How Does Charging Impact the Electrical Infrastructure

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Auto Industry Investing $ Billions In New PEVs
6 PEVs Arrived In 2014 and More On The Way

Make	Model	Type	Body Style	Battery (kWh)	AER (miles)	Launch
BMW	i3	BEV; REx	5 door hatchback	22	84/72	Q2 2014
Mercedes	B-Class	BEV	5 door hatchback	36	104	Q3 2014
BMW	i8	PHEV	Sports car	7.1	15	Q3 2014
KIA	Soul	BEV	5 door hatchback	27	95	Q4 2014
Porsche	Cayenne	PHEV	SUV	10.8	22	Q4 2014
VW	eGolf	BEV	5 door hatchback	24	83	Q4 2014

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Auto Industry Investing $ Billions In New PEVs
15+ Models Are On The Way

Make	Model	Type	Body Style	Battery (kWh)	AER (miles)	Launch
Hyundai	Sonata	PHEV	Sedan	9.8	22	Q1 2015
Chevrolet	Volt	PHEV	Hatchback	18.4	50	Q3 2015
BMW	X5	PHEV	SUV	9	20	Q3 2015
Audi	A3 etron	PHEV	Wagon	8.8	30	Q3 2015
Mercedes	C350	PHEV	Luxury sedan	6.2	20	Q4 2015
Tesla	Model X	BEV	SUV/Crossover	TBD	250	Q4 2015
Mercedes	S-Class	PHEV	Luxury sedan	TBD	TBD	Q4 2015
Volvo	XC90 T8	PHEV	SUV	9.2	20	Q4 2015
BMW	328e	PHEV	Luxury sedan	TBD	22	Q1 2016
Mitsubishi	Outlander	PHEV	SUV/Crossover	TBD	TBD	Q2 2016
Chrysler	Town & Country	PHEV	Minivan	TBD	TBD	Q4 2016
Volvo	V60	PHEV	Wagon	TBD	TBD	Q4 2016
Audi	Q7 etron	PHEV	SUV	TBD	25	Q4 2016
Nissan	Leaf	BEV	Hatchback	TBD	TBD	Q4 2016
Chevrolet	Bolt	BEV	Hatchback	TBD	200	Q4 2017
VW	Cross Coupe	PHEV	SUV	14.1	20	Q4 2017
Subaru	TBD	PHEV	Crossover	TBD	TBD	Q4 2017
Porsche	Pajun	BEV	Luxury sedan	TBD	TBD	Q4 2018
Jaguar	F-Pace	BEV	Crossover	TBD	300	Q2 2019

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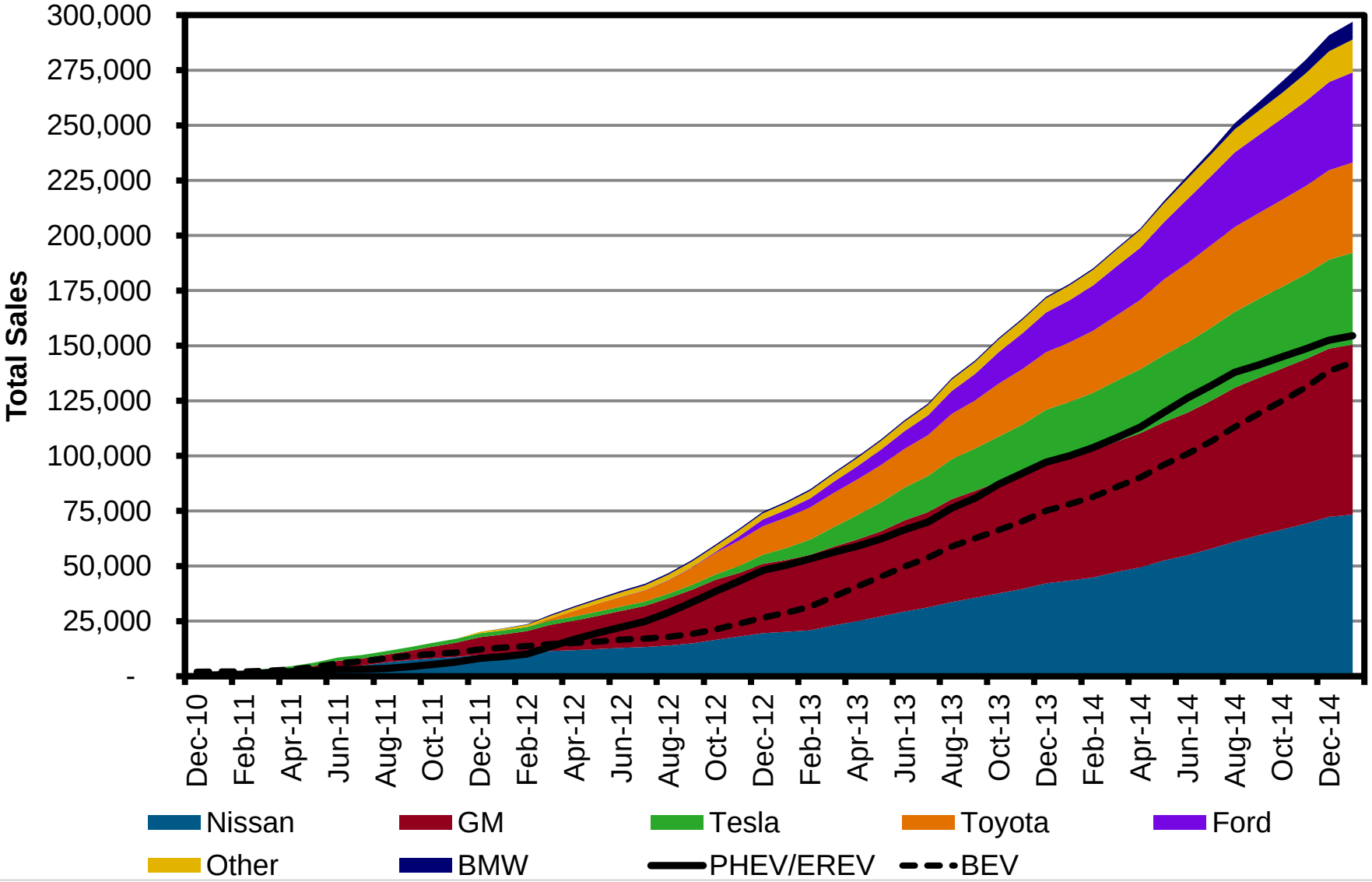
Macro Level View

- The US has about 300M automobiles – one each per head
- 0.1% today are PEVs – about 280,000, growing at 40% year over year
- California has over 100,000 PEVs – that is 100MW load on average, 300MW peak (about 2 power plants)
- California also required to have 1.5M PEVs by 2023 – in 9 short years – raising the peak power 15-fold – 1.5GW on average, 4.5GW on peak- that is 8-10 new power plants just to sustain EV charging
- California has projected capacity to deliver 70GW in 2016, whereas average load is 36.4GW, meaning about half of the capacity is idle and it has worsened since 2007

Systematic PEV integration with the grid enables delivery cost reduction by spreading more GWh over the same GW capacity

Cumulative PEV Sales In USA Exceed 297k (1/31/2015)



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Technology Landscape
Plug-in Electric Vehicle Charging Overview

- There are three kinds of electric vehicle charging on the market:
  - **AC Level 1**
    - 120V wall outlet or hard-wired 120V supply
    - Uses J1772 connector (or Tesla connector)
    - 1.44 kW
    - Comes with PEV
  - **AC Level 2**
    - 240V wall box, plug-in or hard-wired
    - Uses J1772 connector (or Tesla connector)
    - Most current models are 3.3 kW, 6.6 kW, or 10 kW
    - Goes up to 19.2 kW (Tesla)
  - **DC Level 2 AKA "Fast Charging"**
    - Commercial only
    - 3 phase
    - 25 kW to 100 kW
    - May use CHAdeMO, SAE Combo, or Tesla connector

Technology Landscape
Electric Vehicle Supply Equipment

- Safely provides electricity to plug-in electric vehicles
- Often called a “charger”
- Connector
  - J1772 (Level 1 and Level 2)
  - CHAdeMO or SAE Combo or Tesla (DC)
- Vary in size and style by:
  - Application
  - Location
  - Functionality (smart or dumb)

AC Level 1

120V at up to 16A

~3 to 5 miles of range per hour of charging

AC Level 2

208/240V at up to 80A

~10 to 20 miles of range per hour of charging

DC Level 2

500V at up to 200A

~80% re-charge in 20 to 30 minutes

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Technology Landscape
Multiple Options For DC Fast Charge Connectors

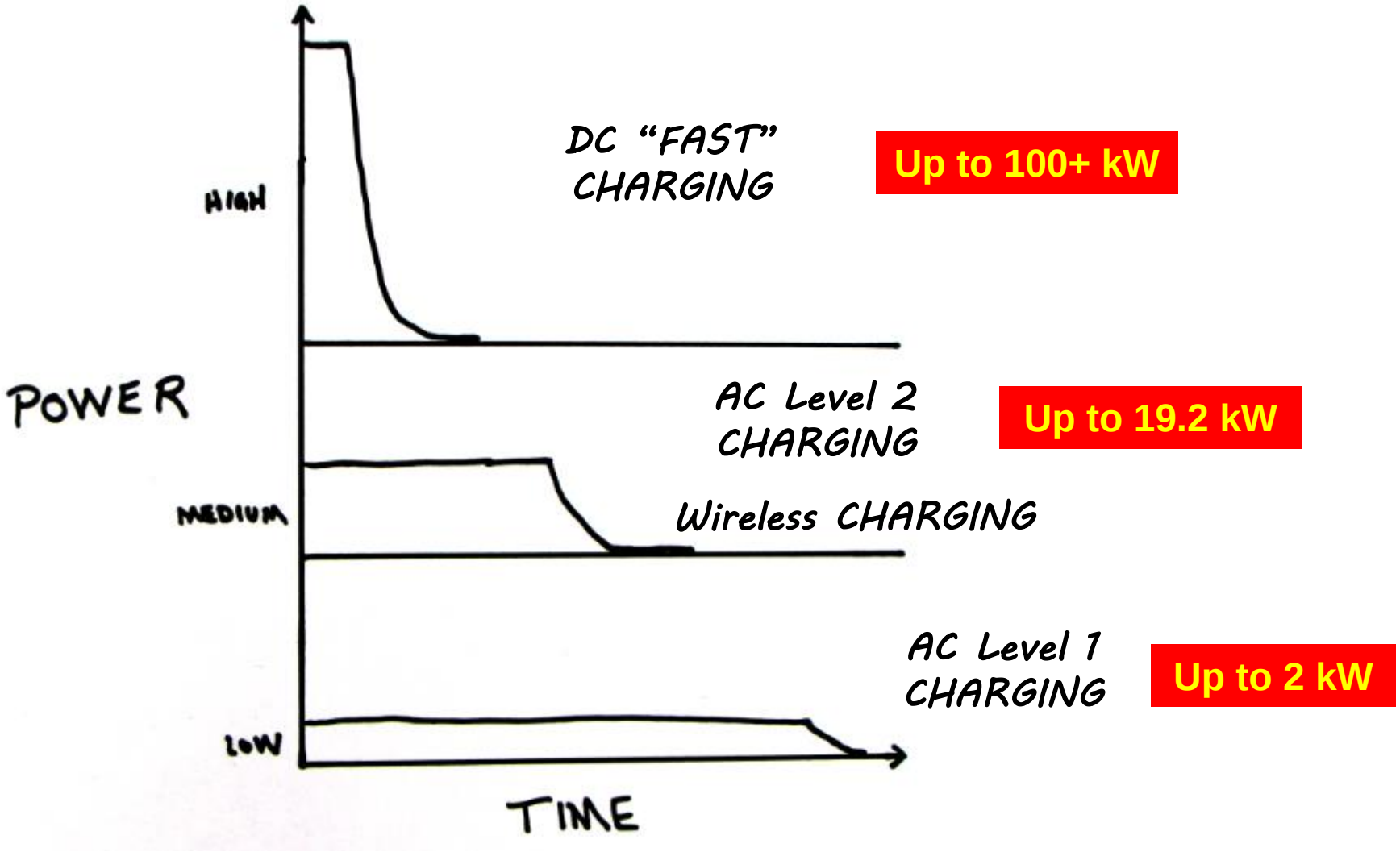
SAE Combo

(USA and Europe)

CHAdeMO (Japan)

Tesla

Power versus Time



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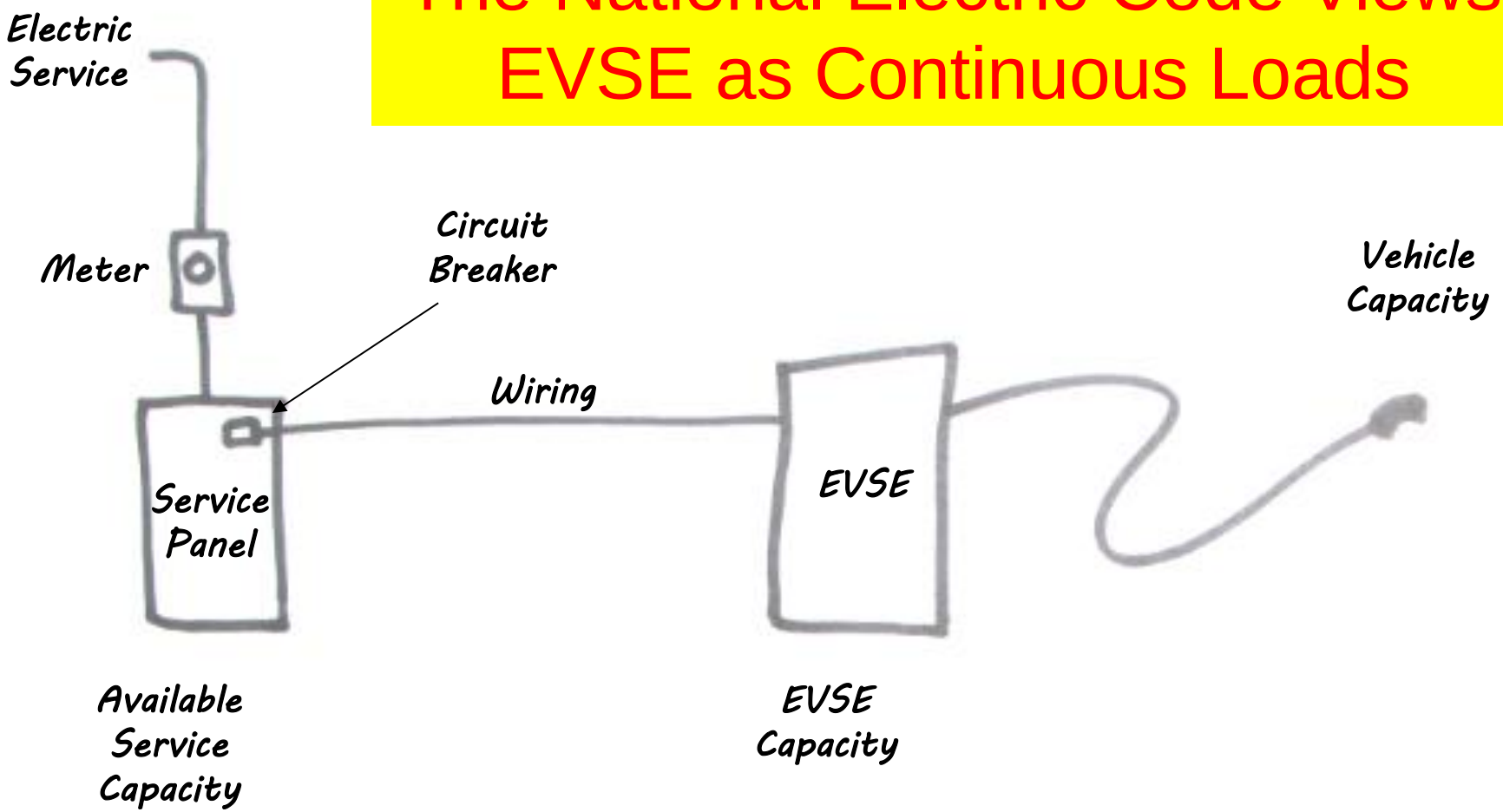
Capacity is Set by the Current Rating of the Weakest Link

The National Electric Code Views EVSE as Continuous Loads



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Infrastructure - Many Challenges Remain

Residential

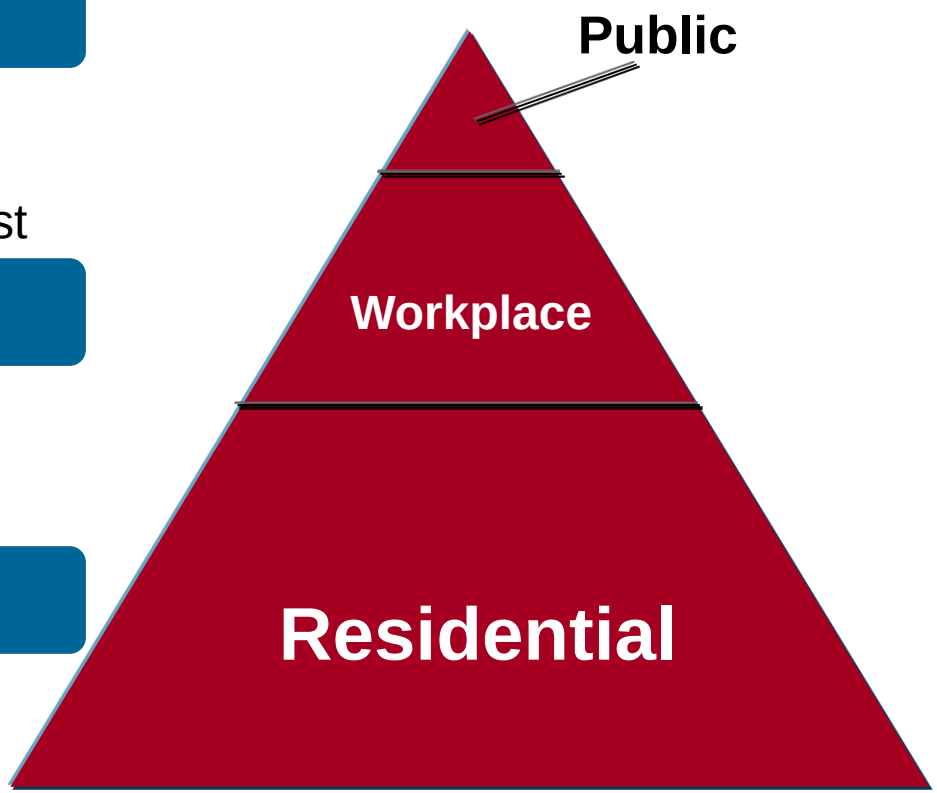
- Multi-unit and tenant dwellings
- Relatively high initial costs
- High adoption of Level 1 at very low cost

Workplace

- Potential has grown—see as driver of adoption
- High installation costs, scaling issues

Public Charging

- Clustering – need to build out networks
- Long-term sustainability of infrastructure
- Underestimated difficulties of locating infrastructure



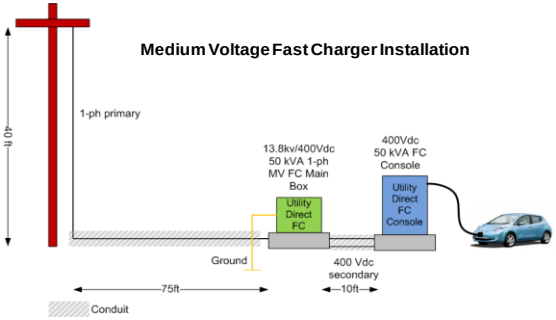
Key Industry Challenges and Outlook

- Role of utility industry
  - Public charging, including workplace
  - Customer support
    - Understanding purchase motivators
  - Grid impact and cost/benefit analysis
- Utility – automotive collaboration
  - Mutual/shared customer
  - Smart charging
    - Cost/benefit analysis, proof of concept, etc.
- Plug-in Vehicles (PEVs)
  - Strong sales, but many concentrated in a few geographic areas
  - Expanding beyond city vehicles
  - Strong halo presence of Tesla

EPRI Has Worked On Electric Transportation For Nearly Two Decades

Research on key ET industry challenges including role of the utility, charging infrastructure, data collection / analysis, utility-automotive collaboration and market transformation

- Vehicle demonstration, data collection, and analytics
- Infrastructure systems designs, costs, & economics
- DC charging research — medium voltage fast charging
- Smart charging programs
- Utility PEV readiness support
- Service territory-specific PEV sales tracking and load forecasting
- Hub of collaboration between utilities and automakers
- Assessment of consumer expectations
- PEVs and distributed resources
- EV energy management circuit breaker



Support introduction and market success of transportation electrification

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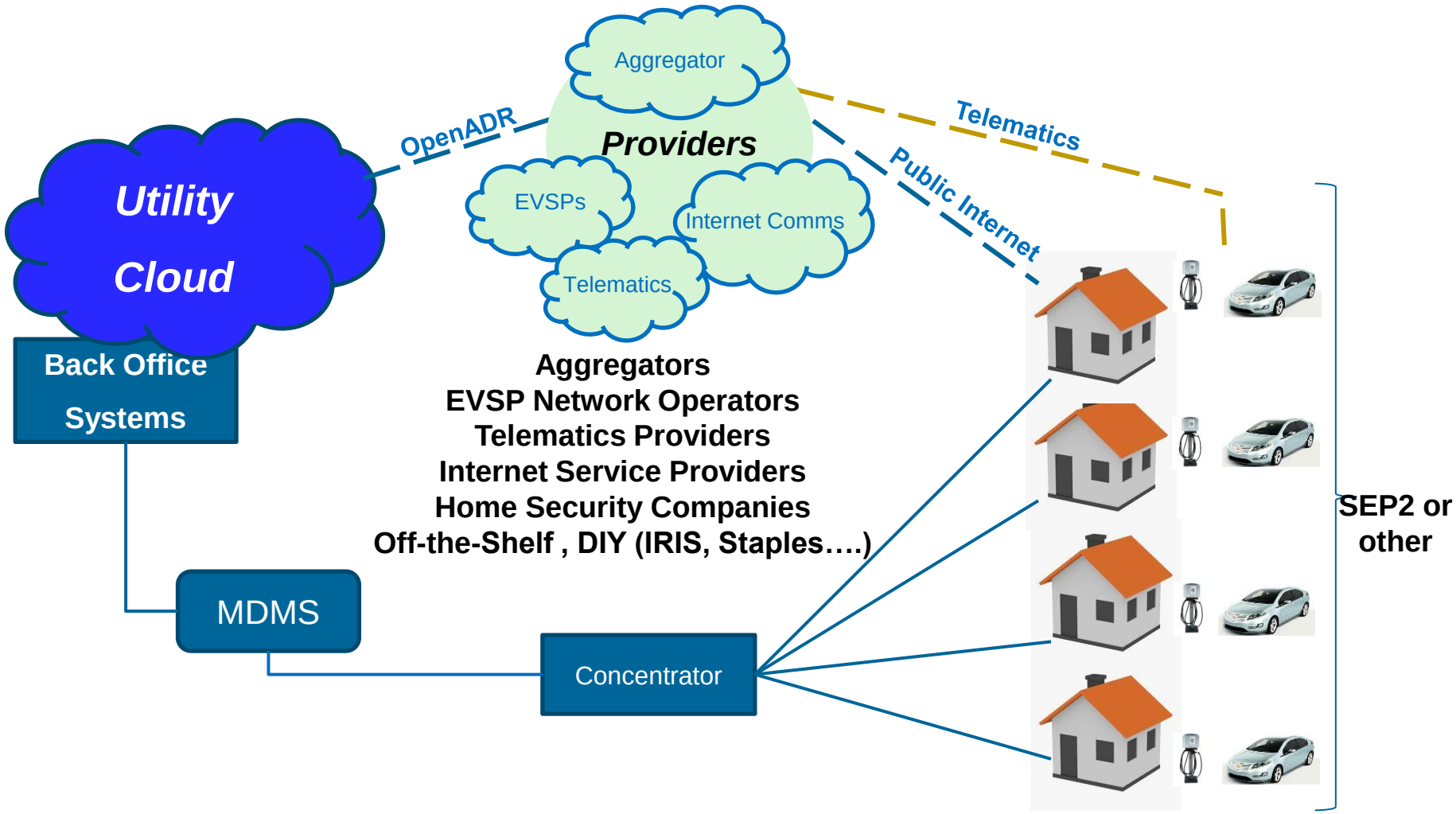
Emerging Load Management Landscape



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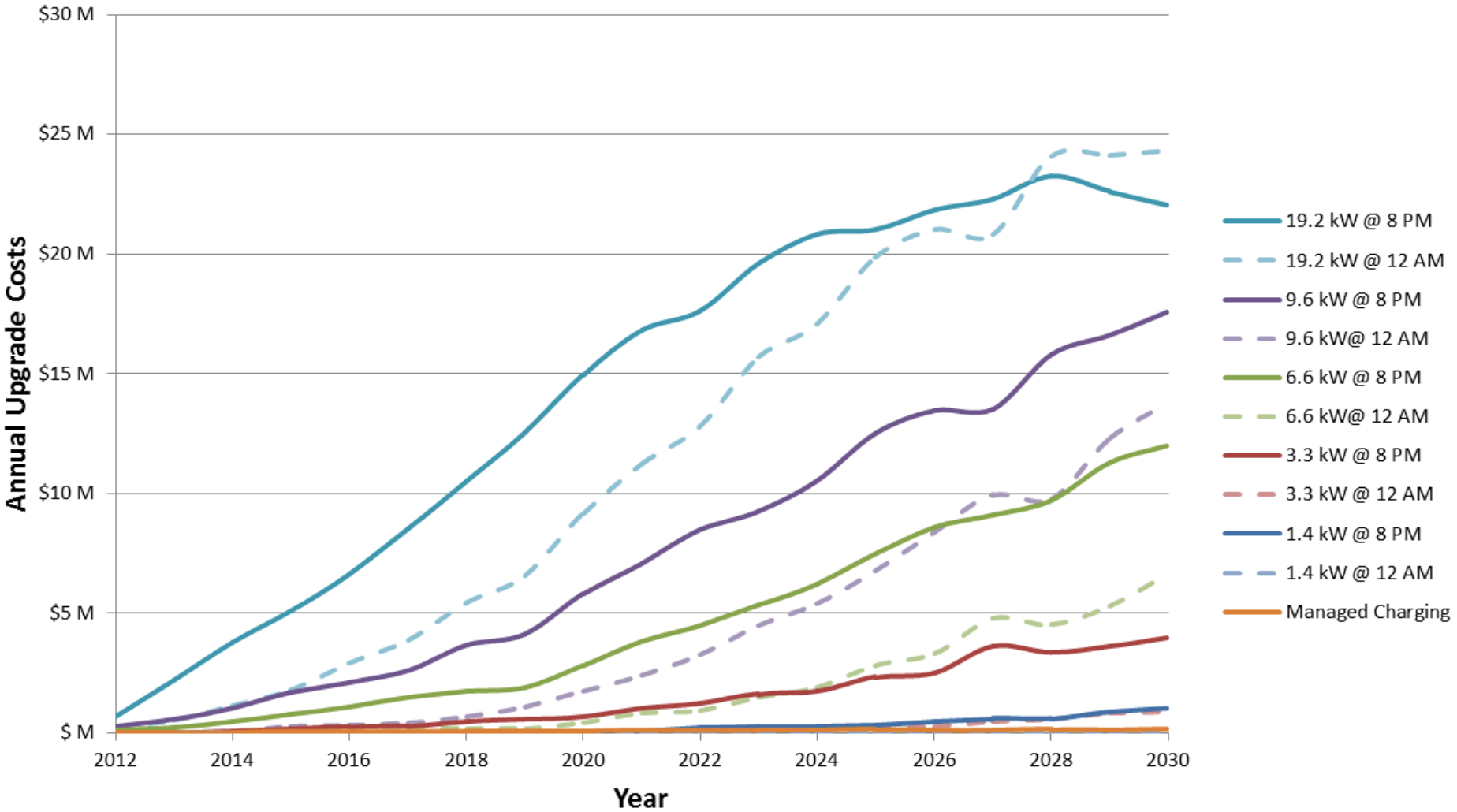
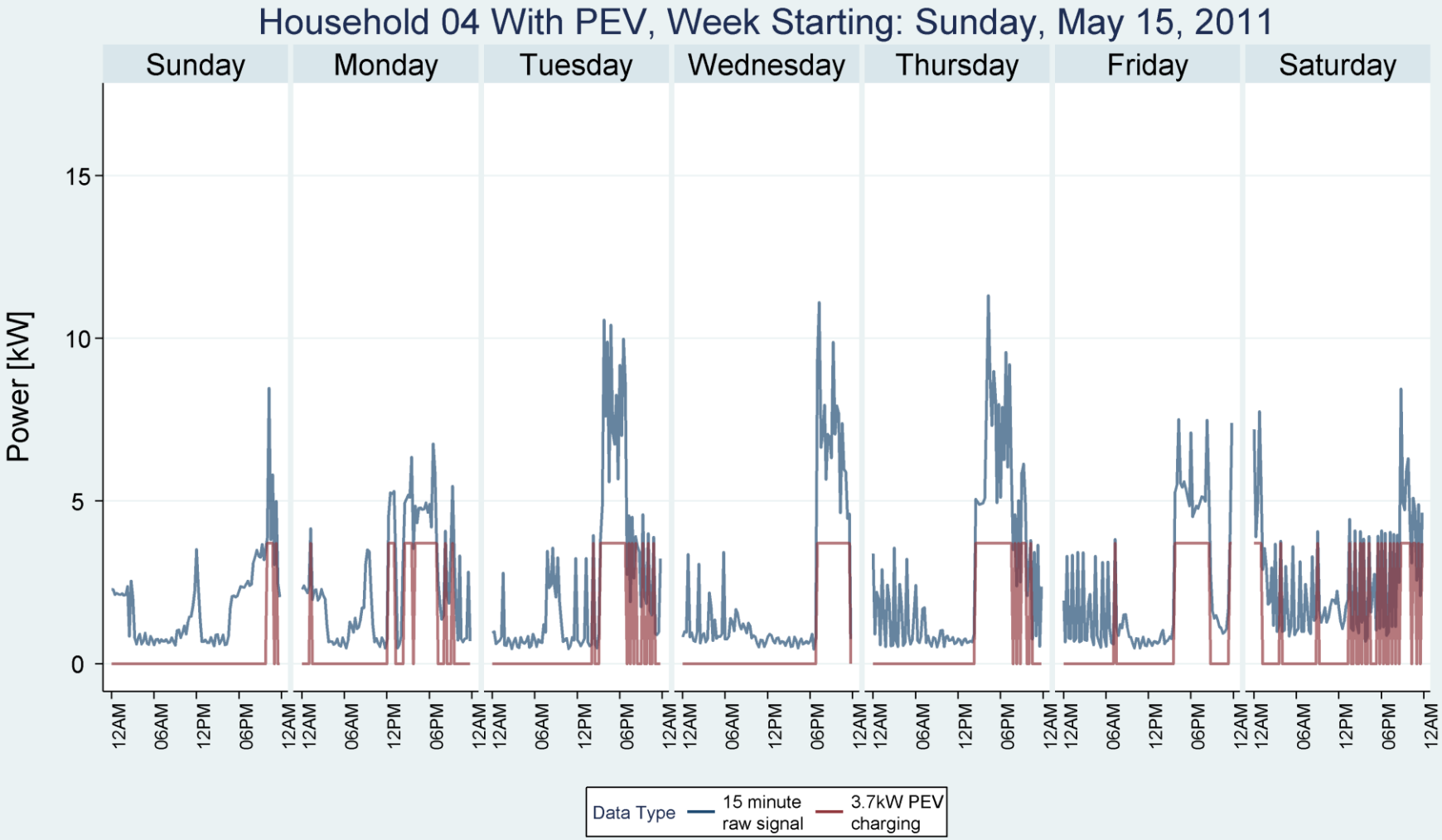
Distribution Infrastructure Upgrade Cost Sensitivity to Charge Rate for a Homogeneous PEV mix



PEV Location Determination Using Smart Meter Data



Source: Oncor.

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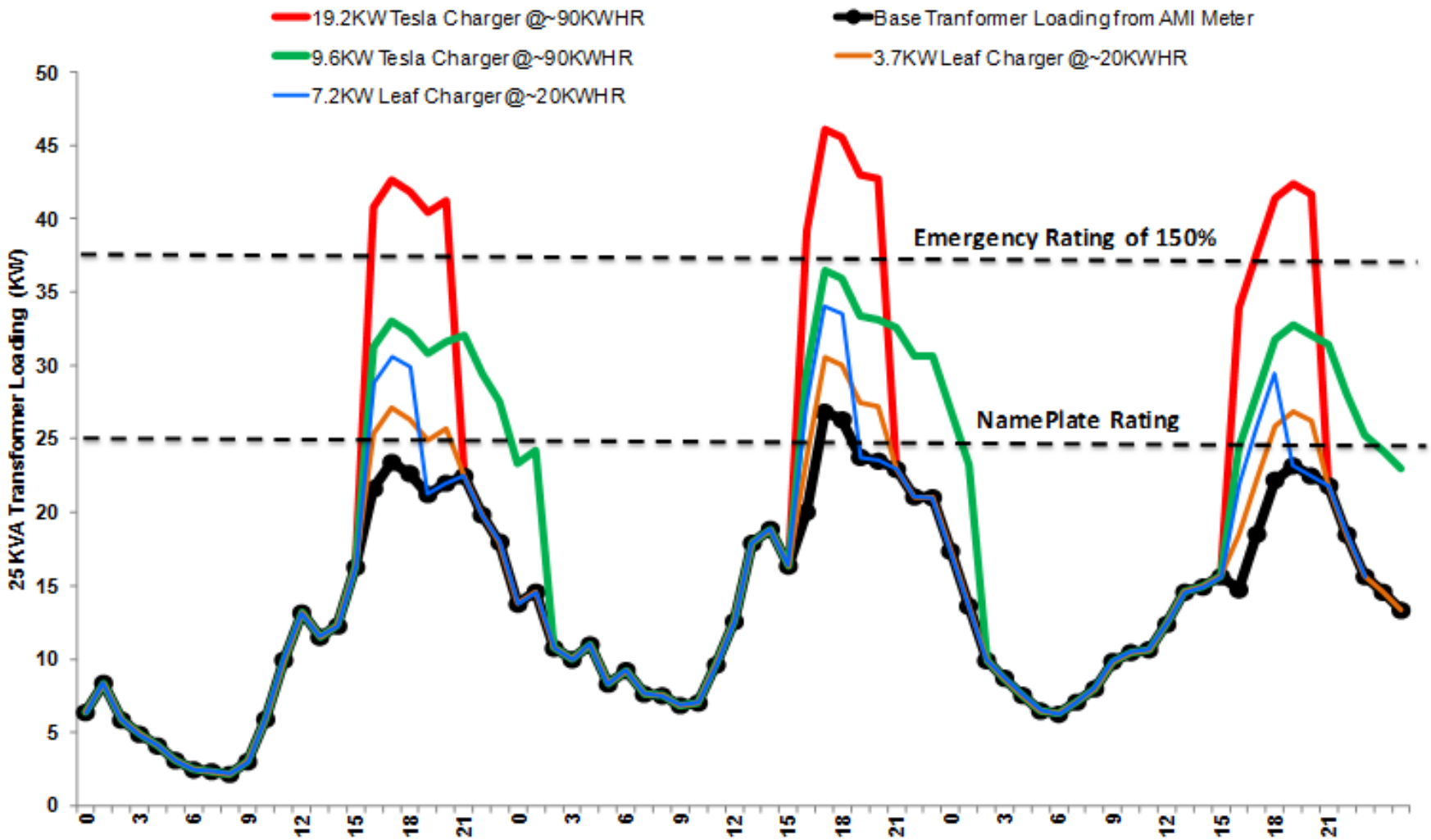
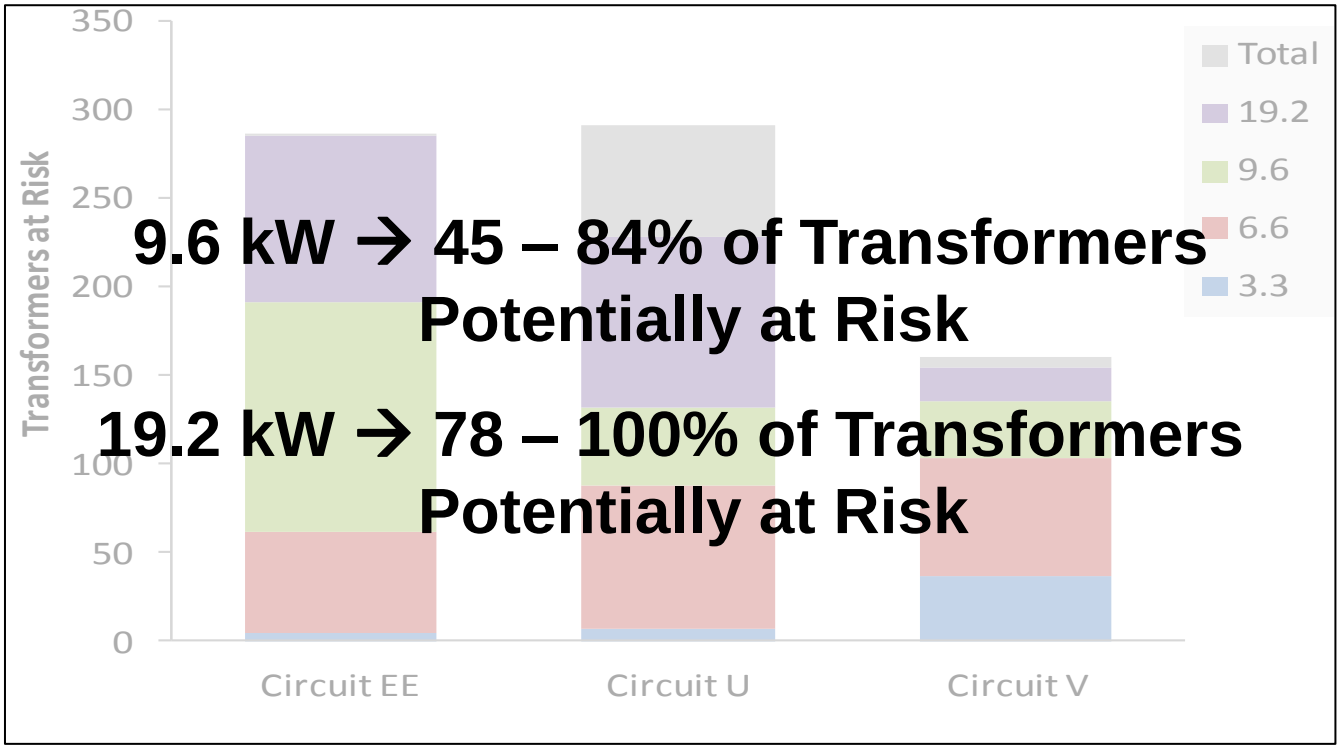
Sensitivity of Different PEV Charge Levels on Example 25KVA Distribution Transformer Loading



Increasingly High Charge Rates Create Disproportionate Grid Impacts – 3 CA Distribution Circuits



Charge Rate	Count of Transformers at Risk (% of Transformers at Risk)		
	Circuit EE	Circuit U	Circuit V
3.3	5 (2%)	7 (2%)	37 (23%)
6.6	62 (22%)	88 (30%)	103 (64%)
9.6	192 (67%)	132 (45%)	136 (84%)
19.2	285 (100%)	229 (78%)	155 (96%)
Total Xfmrs	286	292	161

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Load Management Programs - Principal Approaches Within the Utility Industry

Minimal Intervention – **Lack of customer involvement**

- On/Off control
- Similar to A/C programs

Smart EVSE – **Lack of customer involvement**

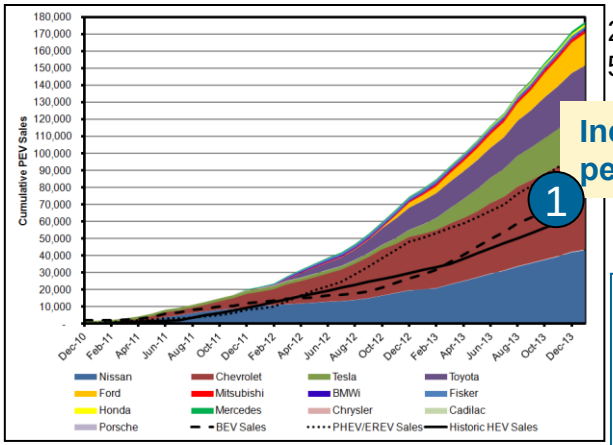
- Utilities like it - allows utility to control fixed endpoint
- Network vendors like it – enables them to be aggregators
- Not so popular with consumers or OEMs

Smart Charging – **Enables Customer Preferences**

- Direct, low-cost, open standards-based, utility to PEV path
- Complemented by automotive telematics

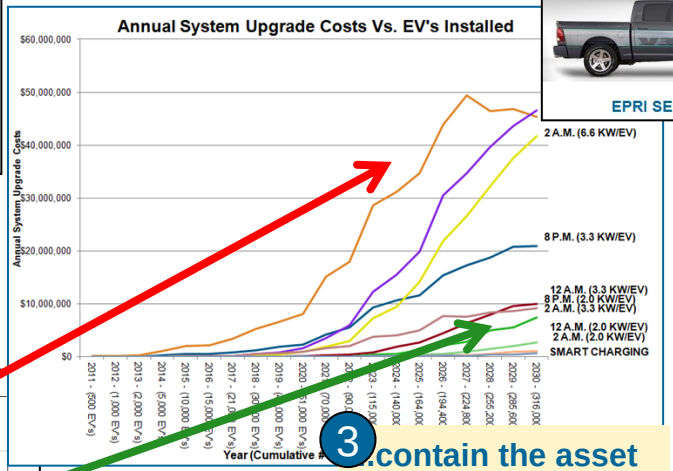
Customer-focused load curtailment of PEV charging enables environmentally responsible and increased PEV mobility

Smart Charging has biggest impact near-term in asset upgrade cost containment – if done right

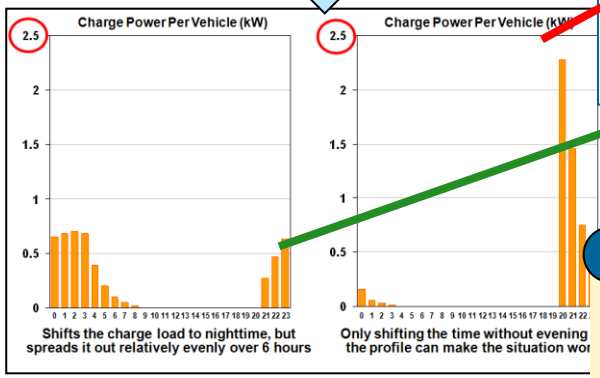


215,600 on 5/31/14

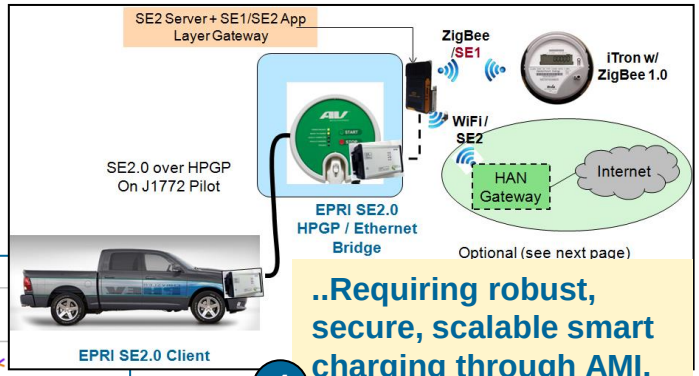
1 Increasing PEV penetration…



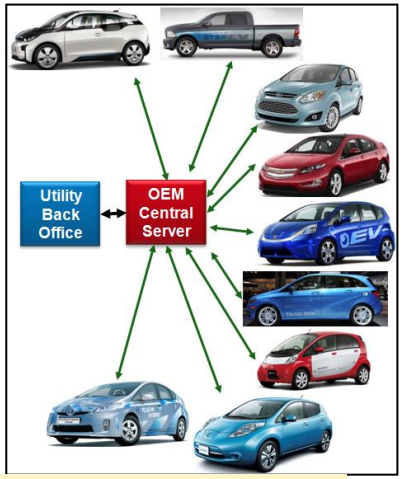
3 ..contain the asset upgrade costs..



2 ..Drives up charging demand, which can be managed to…



4 ..Requiring robust, secure, scalable smart charging through AMI, HAN…



5 ..And/or third-party telematics systems based PEV connectivity

Challenge – how to tie distribution system stress with smart charging that responds to bulk level pricing and DR

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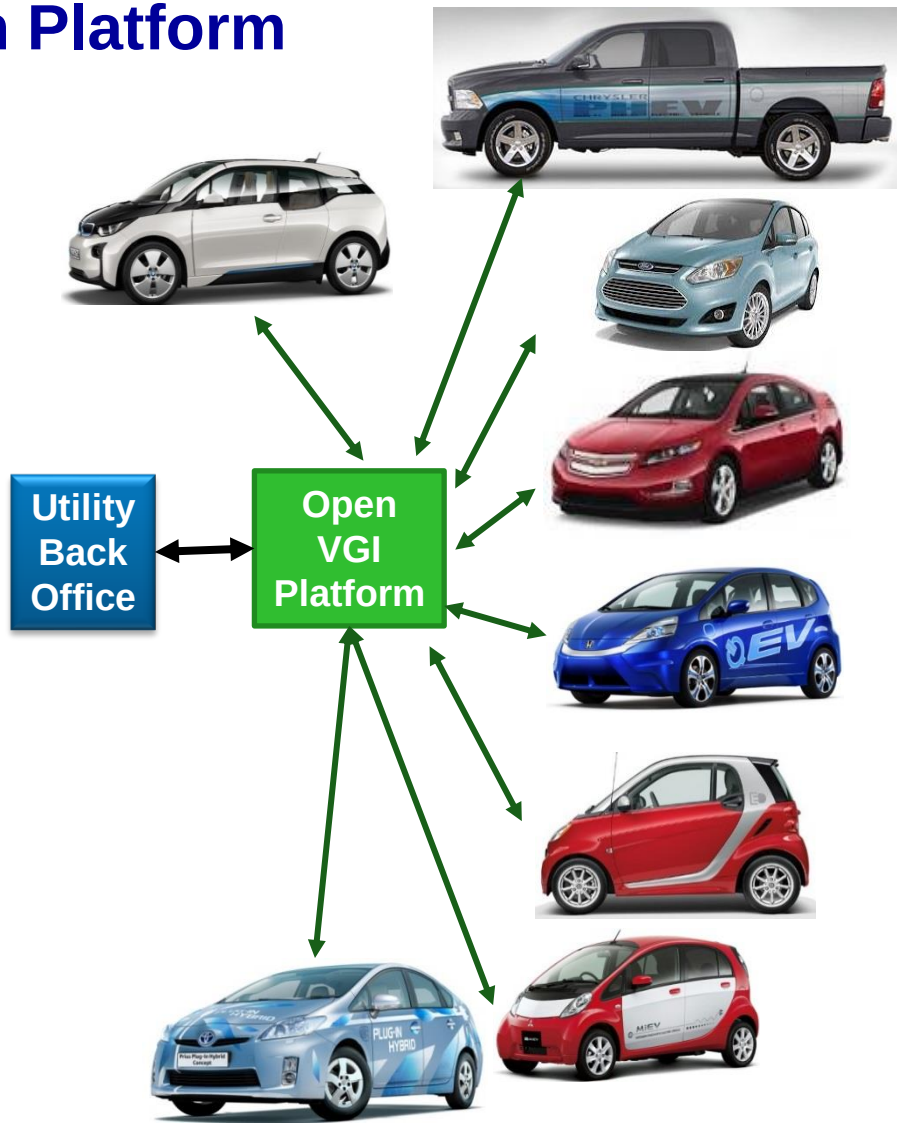
Open Vehicle-Grid Integration Platform

- Joint utility and automotive industry effort – Determine a common interface architecture
- Single unified control interface to PEVs from OEM manufacturers
- Path to production for on-vehicle technology that is Customer-Centric
- Open and extensible standards based – OpenADR 2.0b and SEP2
- Communications through the Cloud and/or AMI/HAN



CHRYSLER Ford GM HONDA Mercedes-Benz MITSUBISHI MOTORS TOYOTA

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What Does the Future Hold

- Smart Grid-Enabled PEVs
- Unified Platforms for Grid Services encompassing
  - PEVs
  - Storage
  - Renewables
  - Flexible Loads
- Utility Programs that Incentivize asset utilization improvement - ‘Nega’Watts vs. MegaWatts
- Diversity of Communication Methods that are interoperable, secure, scalable and extensible
- Lowered total cost of ownership for PEVs, simplified managed charging and grid integration systems
- Happy customers and ratepayers!

Together ... Shaping the Future of Electricity

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