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Transportation Electrification

A Technology Overview

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Transportation Electrification – A Technology Overview

- Market Status of Plug-In Electric Vehicles
- PEV Adoption Forecasting
- Energy and Climate Impacts of PEVs
- Grid Impacts of Plug-In Electric Vehicles
- Charging Infrastructure

Material in this presentation is publicly available at www.epri.com (EPRI Technical Report 1021334)

Market Status of Plug-In Electric Vehicles

Mainstream PEV Commercialization Began December 2010

Chevrolet Volt

- Extended Range Electric Vehicle (EREV - A plug-in hybrid with a guaranteed electric range).
- 25-50 mile advertised range
- Charging: 8-10 hours at 120V, 12A
  3-4 hours at 240V, 15A

Nissan Leaf

- Battery Electric Vehicle
- 100-mile advertised range
- Charging: 20 hours at 120V, 12A
  8 hours at 240V, 15A
  30 min at 400V, 150A

Battery Electric Vehicles

- Plug-in vehicle with rechargeable battery only
- Driving range limited by battery size – industry norm for range ~ 100 miles
  - Tesla is exception, offering longer range
- Nominal recharge time of about eight hours (fully depleted battery)
- The majority of PEV launches through 2012 are BEVs

Mitsubishi 'i' battery electric vehicle. ***Photo courtesy of Mitsubishi.***

Ford Focus Electric battery electric vehicle. ***Photo courtesy of Ford.***

Plug-In Hybrid Electric Vehicles

- Plug-in vehicle with rechargeable battery
- Internal combustion engine allows for extended driving
- Typically based on hybrid vehicle technology (e.g. Prius Plug-In)
- 10 – 40 miles electric range
- Likely to blend electricity and gasoline at higher speeds, power

Toyota Prius Plug-In Hybrid. ***Photo courtesy of Toyota.***

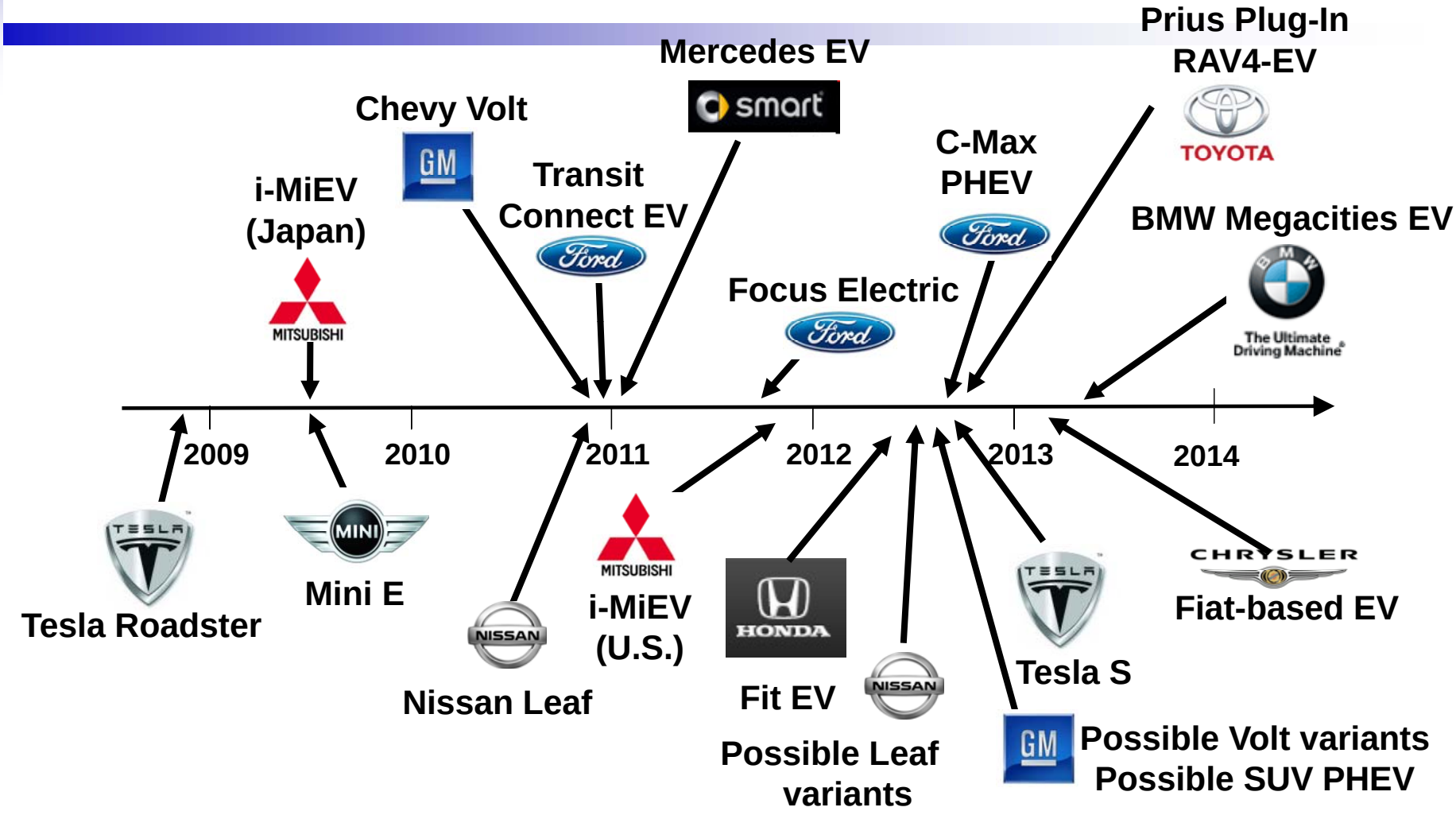
Ford C-MAX Energi plug-in hybrid. ***Photo courtesy of Ford.***

Extended Range Electric Vehicle

- A type of PHEV—rechargeable battery plus a combustion engine
- EREVs drive like BEVs until battery is depleted then switch to hybrid mode
- Something of a ‘new’ category
  - Many consider to be distinct and separate category from PHEVs
- EREVs can also drive for extended distances between charges using engine
- Electric range typically longer, 25-50 miles

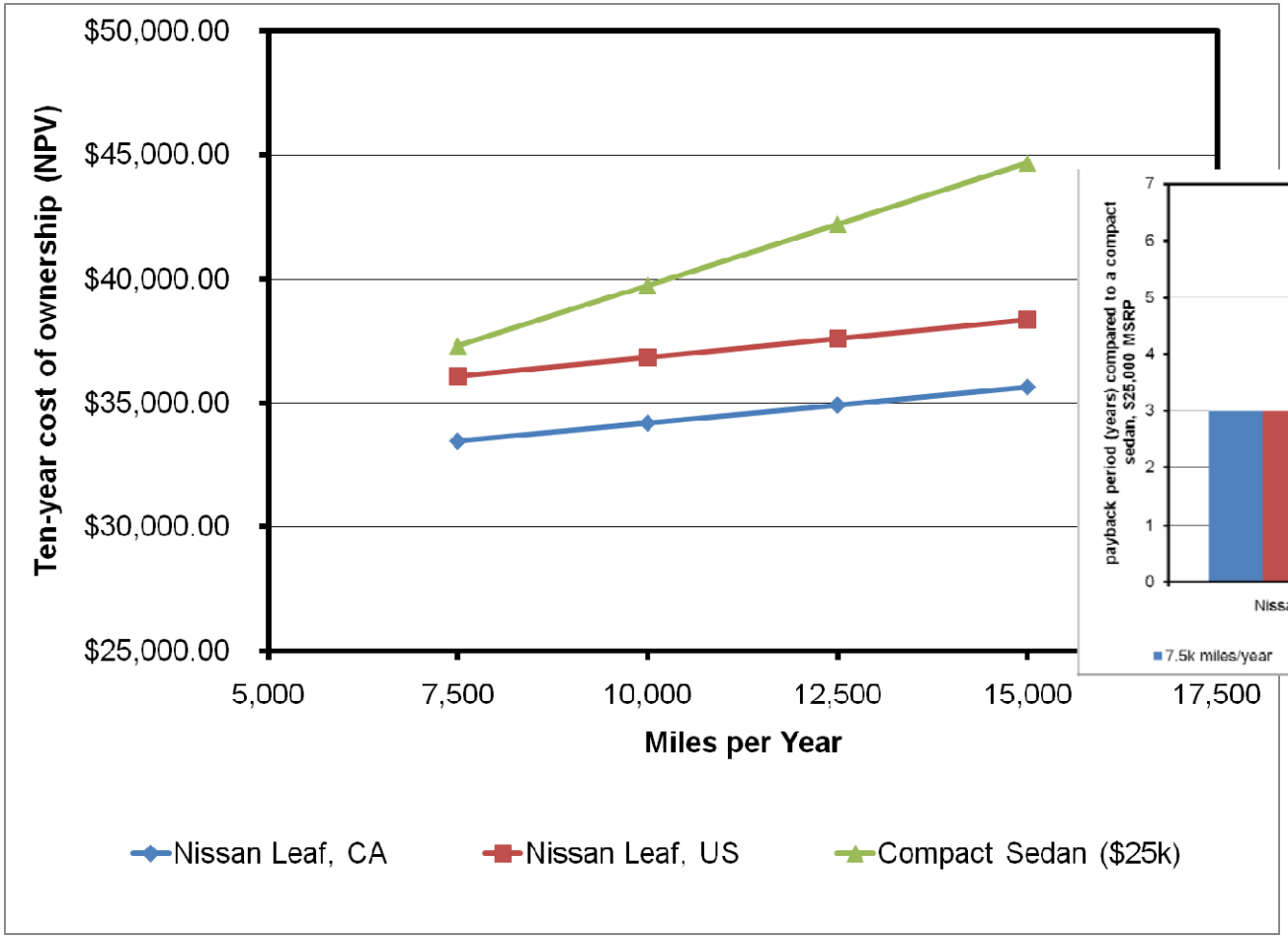
Chevrolet Volt Extended Range Electric Vehicle (EREV). ***Photo courtesy of General Motors***

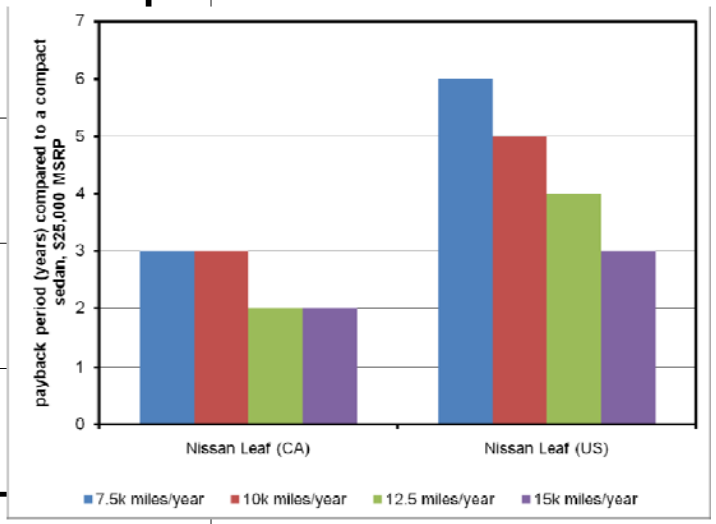
Plug-In Vehicle Commercialization Timeline



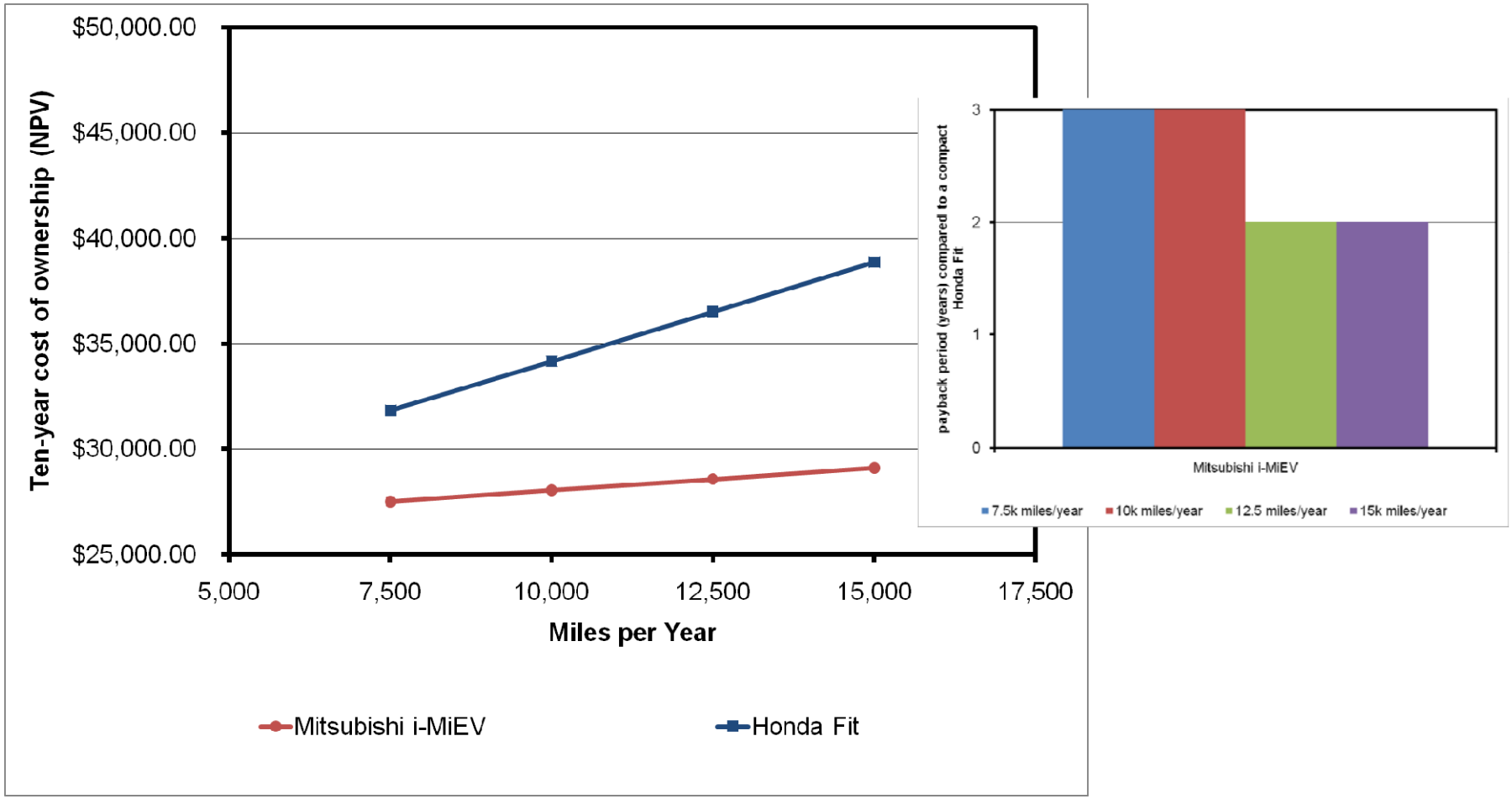
For comparison, between 1999 and 2004, there were three hybrids introduced to the U.S. market (Prius, Insight, Civic Hybrid)

EV Cost of Ownership is Competitive Today
Nissan Leaf vs. Compact Sedan

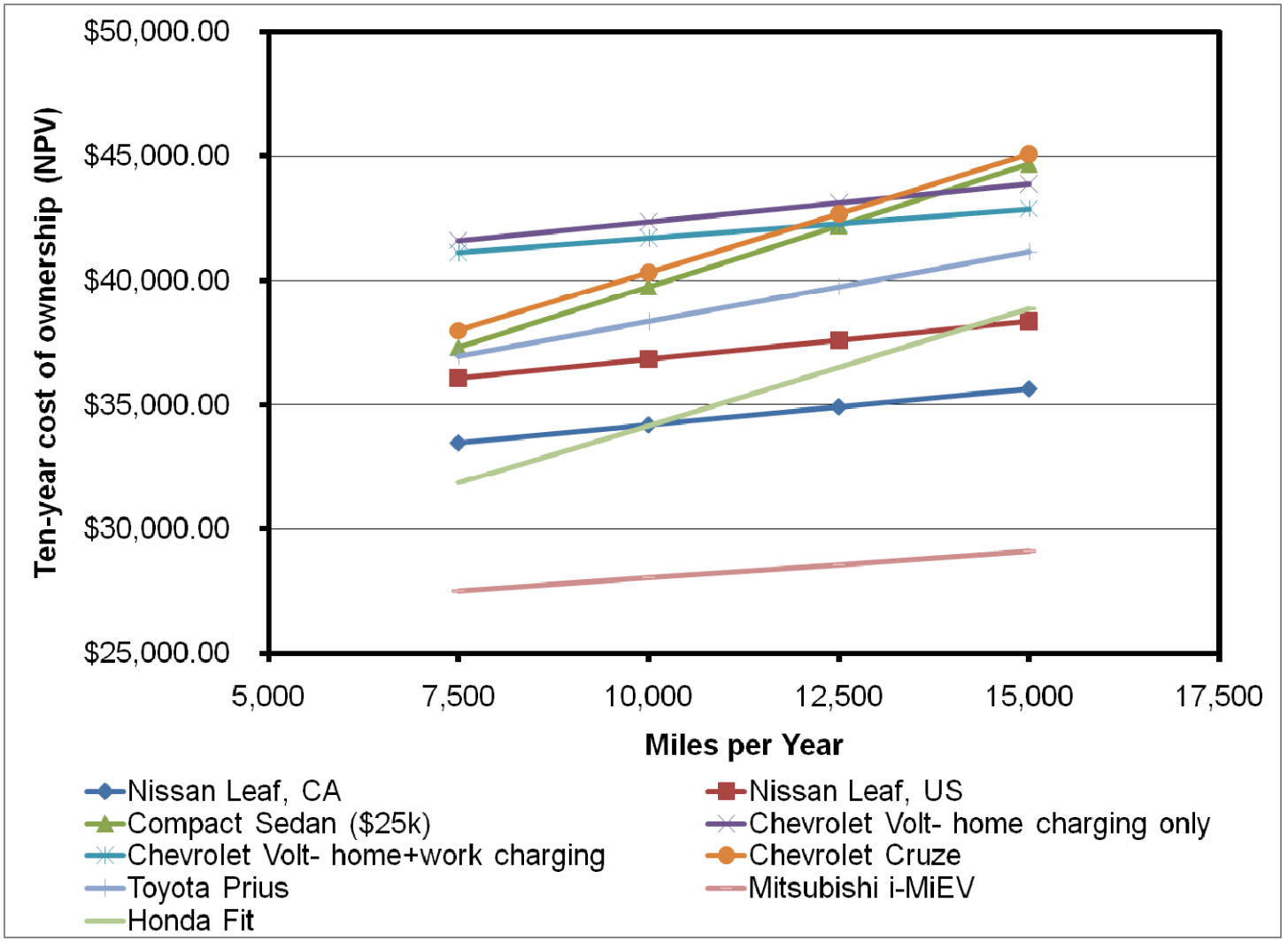




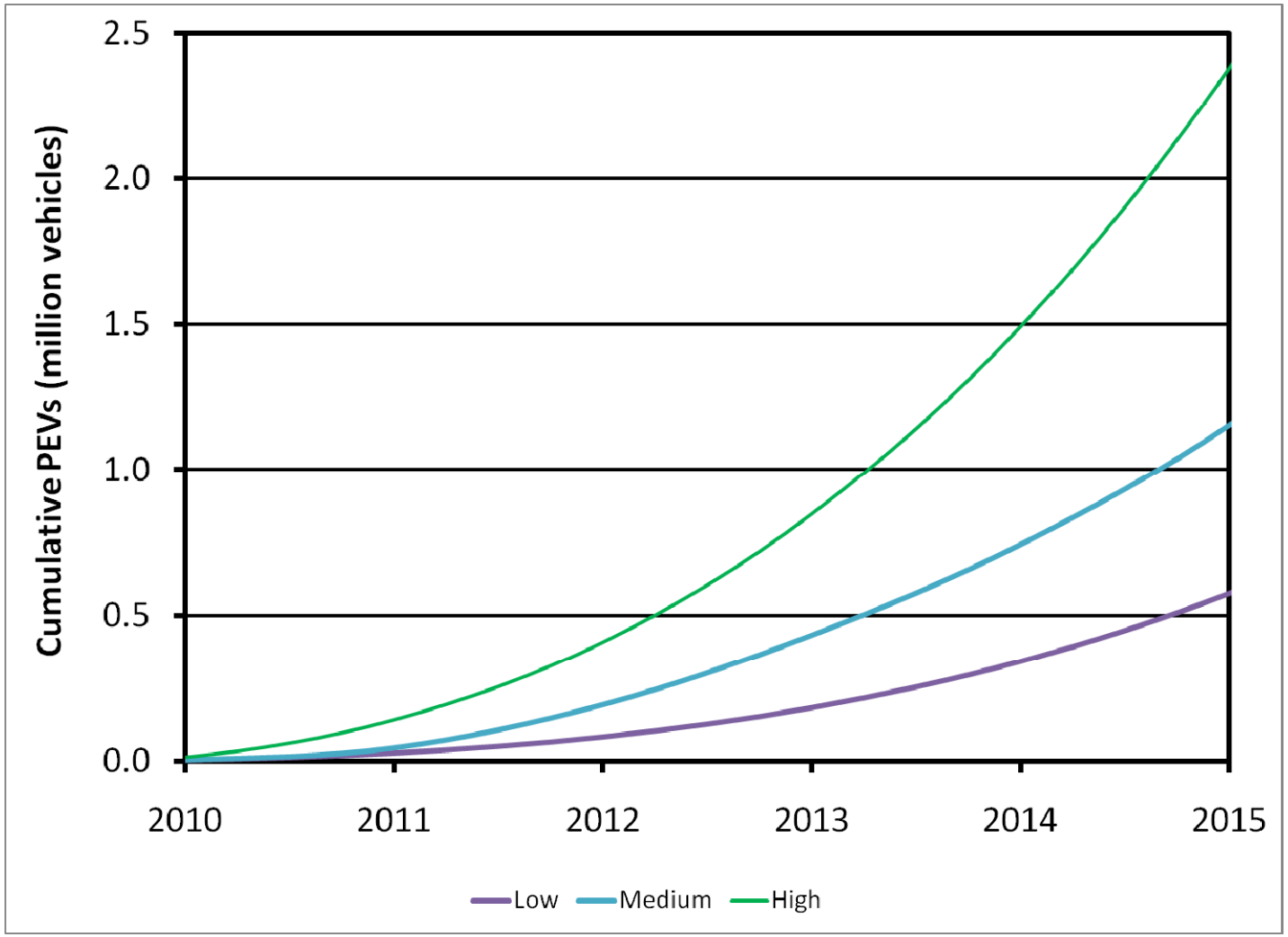
Mitsubishi i-MiEV vs. Honda Fit



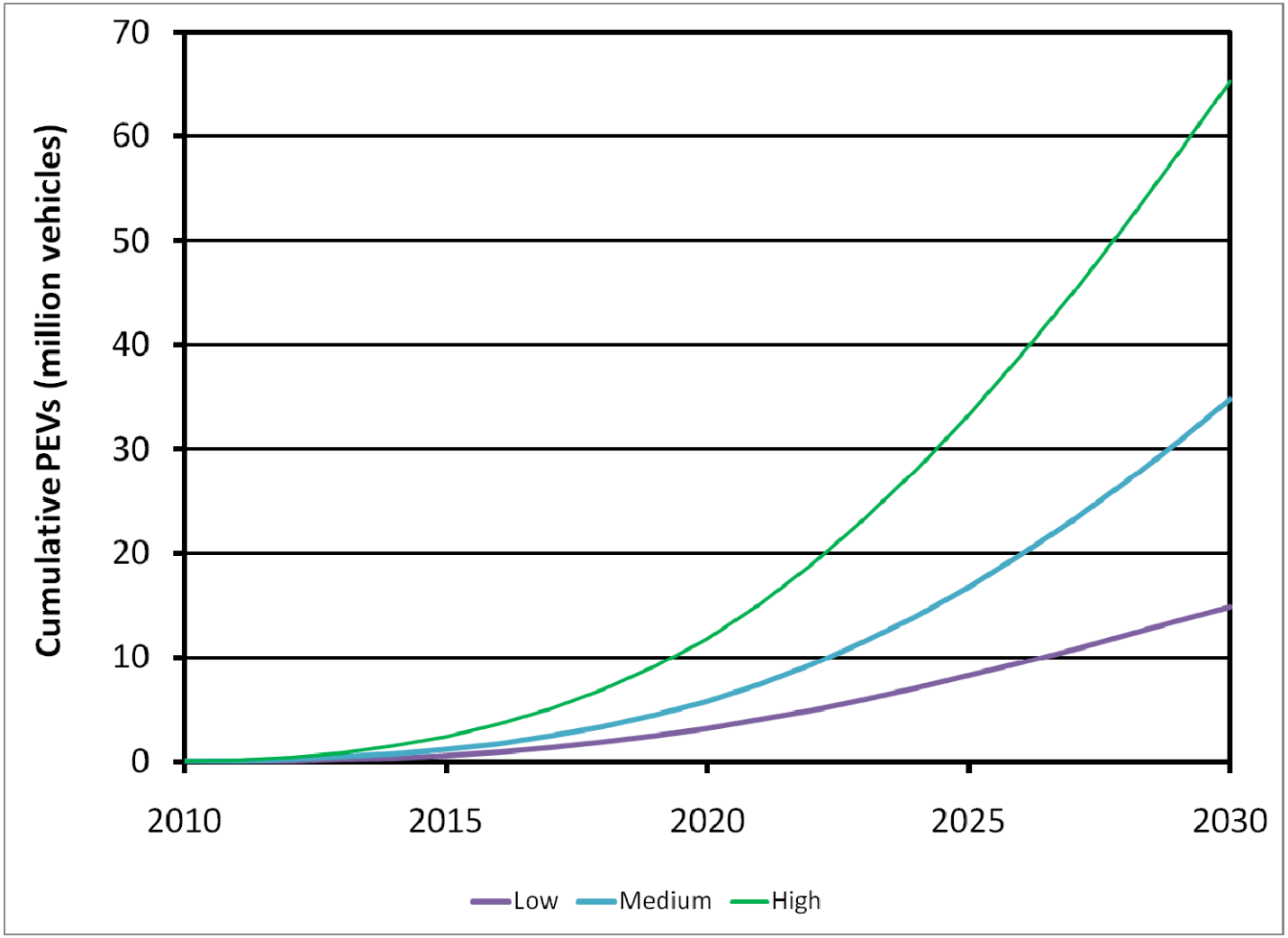
Ten-Year Cost of Ownership ($ in NPV)



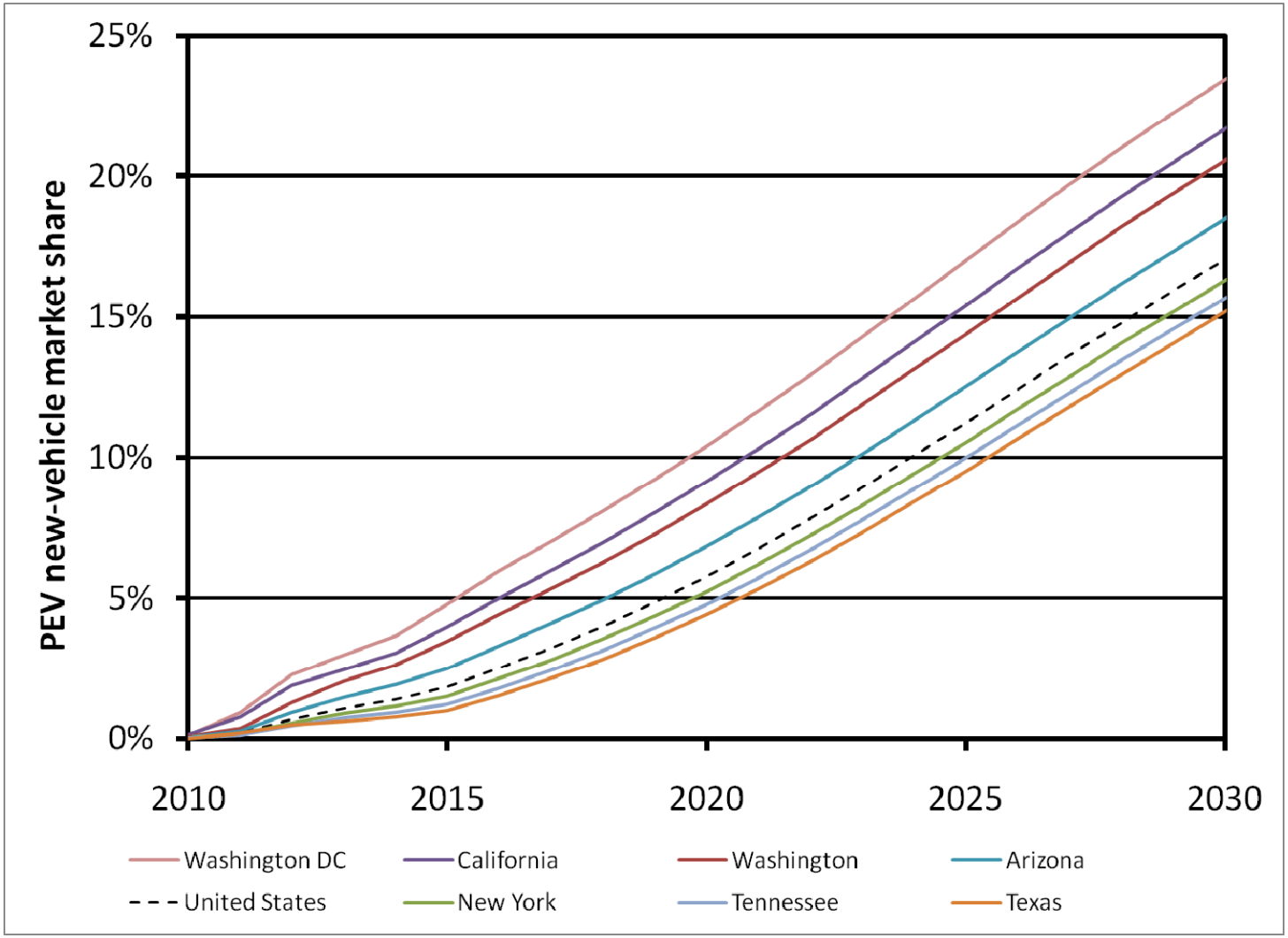
Cumulative PEV Sales from 2010 – 2015



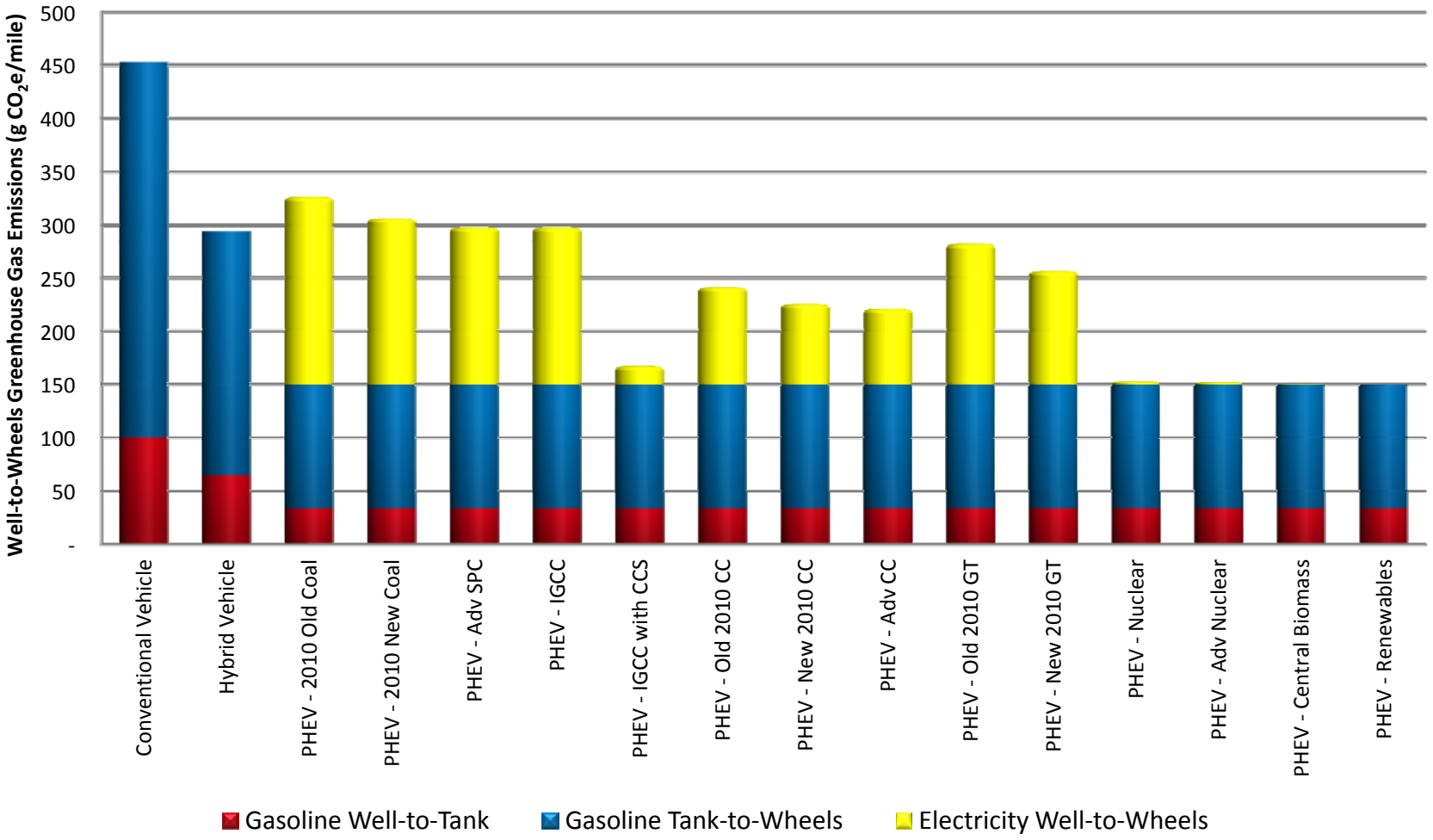
Cumulative PEV Sales from 2010 – 2030



Regional Variations in PEV Adoption
Currently based on HEV adoption

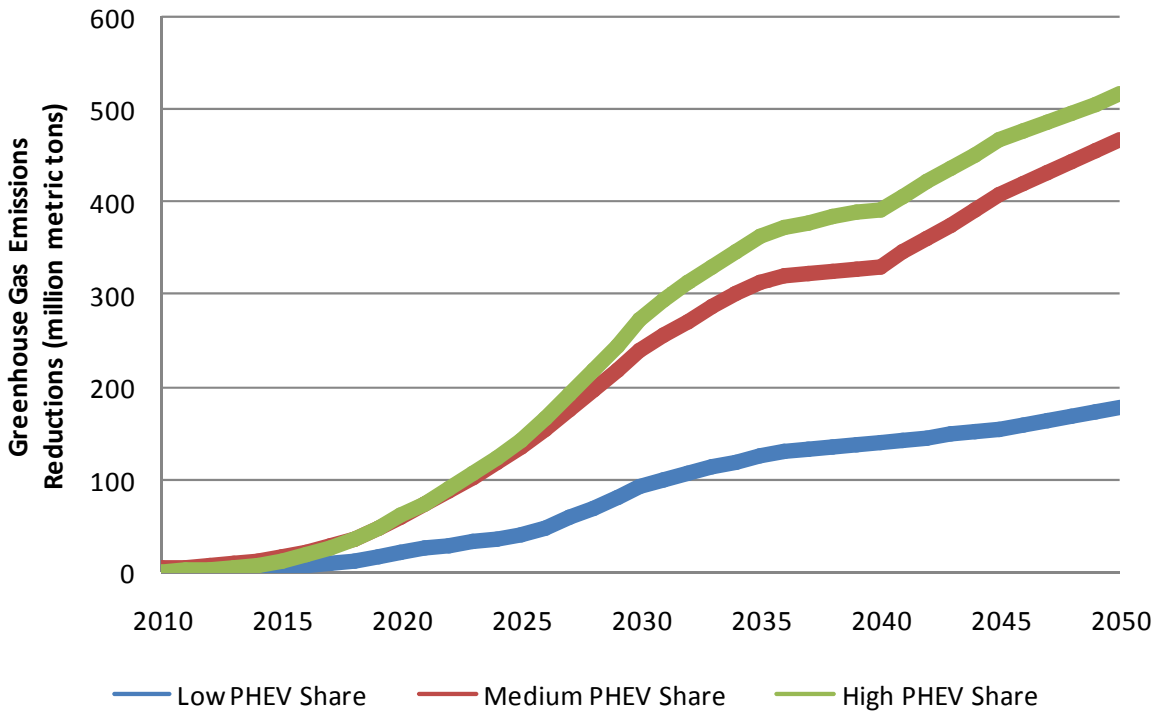


Power Plant-Specific PHEV Emissions in 2010
PHEV 20 – 12,000 Annual Miles



Greenhouse Gas Emissions

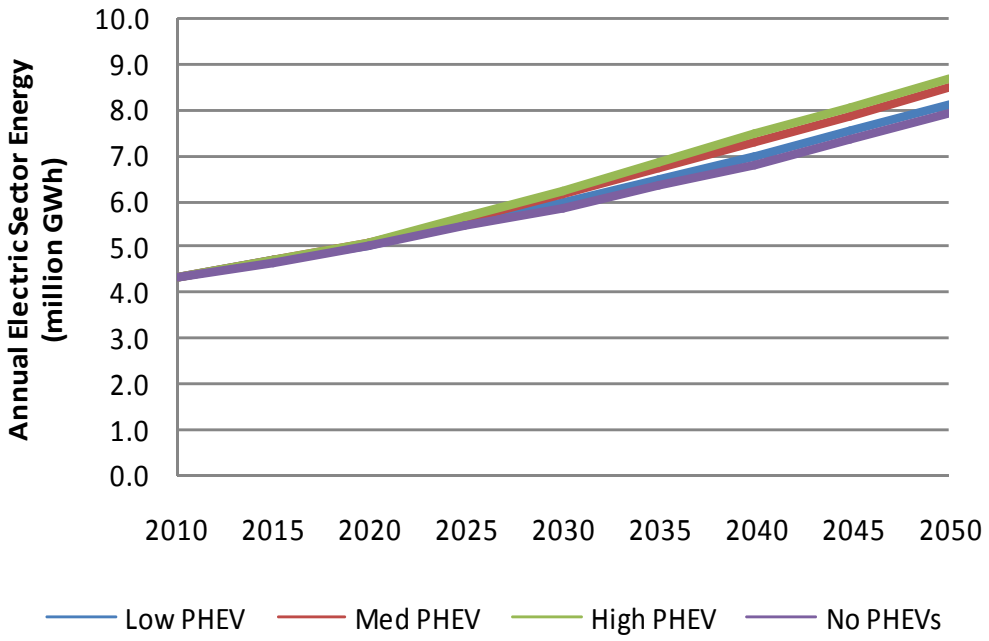
- Electricity grid evolves over time
- Nationwide fleet takes time to renew itself or “turn over”
- Impact would be low in early years, but could be very high in future
- A potential 400-500 million metric ton annual reduction in GHG emissions



Annual Reduction in Greenhouse Gas Emissions From PHEV Adoption

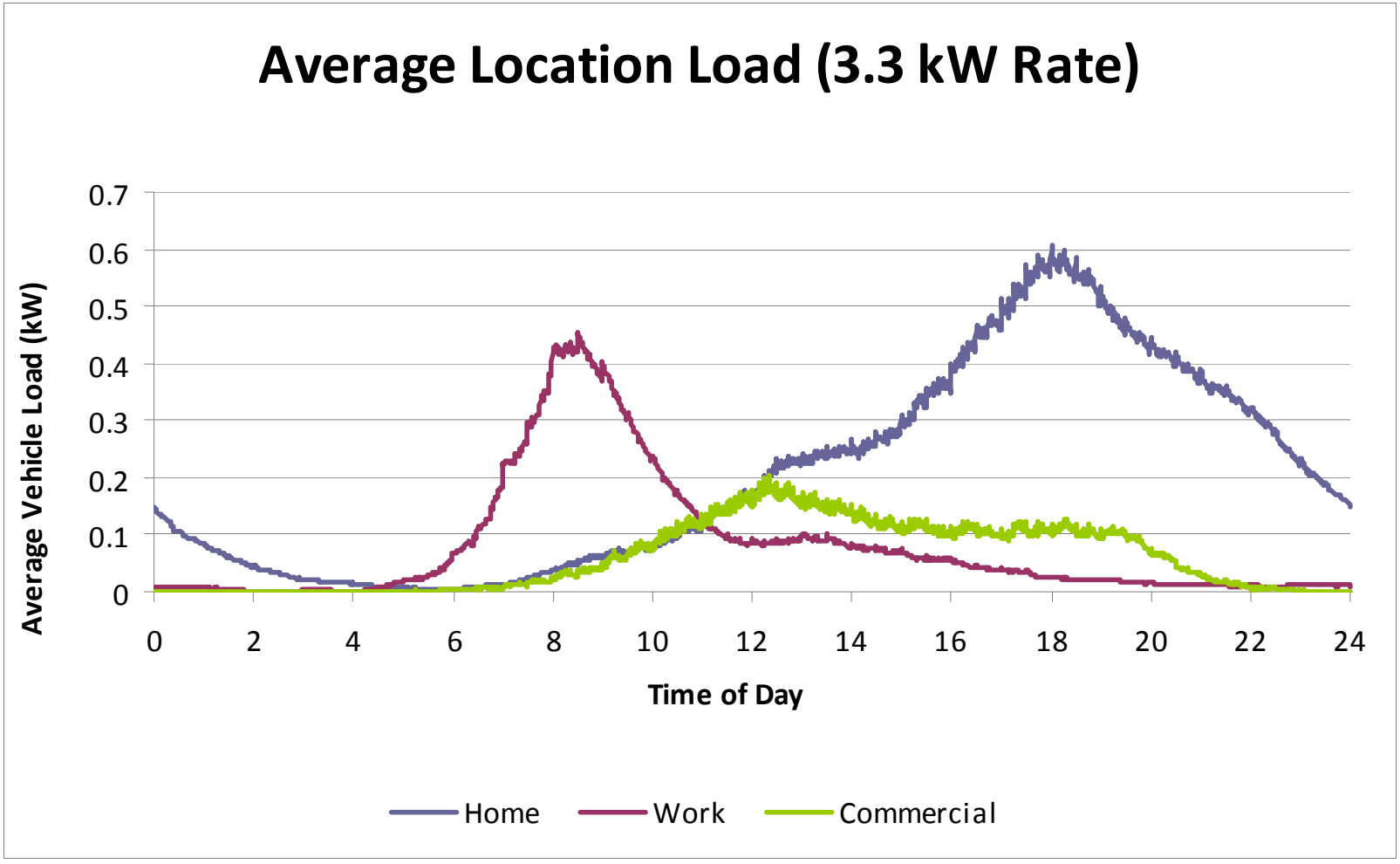
Impacts to Energy
Electricity and Petroleum

- Moderate electricity demand growth
- Capacity expansion 19 to 72 GW by 2050 nationwide (1.2 – 4.6%)
- 3-4 million barrels per day in oil savings (Medium PHEV Case, 2050)

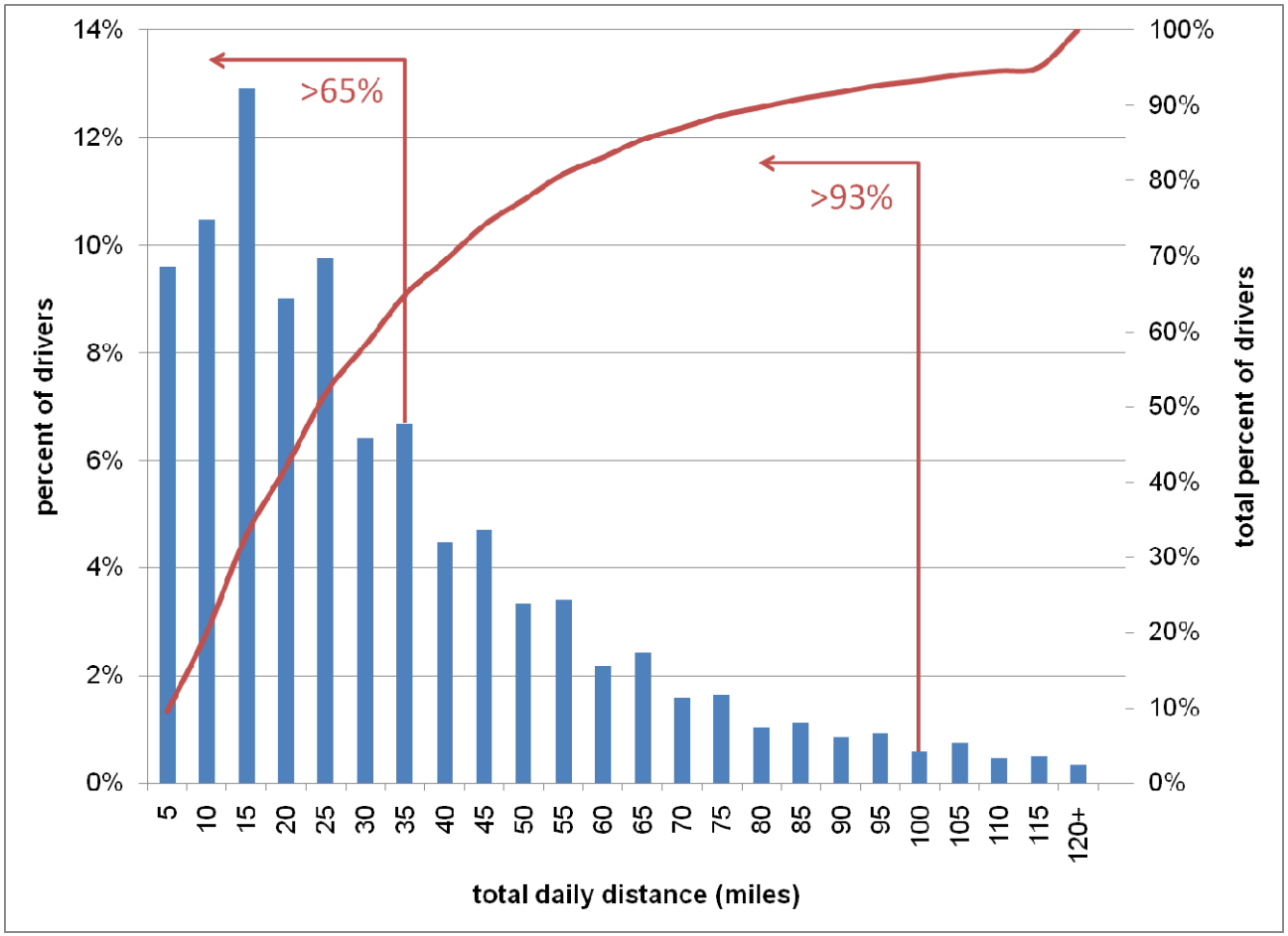


Electricity Demand: Medium CO_2 Case

Grid Impacts by Charging Location
Residential (Home), Workplace, Public (Commercial)



Most Daily Trips are Relatively Short



Charging Infrastructure
PEVs Generally Have Three Charging Options

120V – Level 1

Portable cordset
Use any 120V outlet

Up to 1.44 kW

DC Fast Charging

Up to ~ 50 – 60 kW

Fast, expensive

Standard not yet in place

240V – Level 2

Permanent charge station (EVSE)

Typ. 3.3 – 6.6 kW, but up to 19.2 kW

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PEV Charging Options Defined

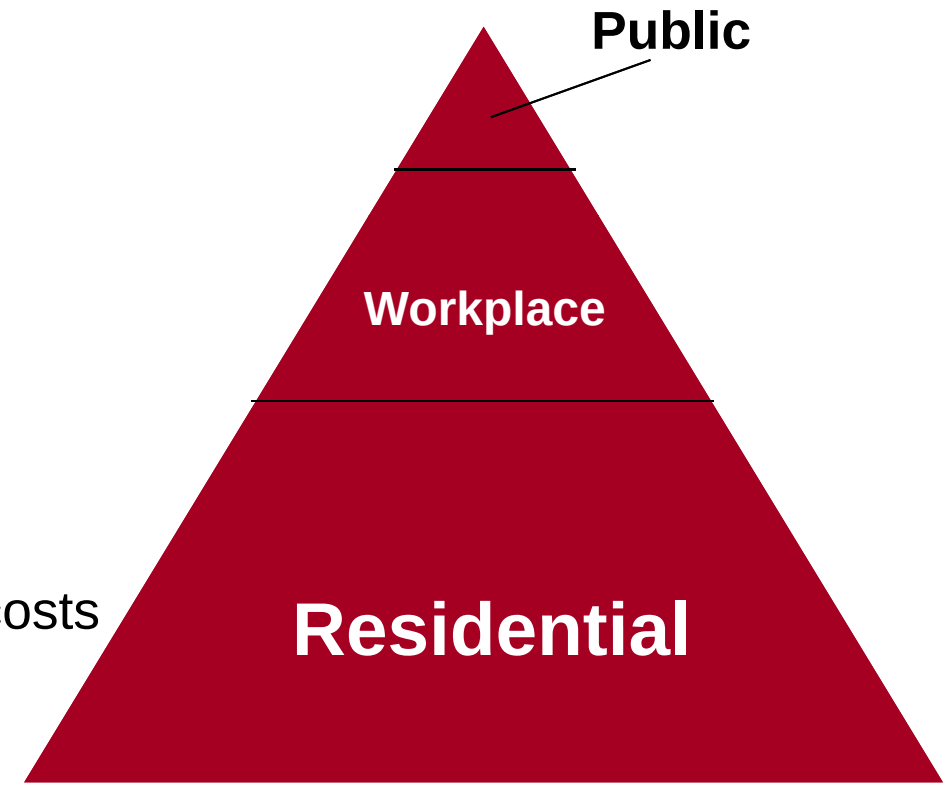
- AC charging – Level 1
  - 120 VAC input
  - EVSE (electric vehicle supply equipment) is a portable cordset compatible any standard 120 volt outlet
  - 1.44 kW maximum continuous charge rate (12 amps)
  - Overnight charge sufficient for ~40 miles of EV driving
- AC charging – Level 2
  - 240 VAC, single phase input
  - EVSE is hard-mounted
  - 19.2 kW maximum continuous charge rate (80 amps)
    - 3.3 kW to 6.6 kW is more typical

PEV Charging Options Defined

- DC Fast Charging
  - 480 VAC, three-phase input (208 three-phase also possible)
  - High-power station converts AC to DC and delivers directly to battery pack
  - Power levels current up to 60 kW
    - Approximate charge times of 30 minutes for typical BEVs
    - Higher power levels possible in the future
  - U.S. standard for DC charge connector still a work-in-progress

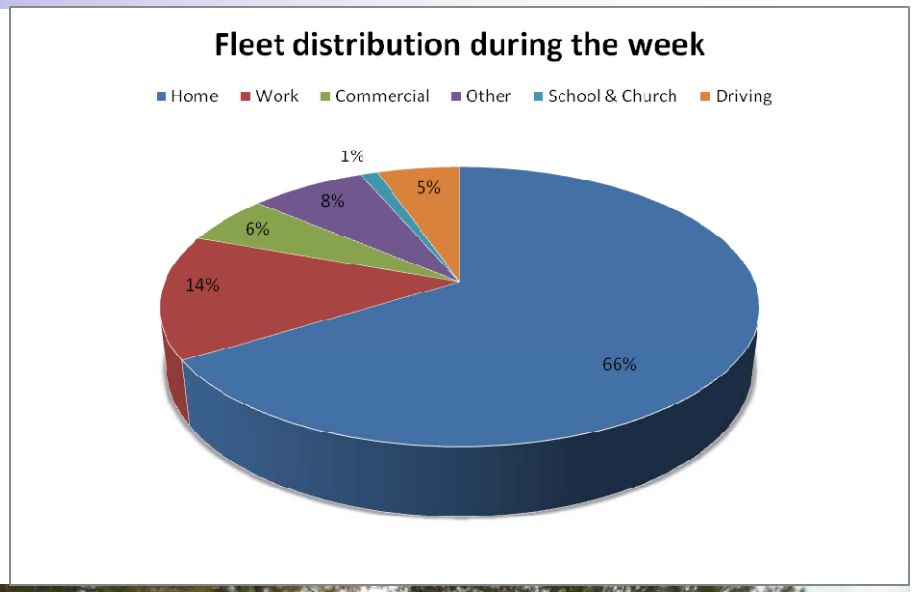
Understanding and Planning Charging Infrastructure

- **Build Today's Infrastructure Today**
- Infrastructure is expensive
  - ~ $1500 home, $2500+ public
- Focus on Residential
  - – 95% of vehicles end day at home
  - – Costs can exceed $2200 - $2500
  - – Cost and lead time minimization
- Workplace
  - – Fleet education and certainty of costs
- Public Charging
  - – Critical vs. convenience
  - – Viable business models
  - – Long-term sustaining of infrastructure



Workplace Charging has a Significant Role

- Likely 2nd most frequent charging location
- Can be expensive
- Employer uncertainty regarding costs, tax implications
- Commercial fleet electrification faces similar uncertainties on cost and deployment of infrastructure
- Employer and fleet outreach is critical



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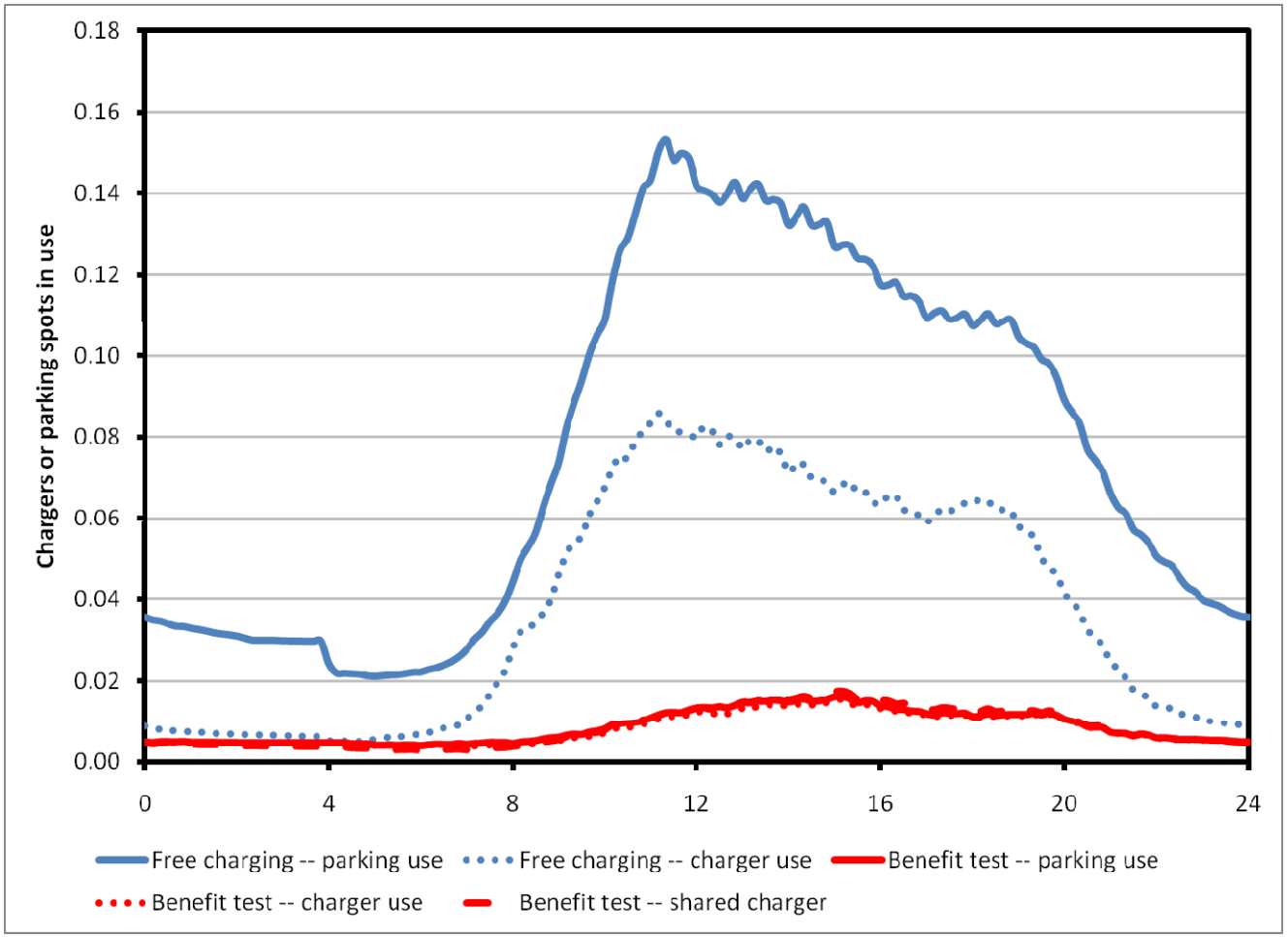
Challenges with Public Infrastructure

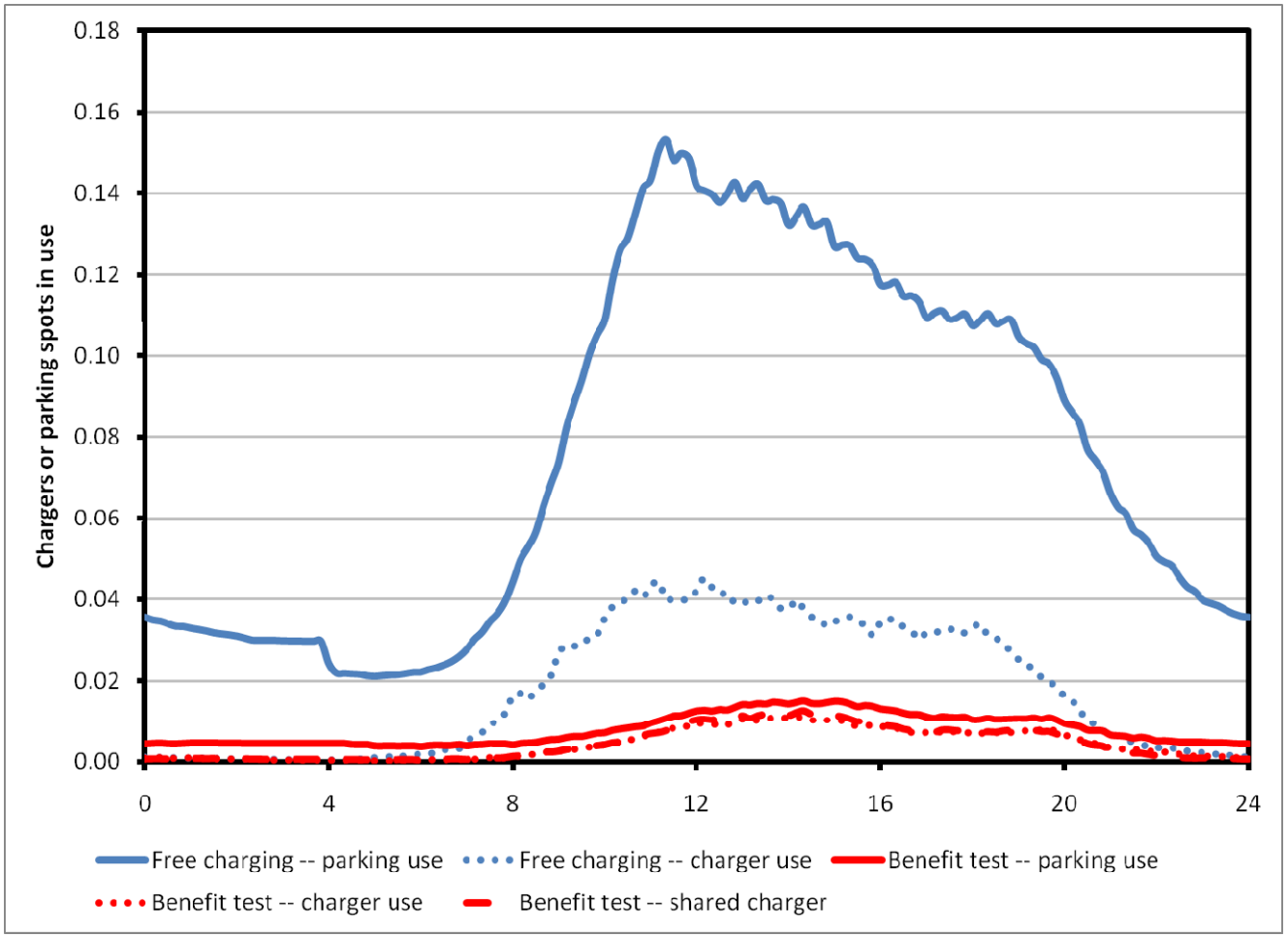
- We do not currently have a sustainable private business model—that is also attractive for the customer
  - It is difficult to earn a return on a public EVSE installation
- Proliferation of battery EVs creates needs for widespread AC charging, capitally intensive DC charging
- Some are considering membership models to support
  - NRG Energy (non-utility)
  - Austin Energy (utility)
- Point-of-use payments exist, but are and likely will remain financially unattractive
- Apartment and other multi-unit residential scenarios approximate the cost issues of public infrastructure

Results – BEV100 1.44kW commercial charger



Similar to the work charging scenarios, the shared charger model is not ideal.

Results – BEV100 6.6kW commercial charger



Very little change in the number of benefit tested spots in use between charge powers.

Summary

- Vehicles are coming! We will learn a lot in the next couple years as a variety of vehicles are deployed
- In almost all cases, greenhouse gas emissions and criteria pollutants are favorable for electric vehicles and plug-in hybrid electric vehicles
- Relatively high numbers of plug-in vehicles can be accommodated without significant changes to the grid. Managing the interaction between the vehicles and the grid can increase overall benefits
- Supplying infrastructure will be challenging. There is a lot to learn. The amount of required infrastructure is relatively low as long as charging incentives are not overly sold