The state of the EV market and smart charging

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Contents

I. Countries and cities proposing ban of gas and diesel cars

II. Nearly 100 EVs announced by 2023

III. Investment in public charging infrastructure

IV. Rise of higher power DC fast charging

V. Smart charging

I. Countries and cities proposing banning gas and diesel cars

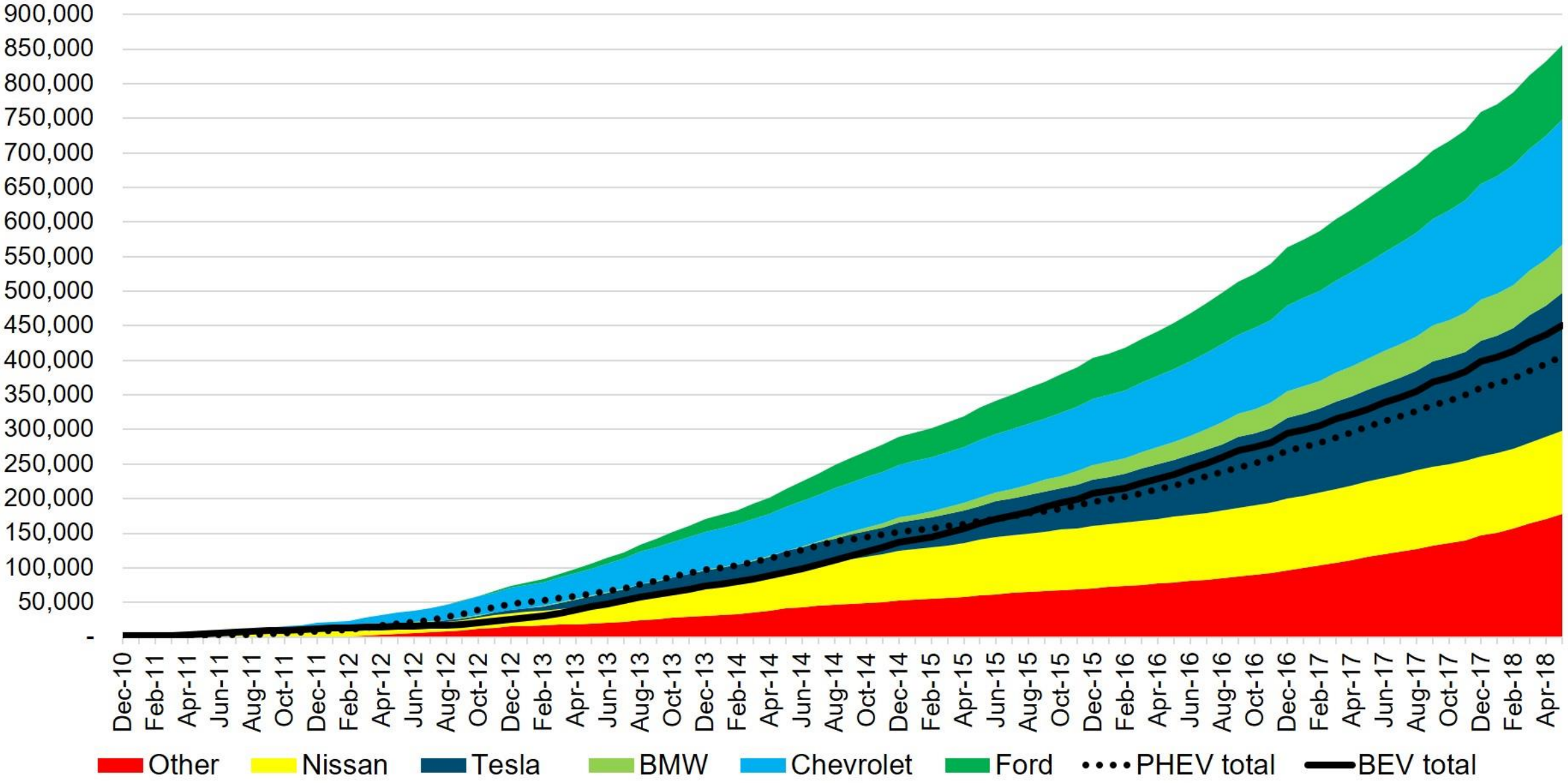
Country	Proposed Ban
Norway	2025
Netherlands	2030
Germany	2030
India	2030
Scotland	2032
UK	2040
France	2040

City	Proposed Ban
Madrid	2020
Copenhagen	2019
Munich	TBD
Stuttgart	TBD
Oslo	2019
Bogota	TBD
London	2025
Madrid	2025
Paris	2025
Athens	2025
Mexico City	2025
Brussels	2030
Oxford	2030

- Big announcements
- Details are important
- Many announcement doesn't contain details

Updated: 6/2/2018

II. US EV sales exceed 856k through May 2018



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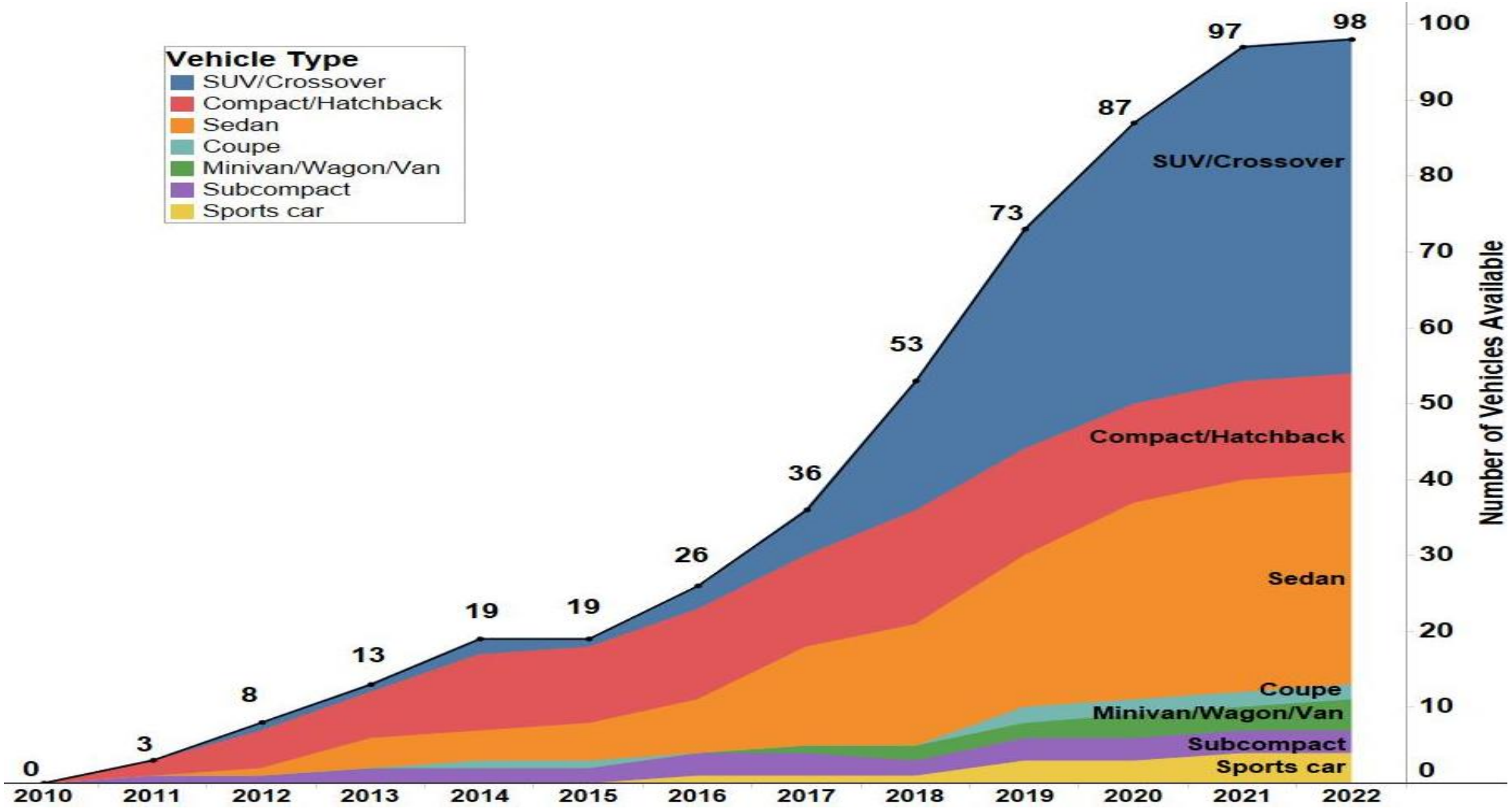
II. Customer choice increasing with ~~98~~ 99 EVs by 2023



Updated 5/24/2018

II. More and more EVs will be SUVs, crossovers, and vans

Source: Dan Bowermaster, Los Angeles, December 2017; www.insideevs.com, accessed 3/28/2018

III. Utilities are proposing ~$2.8B in EV charging infrastructure

Hawaiian Electric $1.2M (0/12)

Seattle City Light $2.8M (0/2)

AVISTA $4.2M (205/4)

PUGET SOUND ENERGY $2.5M (~5,000/0)

PGE $3.4M

PACIFIC POWER $4.6M

PG&E $130M $253M

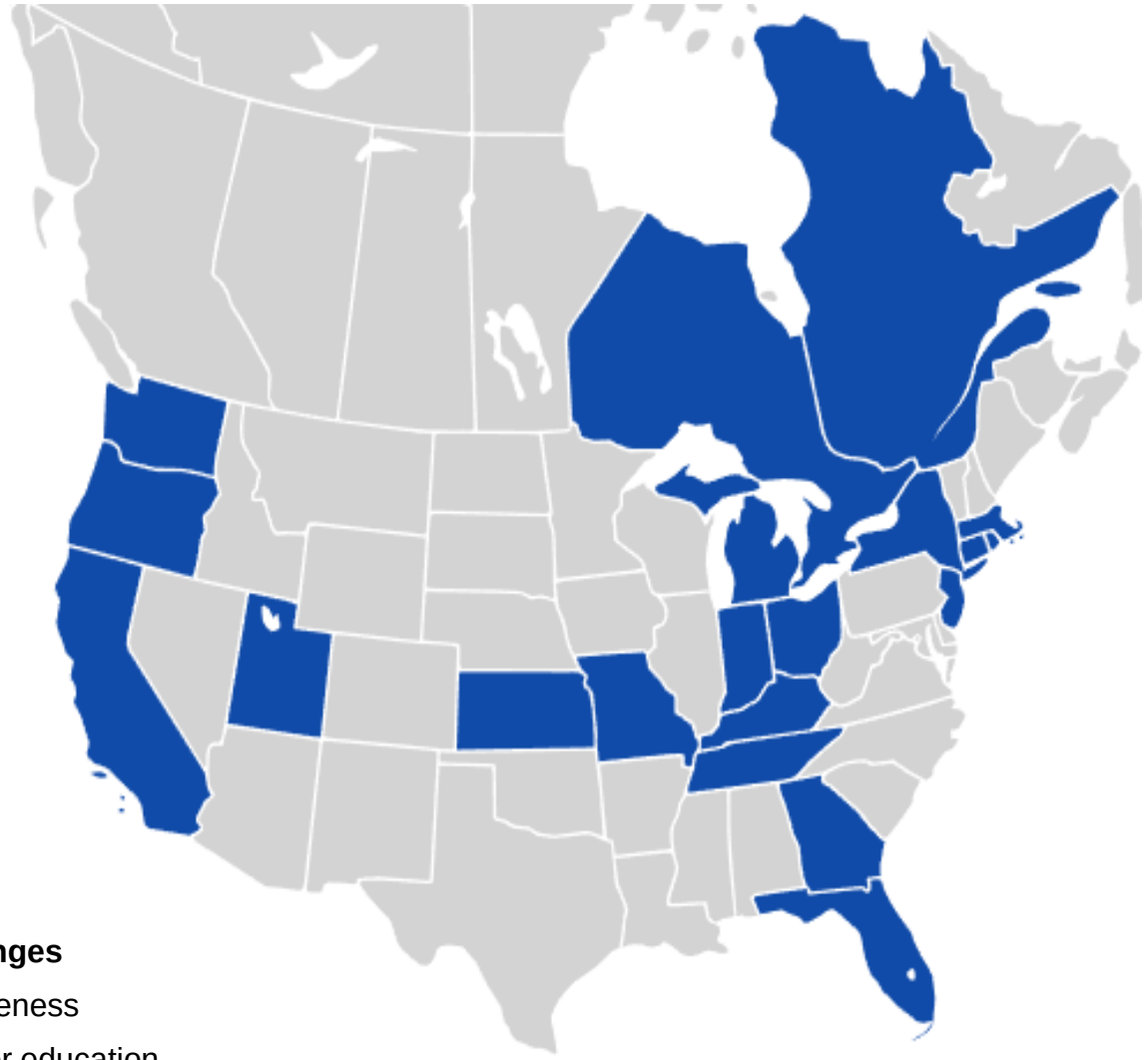
SOUTHERN CALIFORNIA EDISON $22M $573M

SDGE $45M

Sempra Energy $244M

ROCKY MOUNTAIN POWER $10M

Consumers Energy Count on Us $7.5M



$2.0M (1,175/107) Hydro Québec

$20M (200/300) Ontario

$25M conEdison

$45M EVERSOURCE ENERGY

$25M nationalgrid

$11M Narragansett

$1.7M delmarva power

$14.9M atlantic city electric

$300M PSE&G We make things work for you.

$3.7M ipl an AES company

$10.5M AEP

$0.6M $18M Ameren

$20M (920/16) KCP&L

$0.5M LG&E KU PPL companies

$10.45M (2,400/37) GEORGIA POWER A SOUTHERN COMPANY

$1.46M

$0.4M Gulf Power

$8M DUKE ENERGY FLORIDA

Legend [Budget $ (L2/DCFC)]
Make-ready / rebate
Utility-owned
Hybrid

Key Challenges

- EV awareness
- Customer education
- Easy and reliable public charging infrastructure (to find, access, use, and pay)

Updated: 6/12/2018

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How will charging EVs impact the grid? Two looks

EPRI Grid Impact Phase 1 Study, 2012

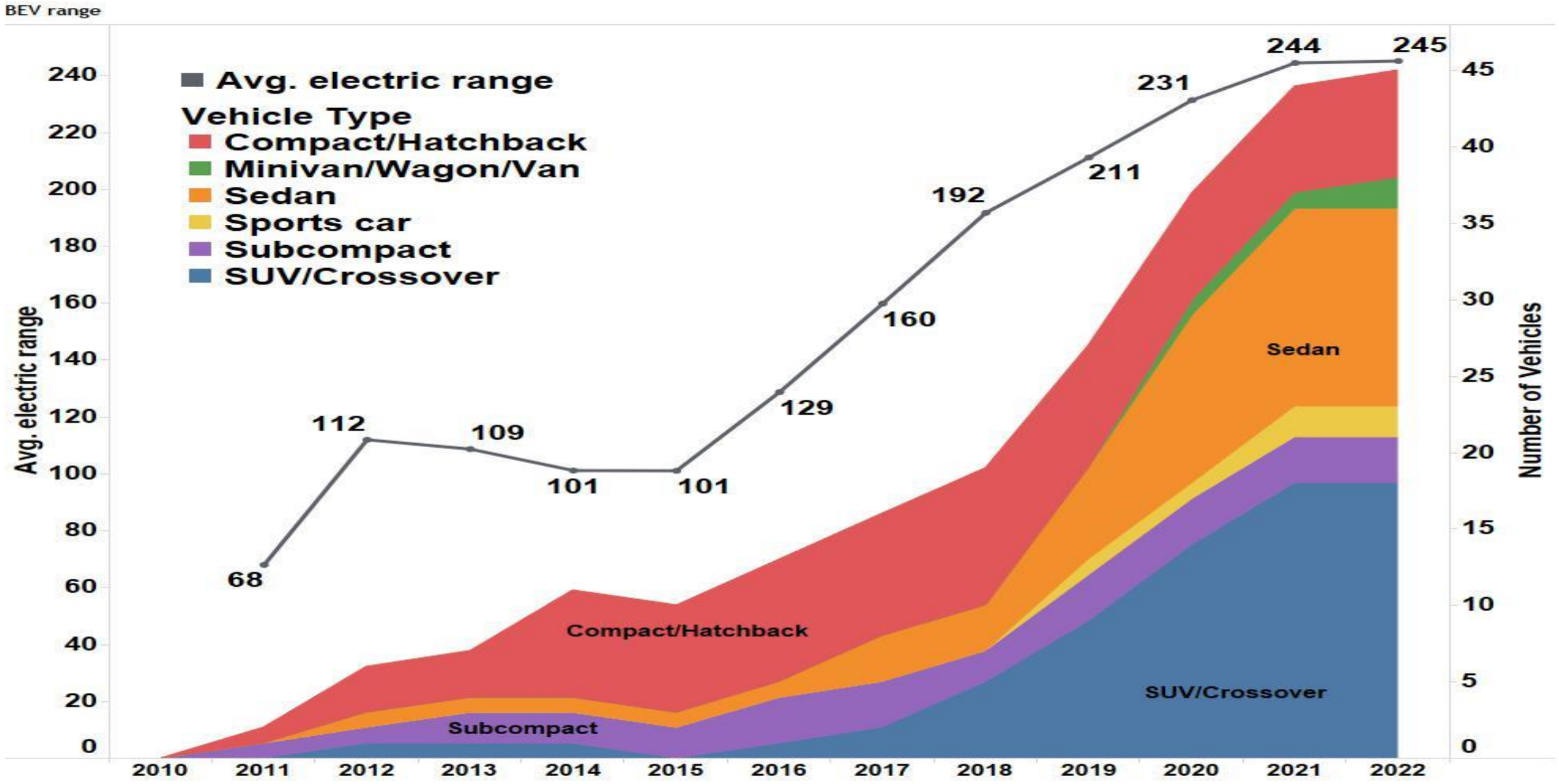
AC Charge Rate of EV	Circuit 1 Needed Upgrades (of 286 Transformers)	Circuit 2 Needed Upgrades (of 292 transformers)	Circuit 3 Needed Upgrades (of 161 transformers)
3.3 kW	5 (2%)	7 (2%)	37 (23%)
6.6 kW	62 (22%)	88 (30%)	103 (64%)
9.6 kW	192 (67%)	132 (45%)	136 (84%)
19.2 kW	285 (100%)	229 (78%)	155 (96%)

California Investor-Owned Utility, EV Upgrade Real World Results, Oct 2017

	PG&E	SCE	SDG&E	Total
EVs	142,732	108,135	26,498	277,365
Service Upgrades	228	197	35	460 (0.16%)

Source: Understanding the Grid Impacts of Plug-In Electric Vehicles (PEV): Phase 1 Study -- Distribution Impact Case Studies, EPRI, 2012; 6th Joint IOU Electric Vehicle Load Research Report: December 2017, p. 8

Trend 1: Range (in miles) of battery electric vehicles (BEVs) is increasing



Updated 5/9/2018

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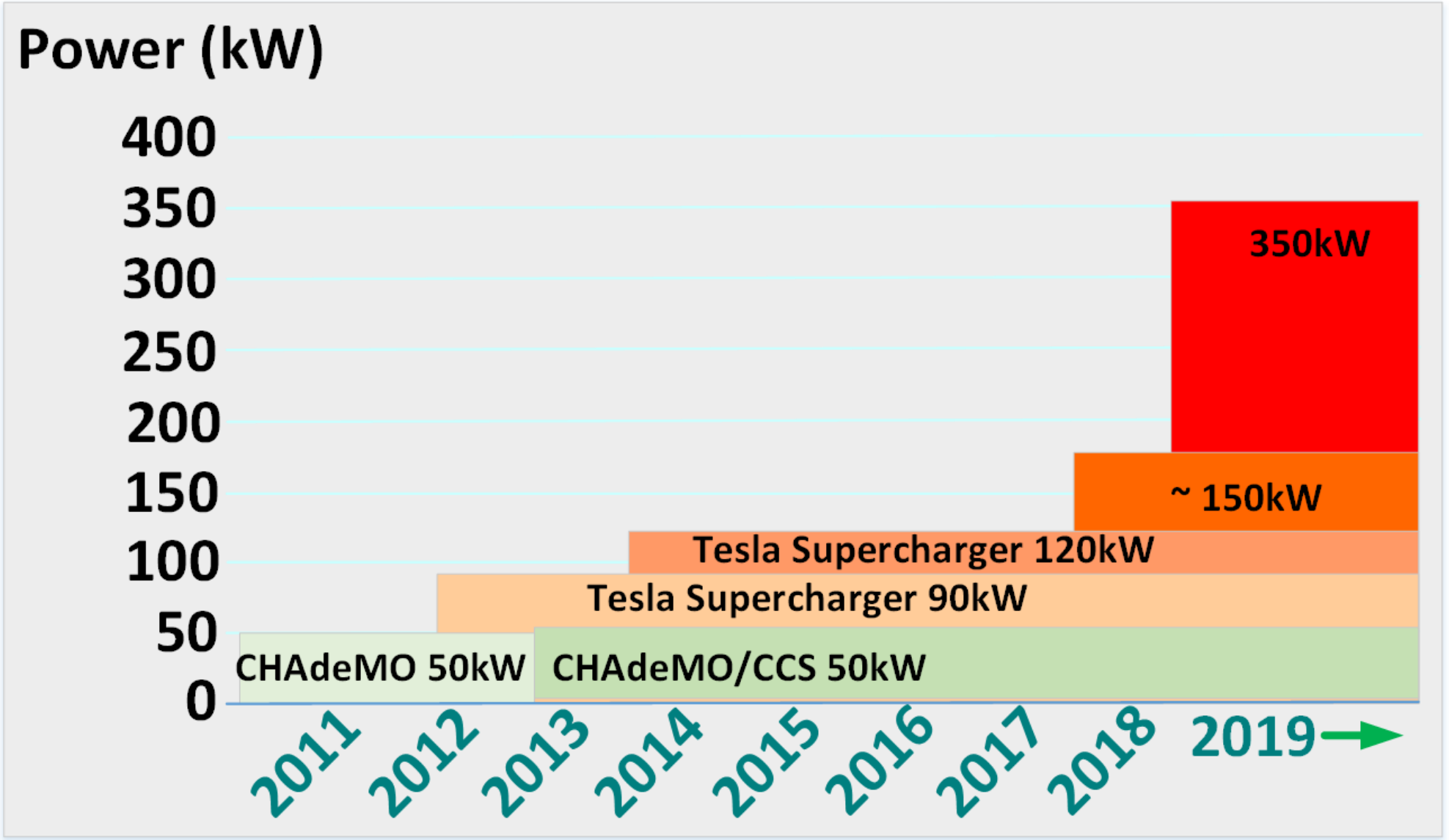
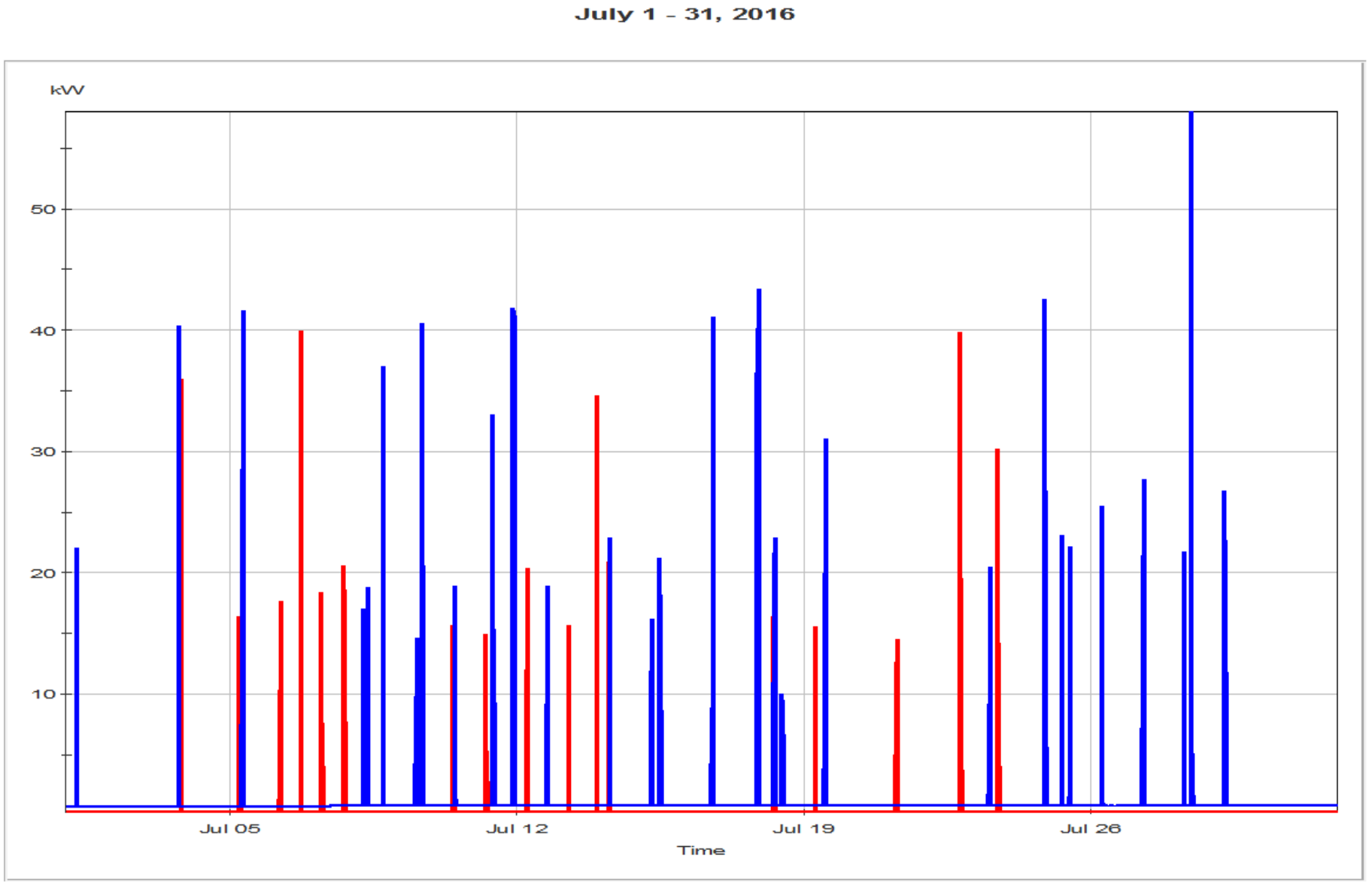
Trend 2: here come the big EVs

Sources: CleanTechnica.com, GreenCarReports.com, SchoolBusFleet.com; electrive.com, LG&E and KU, Dan Bowermaster

IV. Both trends are leading to higher power DC fast charging



DC Fast Charger Load Profiles

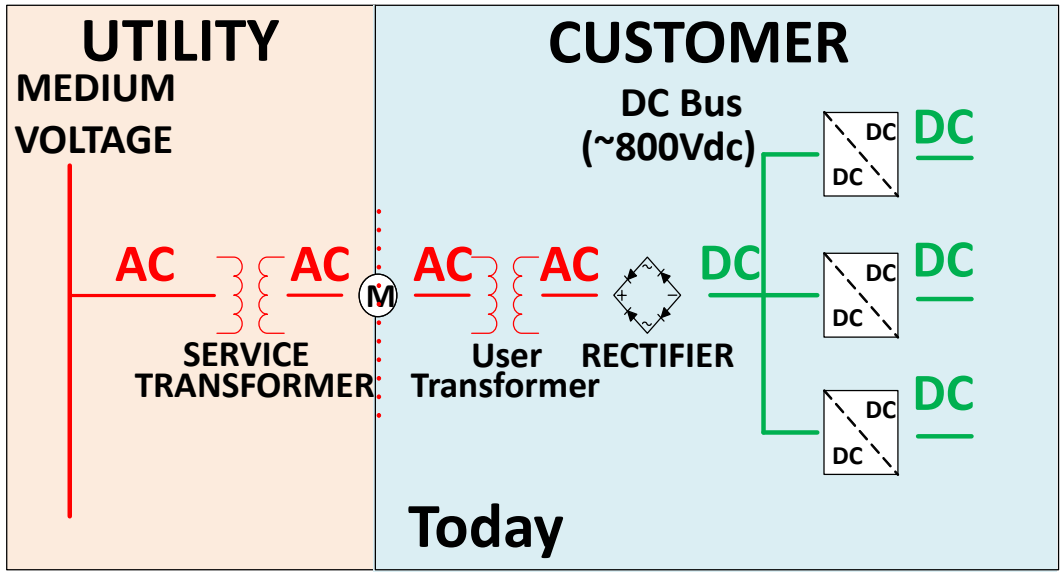


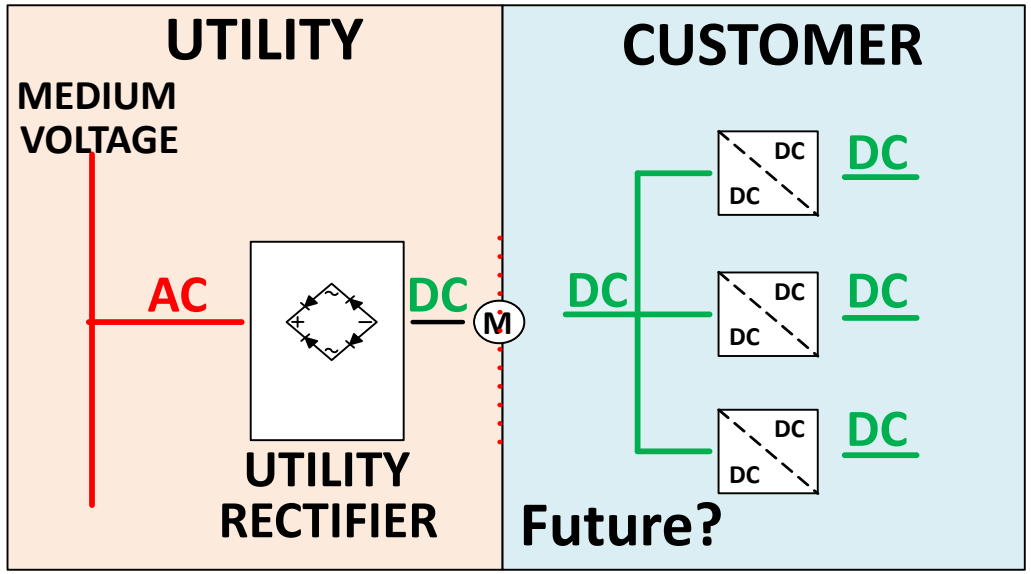
- **“Needle” Peaks**
- **Load factors under 10%**
- **Typical C&I customer rate class average of 40 - 50%**

Electric Heavy Duty Trucks – Tesla Semi example

- Tesla Semi Class 8 Tractor (preliminary)
  - Range of 300 – 500 miles (2 kWh/mile)
  - Estimate - required usable battery pack 600 – 1000 kWh
  - For recharge - add 400 miles in 30 minutes
    - Average charge rate ~ 1.6 MW
    - Peak charge rate significantly higher
    - ‘Overnight’ recharge rate 100 – 200 kW
- Truck and cargo info (U.S.A.)
  - 50% of shipping ton-miles for trips of < 500 miles; 73% are < 1,000 miles
  - Analysis needed - cost effectiveness, driving patterns, and operational impacts
- Cummins and other truck companies also working on EV and other technologies
- Hydrogen fuel cells or battery exchange could also play a role in the future

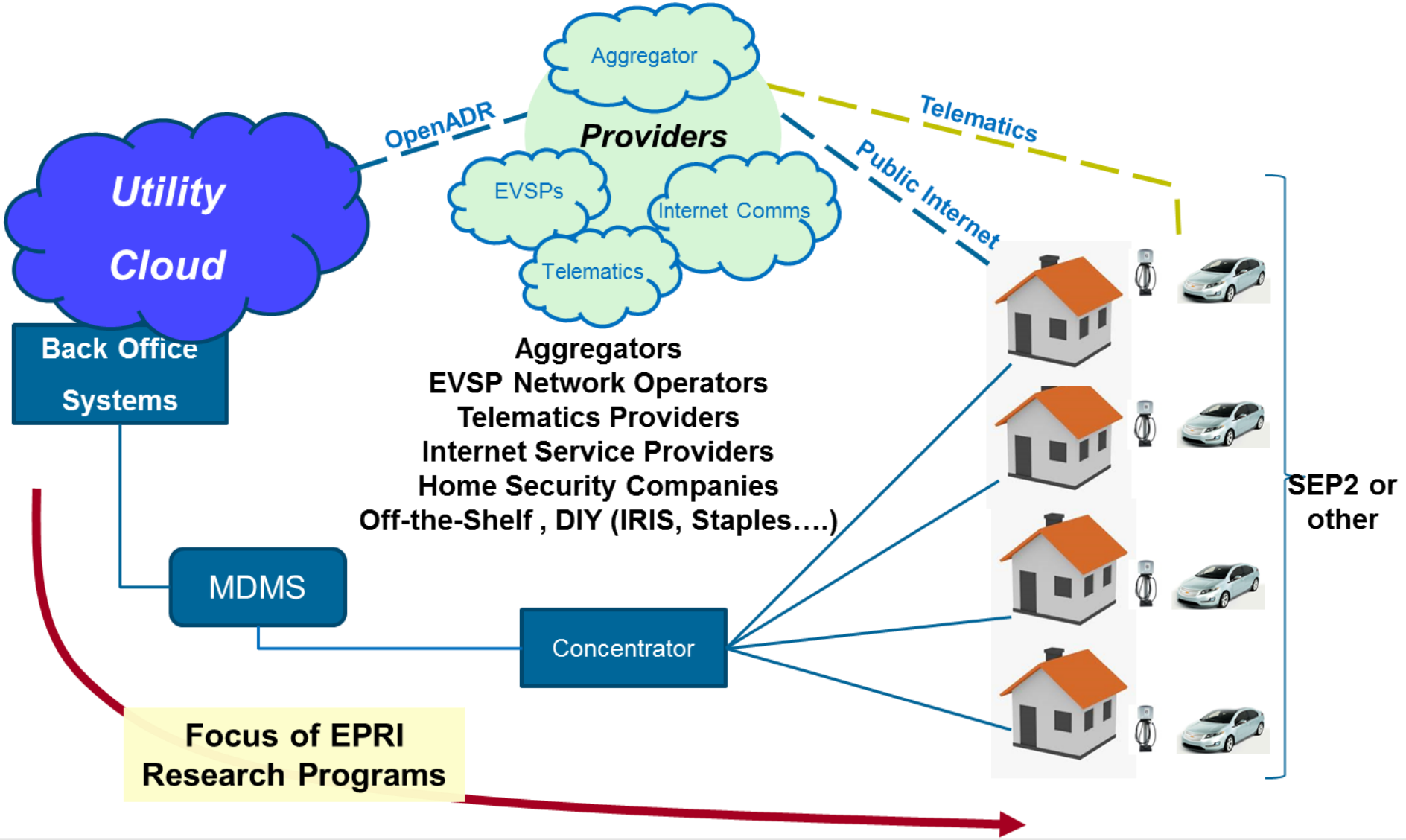
DC-as-a-Service Public Working Group
What if utilities provide DC voltage to customers?





Photos: Dan Bowermaster/EPRI, insideevs.com (2)

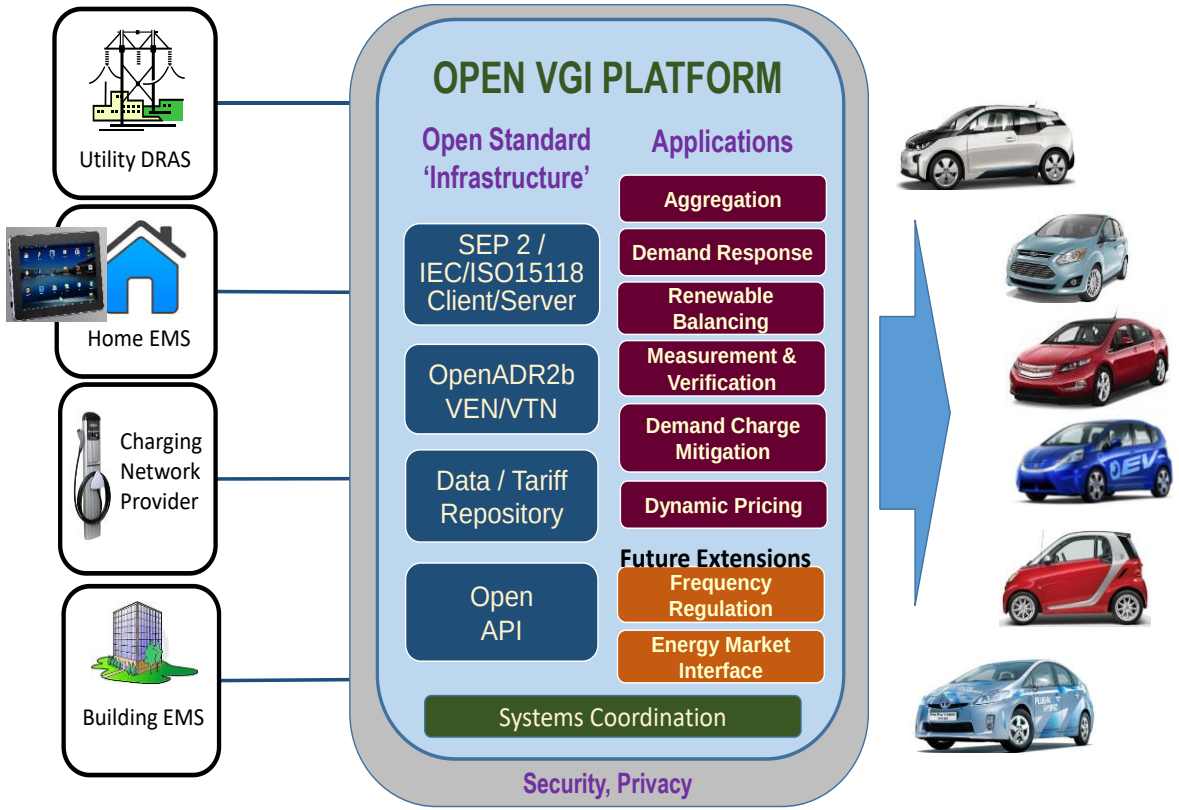
V. Reality is crowded and tough: integrated EV charging management has technical, commercial, and regulatory challenges and opportunities

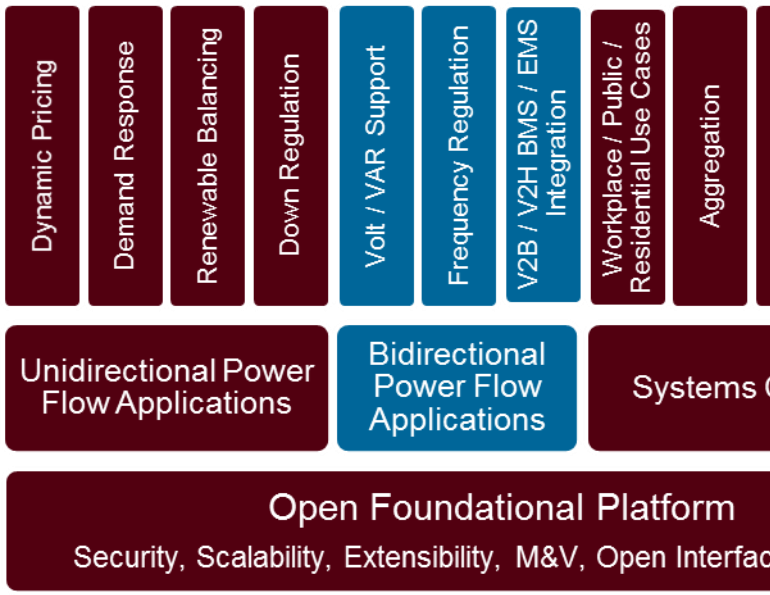


EPRI, automotive and utility industries jointly developing comprehensive Open Vehicle-Grid Integration Platform (OVGIP)

- **Unified, single, open interface to utility or 3rd party DRMS**
- **Engages all stakeholders in the ecosystem**
- **Customer-centric with commercialization intent**

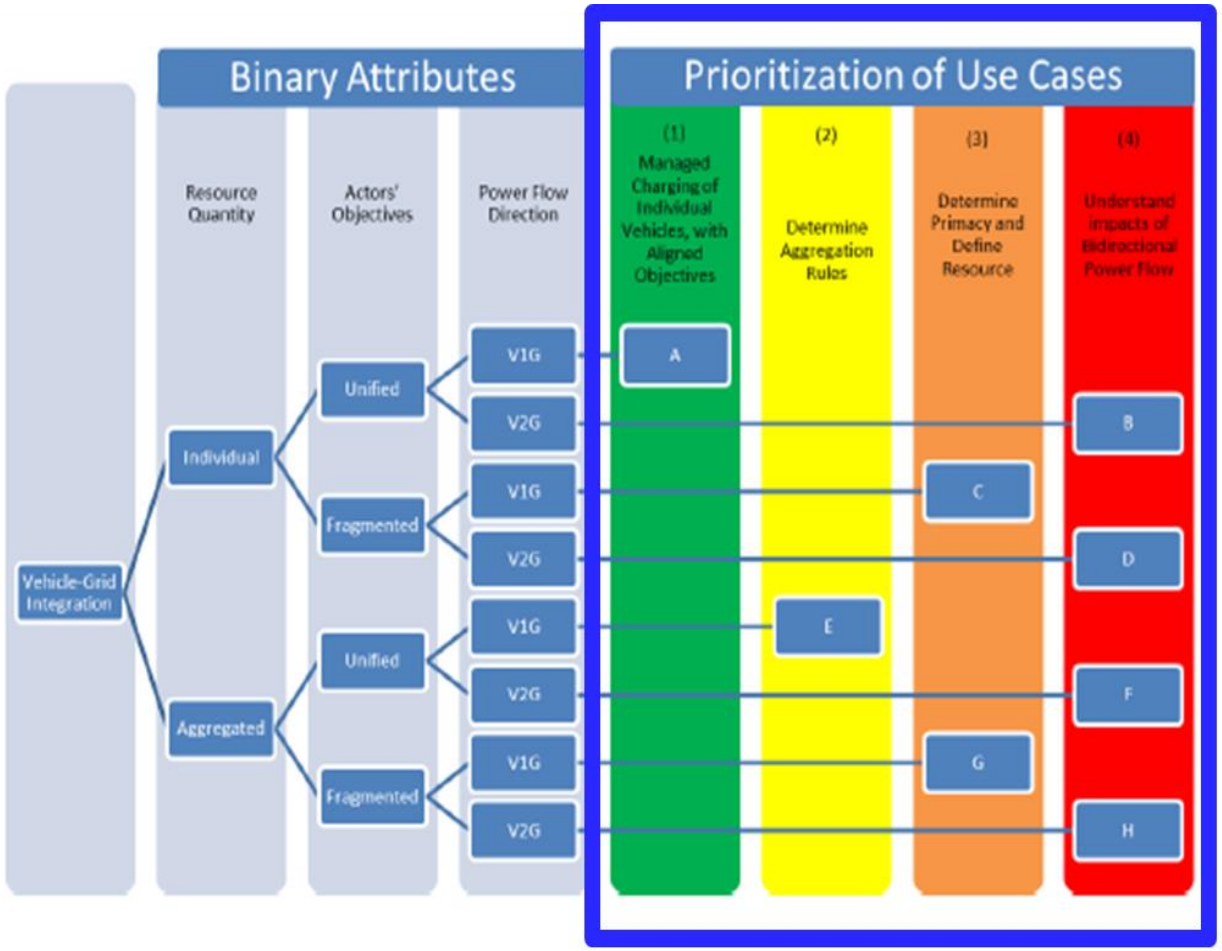
- **V1G first, V2G next**
- **Platform / applications approach**
- **Scalable, secure, low-cost**
- **Phase 2 of development pilot commenced in 2017**





Utility-OEM Open Vehicle-Grid Integration Platform has depth
Its use cases directly address VGI roadmap priorities

VGI Use Case Priorities



OVGIP Use Cases

1 Automated Utility Electricity Rate Tariff Processing

2 Locational Demand Response; Balancing Resource

3 Interface with Home Energy Management System / ESI

4 Interface with Building Energy Management System

5 Pricing Signal Events

6 Interface with EVSE Network Provider

7 Optimized Load Management (ISO/IEC 15118)

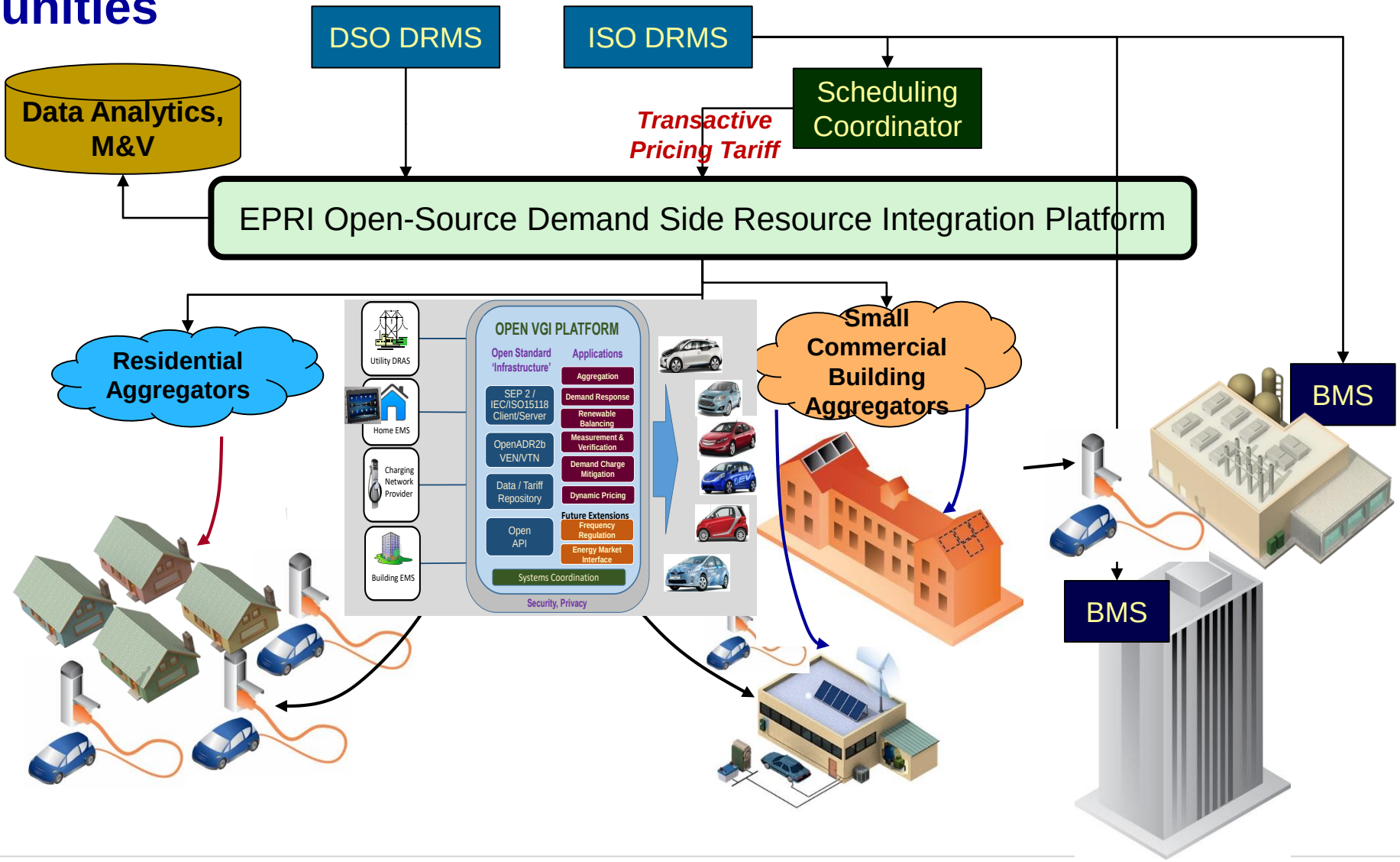
8 Vehicle Roaming

9 EVSE Networking Functionality

10 Metering and Data Exchange

11 Customer Enrollment and Administration

Open Vehicle-Grid Integration Platform has breadth
EPRI leading development of expanded platform to support Advanced Energy Communities



What about EVs and natural disasters?

Includes integration with

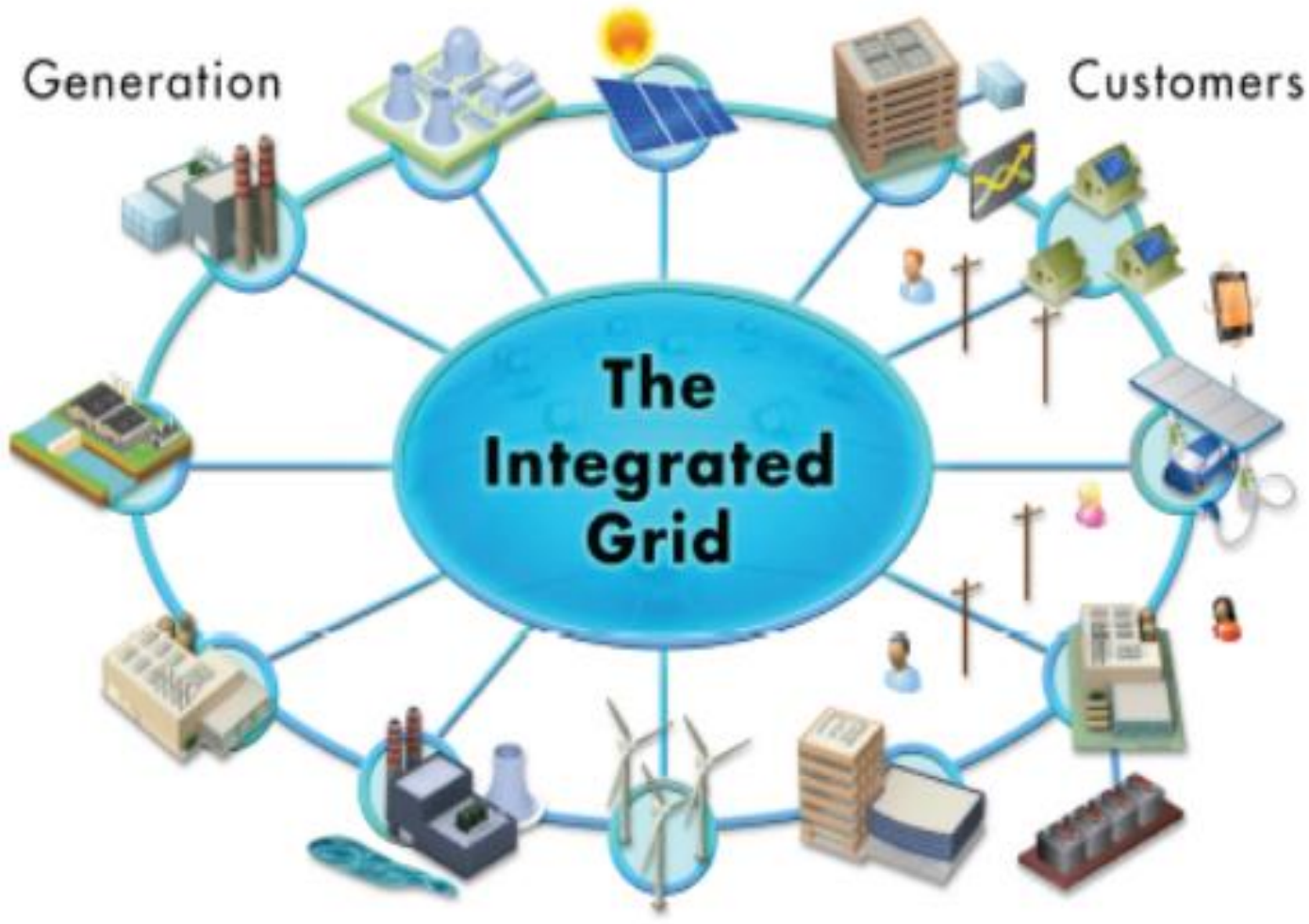
- Managed Charging
- Vehicle-to-Grid
- MaaS based EVs and DC fast charging
- Portable Storage

Courtesy: Maven GIG, FreeWire, OrbComm, Fiat Chrysler Automobiles, General Motors, Chanje, Inc

Summary: Customer-owned resources and EVs a huge opportunity – if customers accept and market exists

- Key observations
  - EVs can be a huge grid resource.
  - Need scalability and security at the lowest possible cost
  - Successful and beneficial integration of EVs contingent upon reliable availability for them to provide grid services

- Key barriers
  - Technology: How to make technology interoperate reliably and integrate with the grid?
  - Value: How to assess and realize value, including appropriate market mechanisms?
  - Customers: Is any of this non-intrusive, customer-centric and friendly?



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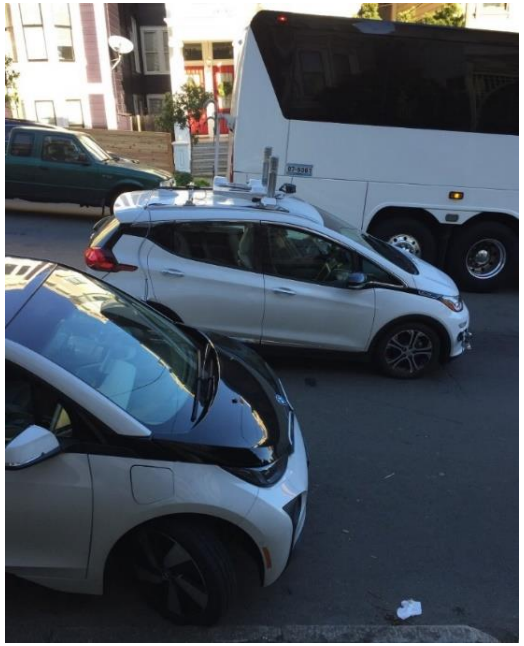
V. Looking Ahead – Today and Tomorrow

Time

- New transportation models
- 200+ mile mass-market battery EVs
- High power charging
- Smart charging programs
- Autonomous driving ($80B invested)



Updated: 5/21/2018

Photos credit: INVIDIA, Jaguar, Wavmo, Nissan, Watson Collins, Dan Bowermaster

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