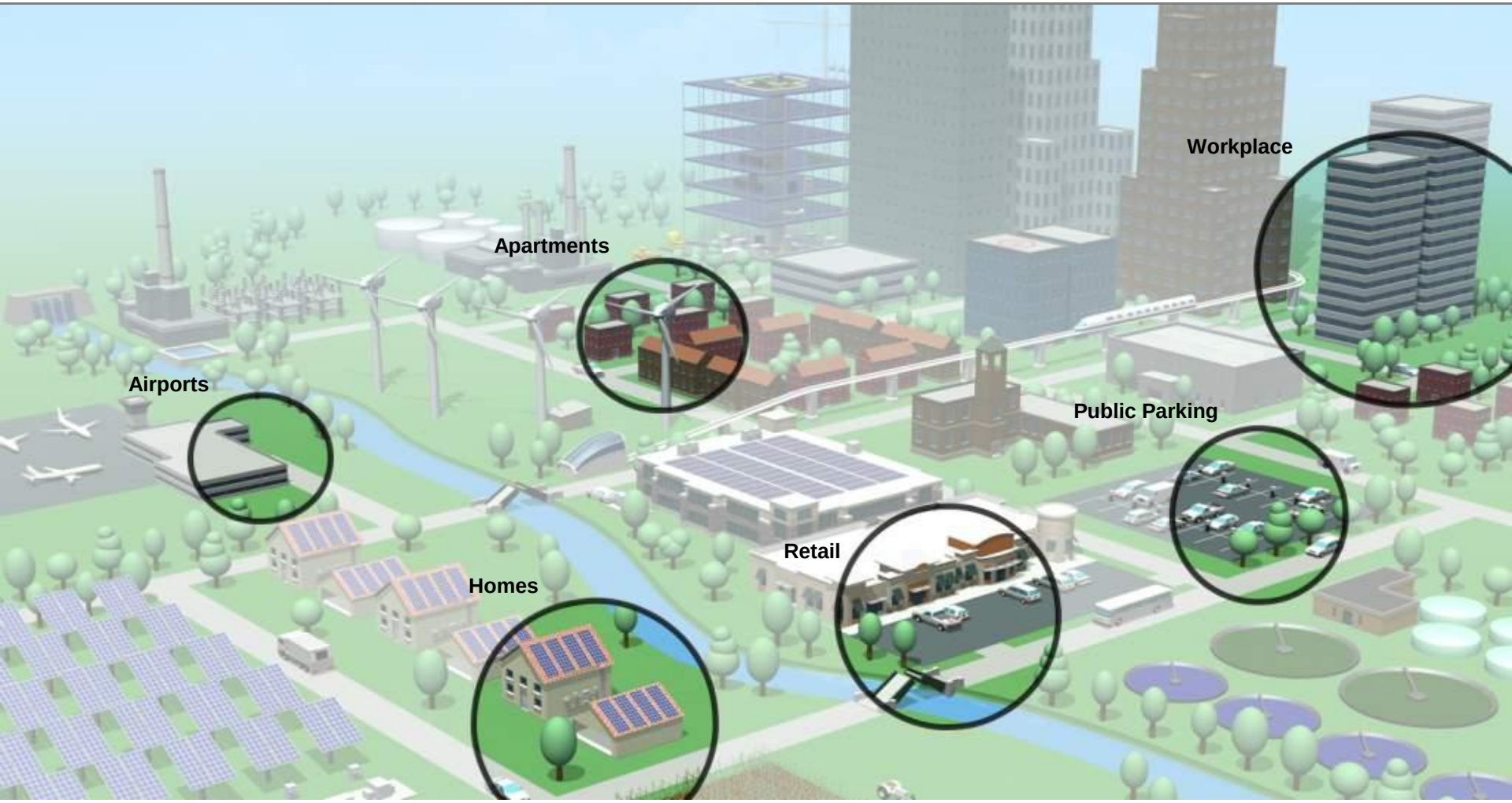
- Interlocks and circuit confirmations
- Little fingers or rain cannot fit between the connections
- EVSE dispenses energy only after checks and balances are made
- Continuous Ground Fault and Overcurrent Protection
- Vehicle only allows power flow once the EVSE confirms it is ready
- System Monitoring to prevent use in a rare case of hardware or firmware failure
- Automatic Shutoff and Safe Breakaway
  - ✓ User releases the connector's latch or drives off with it still plugged in – power will immediately stop

Real Life Example:
This Person Could Use an EV



Gas Stations (Midpoints)
Destinations (Endpoints)

Installation Locations



Garages, public, parking decks, multi-family, workplace, retail, fleets, and quick-charge stations.

Site Evaluation
Cord Management