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Building a U.S. Battery Industry for Electric Drive Vehicles: Automotive Industry Perspective

July 26, 2010

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Ford Motor Company

Sustainability Strategy – Technology Migration

Near Term

- Significant number of vehicles with EcoBoost engines
- Electric power steering – begin global migration
- Dual clutch and 6 speed transmissions replace 4 & 5 speeds
- Flex Fuel Vehicles
- Add Hybrid applications
- Increased unibody applications
- Introduction of additional small vehicles
- Battery management systems – begin global migration
- Aero improvements
- Stop/Start systems (micro hybrids) introduced
- CNG/LPG Prep Engines available where select markets demand

Mid Term

- EcoBoost engines available in nearly all vehicles
- Electric power steering - High volume
- Six speed transmissions - High volume
- Weight reduction of 250 – 750 lbs
- Engine displacement reduction aligned with weight save
- Additional Aero improvements
- Increased use of Hybrid Technologies
- Introduction of PHEV and BEV
- Vehicle capability to fully leverage available renewable fuels*
- Diesel use as market demands
- Increased application of Stop/Start

Long Term

- Percentage of Internal combustion engines dependent on renewable fuels
- Volume expansion of Hybrid technologies
- Continued leverage of PHEV, BEV
- Introduction of fuel cell vehicles
- Clean electric / hydrogen fuels
- Continued weight reduction actions via advanced materials

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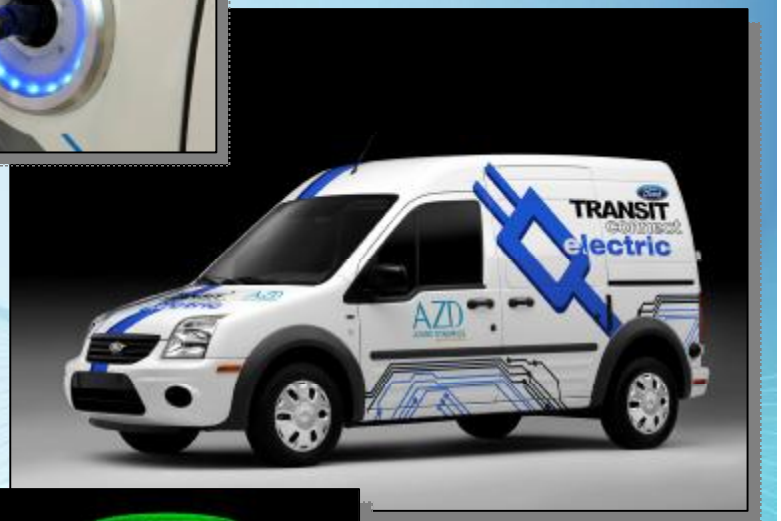
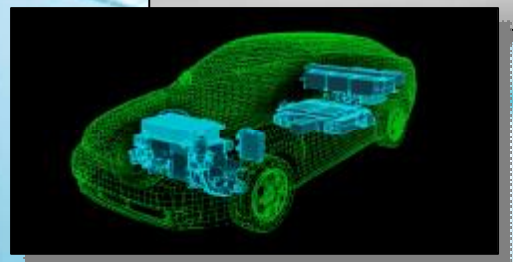
Hybrids, Plug-In Hybrids, and BEVs





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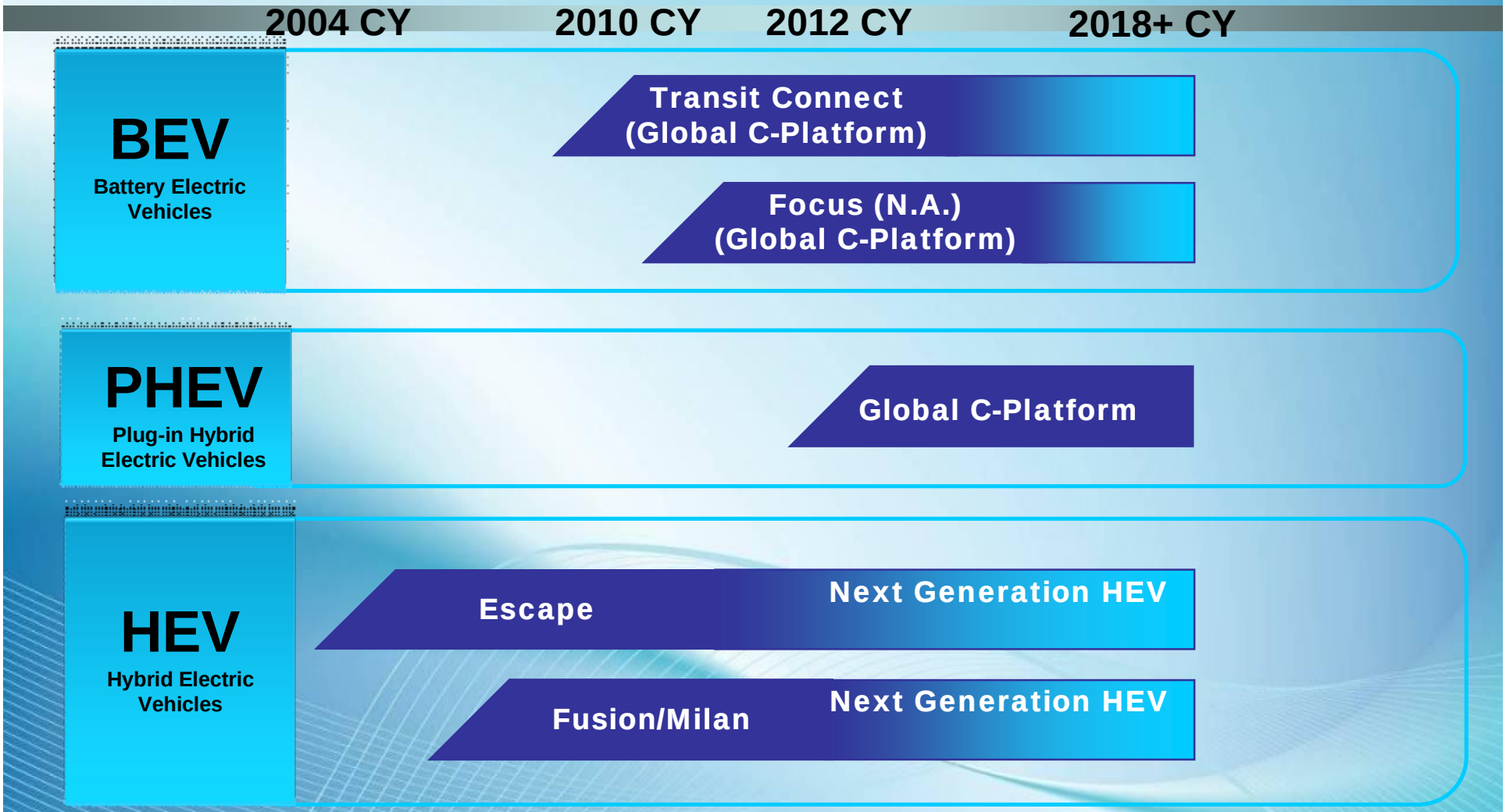
North America – Announced Electrification Projects



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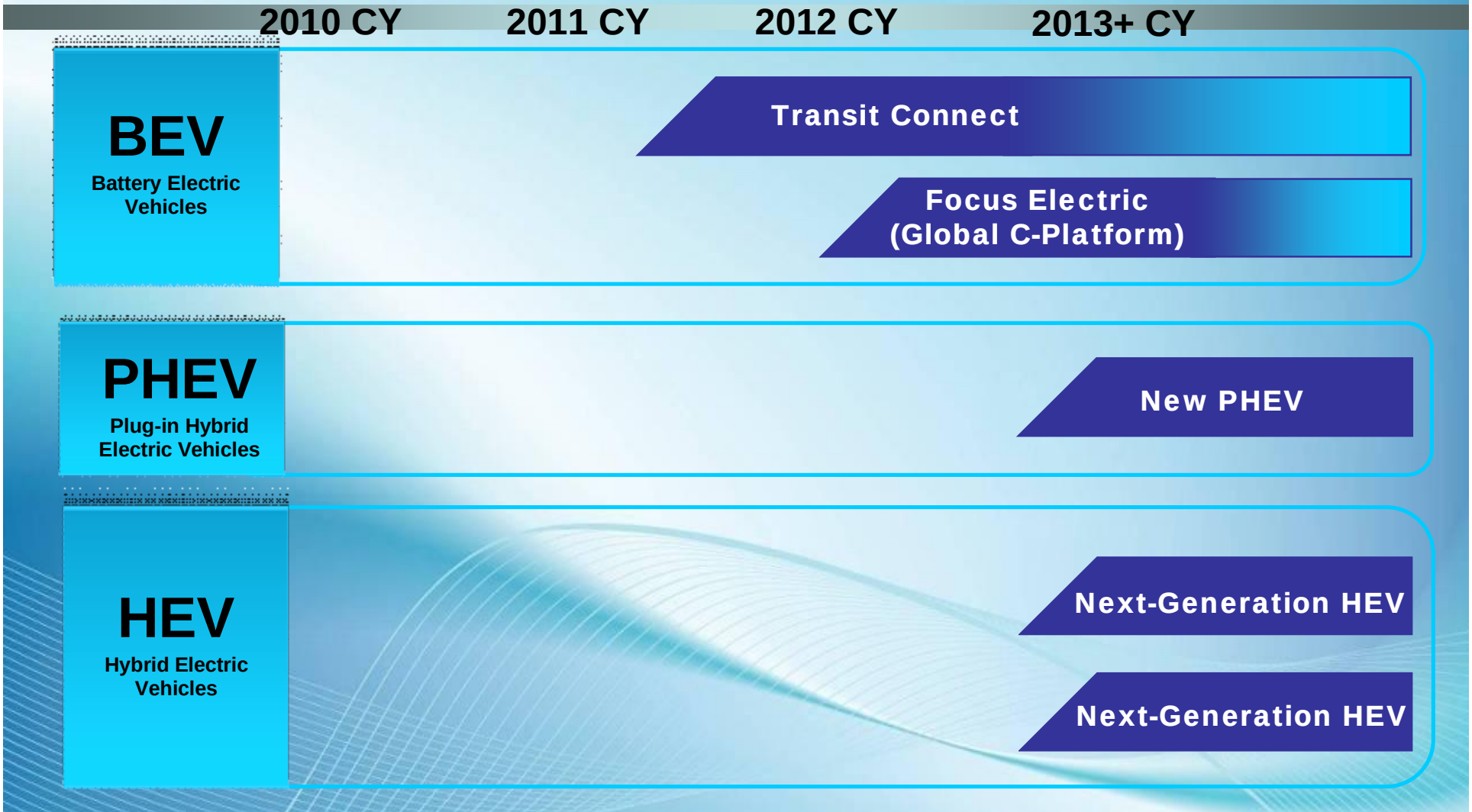
Ford of Europe – Announced Electrification Projects



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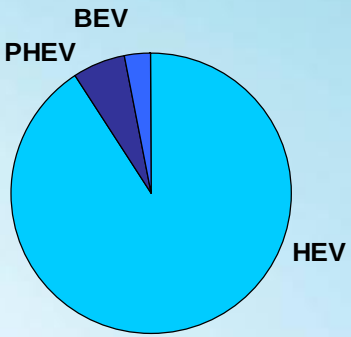
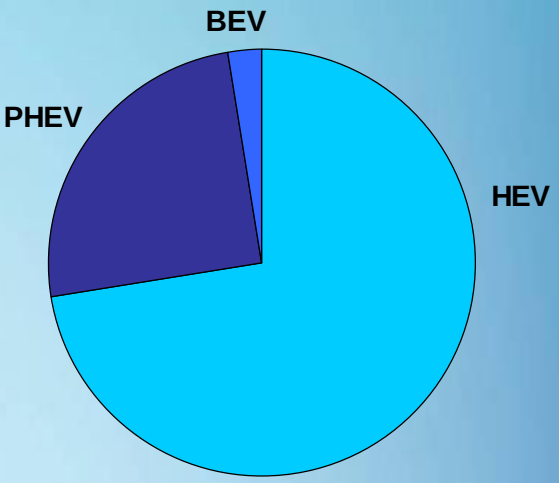
Ford Global Electrification Product Plan

	2010 CY	2015 CY	2020
Ford Global Volume			
% of total Ford volume	**1%**	**2-5%**	**10-25%**

- **Balanced Portfolio**
- **Global Flexibility**
- **Volume will be predominantly HEV**
- **Plug-ins gaining acceptance**

Balanced growth also provides flexibility to react to volatile external factors

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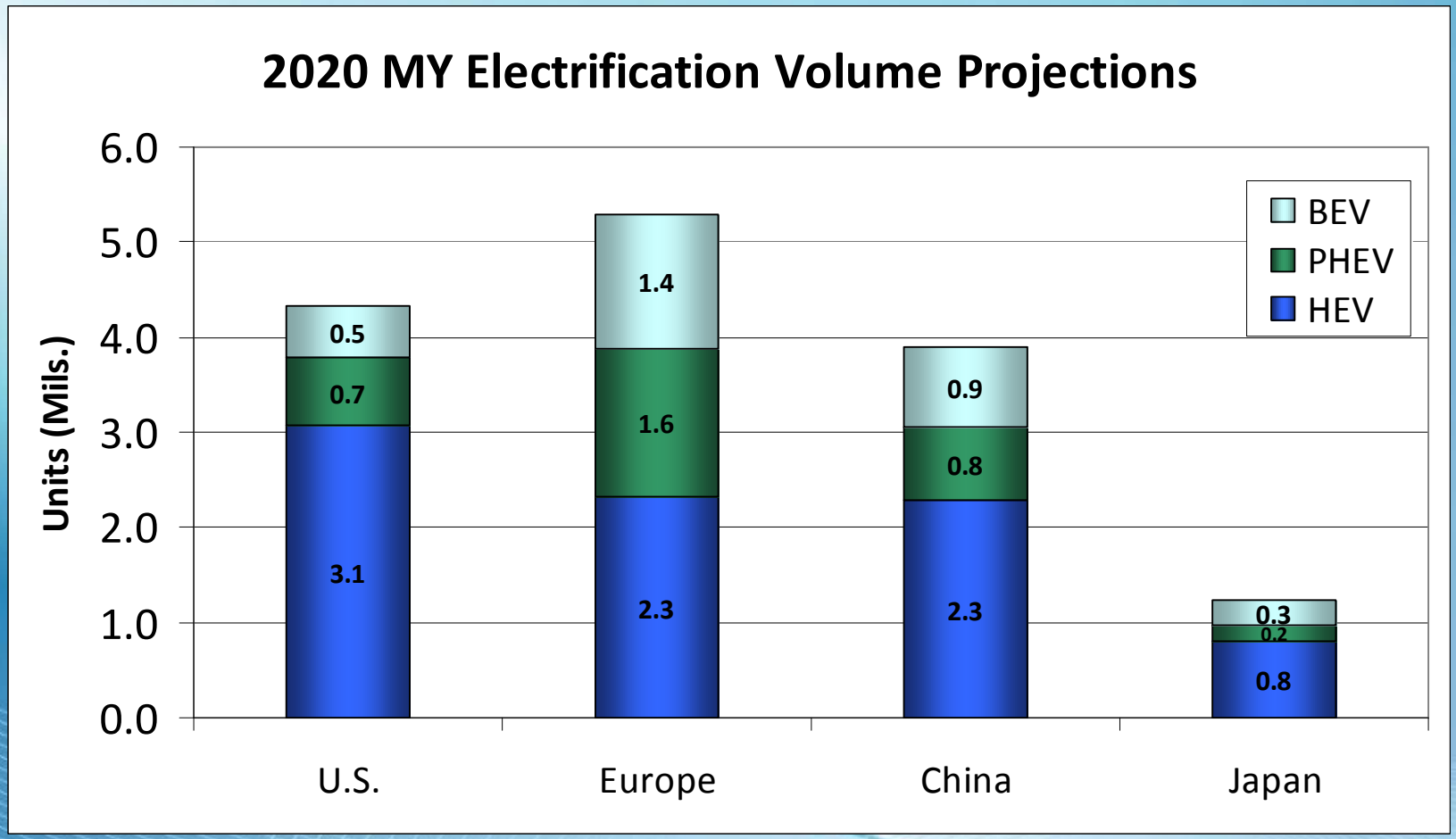
2015MY Global Electrification Volume Projections by Manufacturer



Note: Volume projections are based on forecast data from the following 3rd party studies:
- Roland Berger - Powertrain 2020: China's ambition to become market leader in E-Vehicles (April, 2009)
- Boston Consulting Group - The Comeback of the Electric Car? How Real, How Soon, and What Must Happen Next (December, 2008)
- J.P. Morgan - Global Environmental Series Volume 3 - HEVs Potential Reconsidered in Economic Crisis (May, 2009)
- A.T. Kearney - Retooling the Vehicle for 2020: How Advanced Technologies Will Radically Restructure the Automobile & Automobile Industry (March, 2010)
- Credit Suisse - Electric Vehicles - Global Equity Research (October, 2009)

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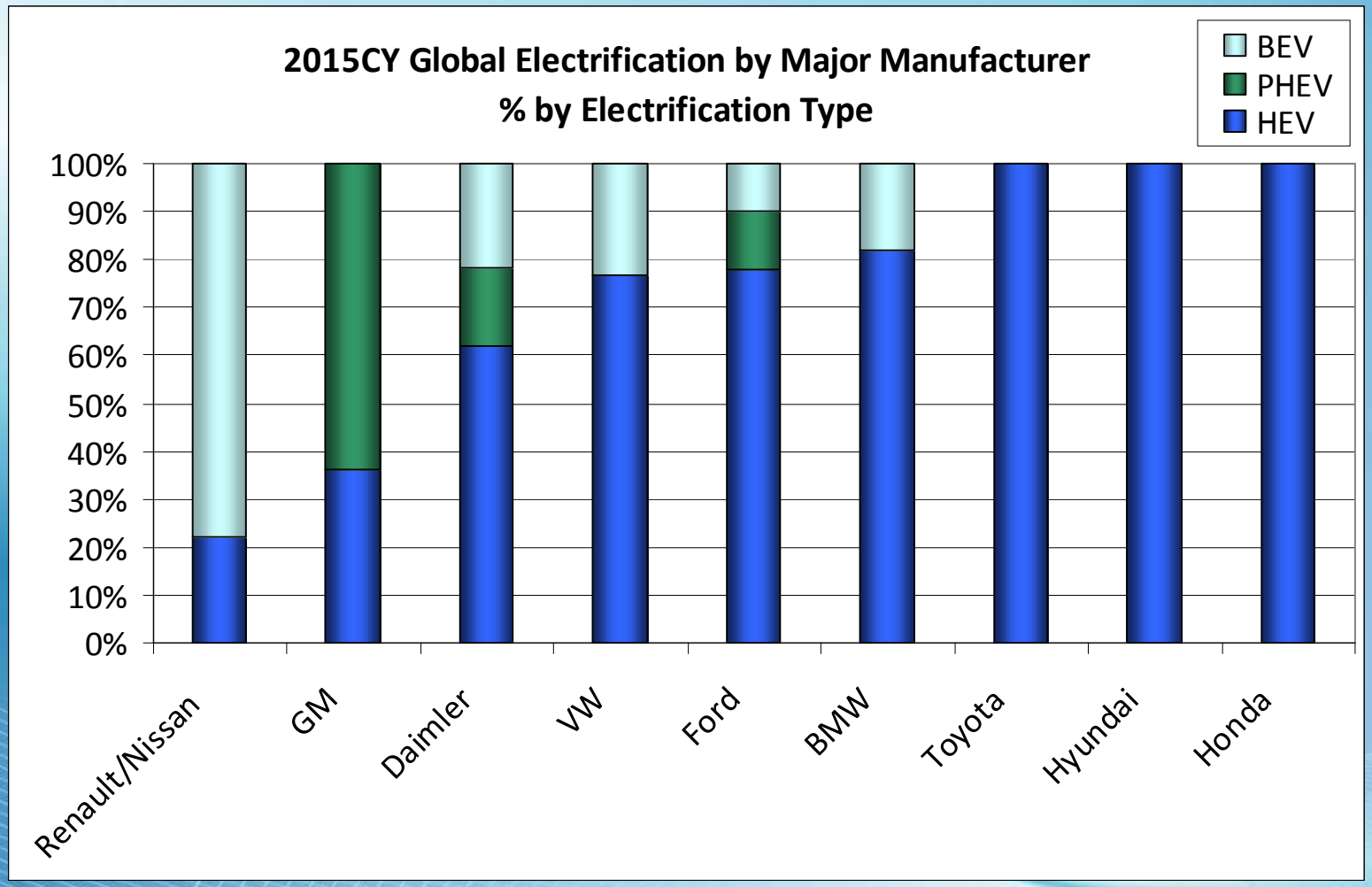
2020MY Global Electrification Volume Projections by Region



Note:
- All data is from CSM Worldwide global comprehensive vehicle production and sales forecasts, 3/05/10.
- Major manufacturers are those with >50,000 electrified vehicle sales projected in 2015

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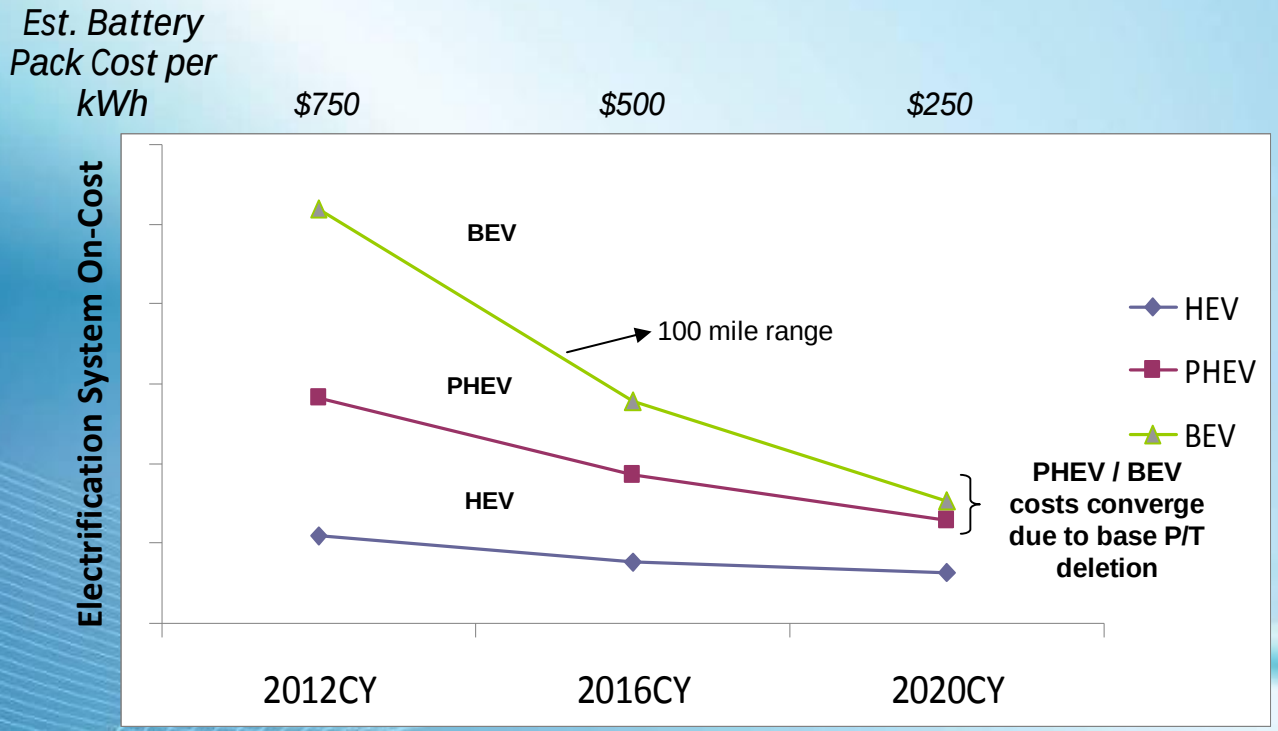
What does it take to support a sustainable mass market electrified vehicle?

- Customer-Focused
  - Great Features
  - Functional Trustworthy Technology
  - Delivers Transportation Needs
  - Affordable



High Vol – 250k+

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Drivers of Hybrid Technology Evolution
Electrification Technologies – Background

Function / System	Engine stop/start	Engine Assist (Downsize)	Regenerative Brake	Electric launch	All Electric Drive	Fuel Economy Improvement
Start/Stop (14V)	YES (> 0.3 sec)	Minimal (< 3 kW)	Minimal (< 3 kW)	NO	NO	3-6%
Mild Hybrid (42V)	YES	Modest (< 9 kW)	Modest (< 9 kW)	NO	NO	8%/12%
Medium Hybrid (100+V)	YES	YES	YES (full benefit)	NO	NO	40%
Full Hybrid (300V)	YES	YES	YES	YES	Yes	55%+
Plug In Hybrid (based on Blended Full)	YES	YES	YES	YES	Yes	80%+
Battery Electric Vehicle	YES	No Engine	YES	YES	YES	Infinite

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Drivers of Hybrid Technology Evolution

HEV → PHEV → BEV Components

	HEV	PHEV	BEV
Battery	Yes (Power)	Yes (Energy)	Yes (Energy)
Electric AC	Yes	Yes	Yes
DC/DC Converter	Yes	Yes	Yes
Regen Brakes	Yes	Yes	Yes
Motor(s)	Yes	Yes	Yes
Inverter(s)	Yes	Yes	Yes
Transmission	Yes	Yes	No
EV Gearbox	No	No	Yes
Charger	No	Yes	Yes

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Drivers of Hybrid Technology Evolution

SMARTGAUGE™ WITH ECOGUIDE

New Knowledge and Skills Needed: Customer and Engineer

New concepts required for Plug-In vehicles

GRAPHICALLY TRACKS DRIVER'S EFFICIENCY

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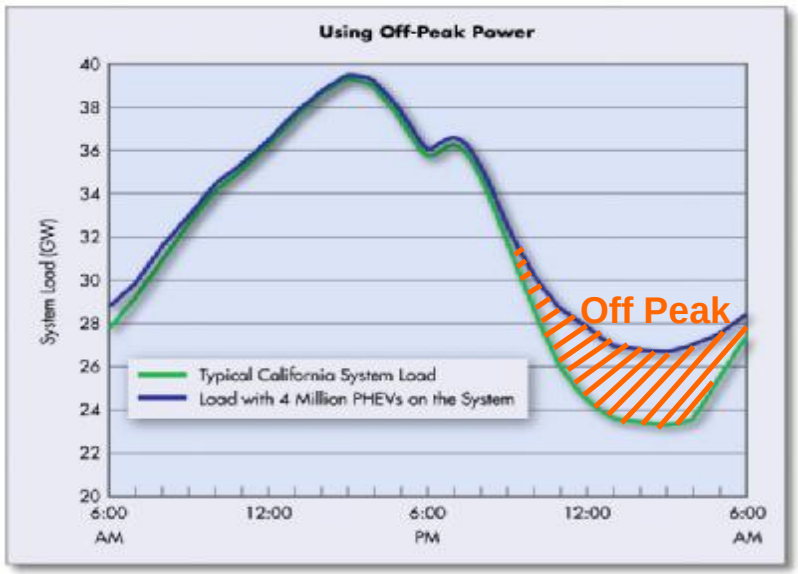
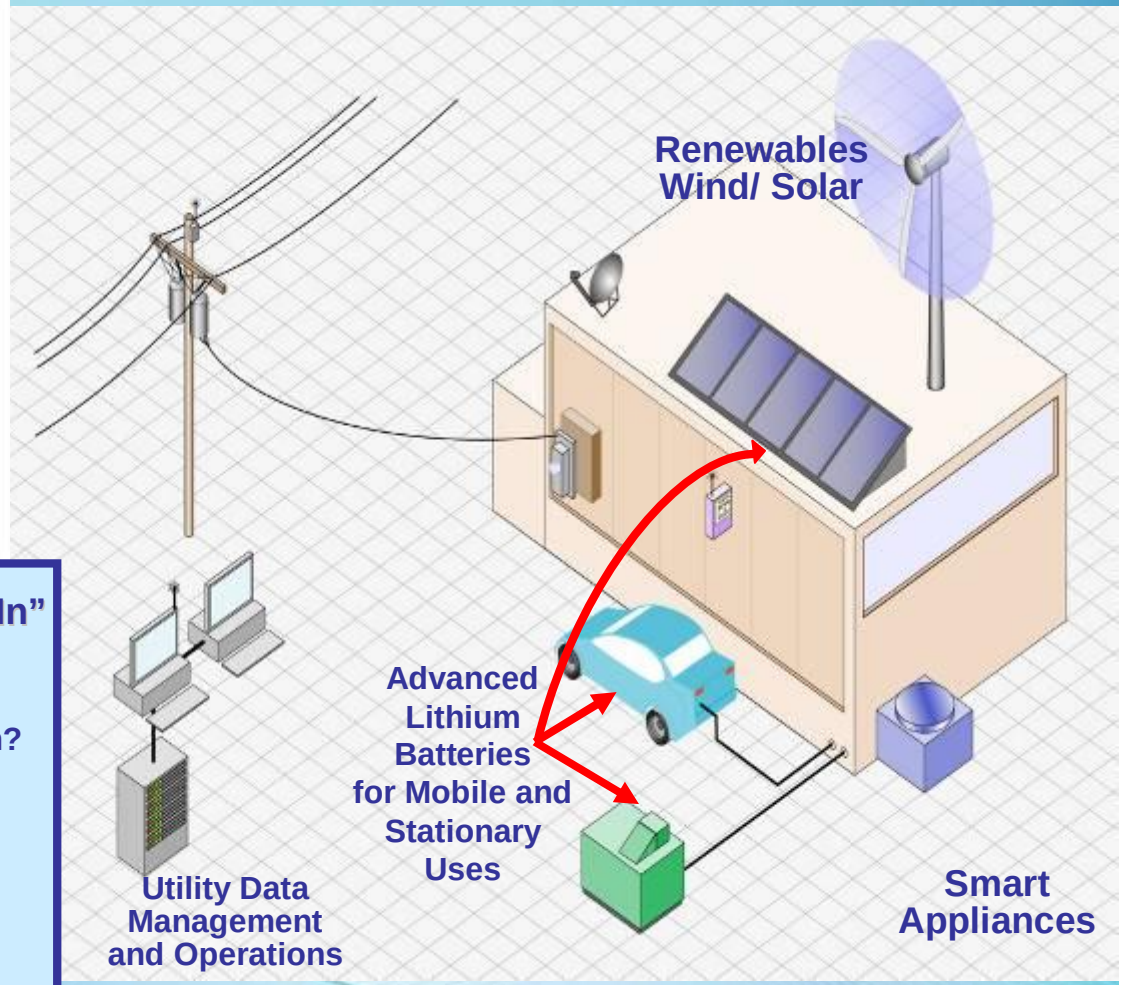
Future State: Integrated Energy World with Utilities & Autos Working Together



Exploring Customer Value From "Plugging In"

- **All New System View:**
  - What components are in the new system?
  - How will the grid and energy flow be controlled in the future?
  - Who are the parties involved?
  - What new integration is needed?
  - What are the key technologies and standards needed?

Many Open Questions…



Integrating a new energy eco-system

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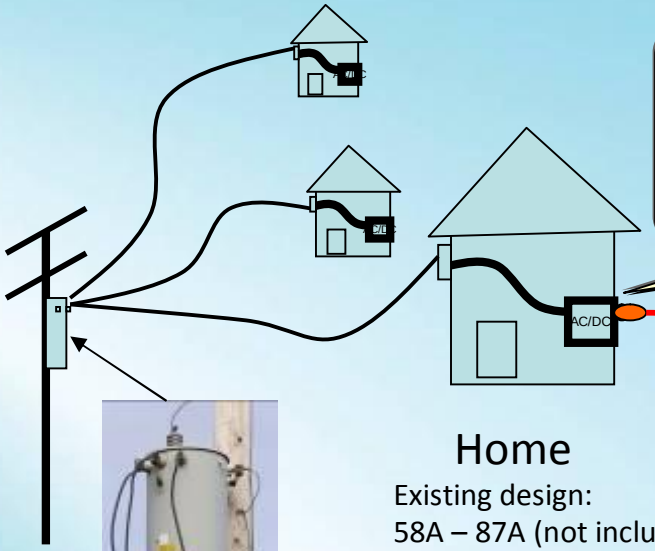
Deep Understanding V2G Connectivity

Distribution Substation

Existing design:
29A – 56A/ home*
per standard utility sizing methods



A 240V @ 30A circuit can provide ~ 6kW continuous charge

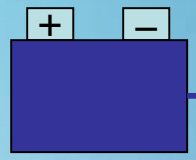
Home

Existing design:
58A – 87A (not including charger)
per NEC220

Multiple Home Pole Transformer

Existing design:
31A – 59A/ home*
per standard utility sizing methods

Detroit Edison connects 5 -7 homes to a 25 kVA transformer



Battery

Existing battery: capable of charging at the vehicle worst case drive cycle discharge rate.

Charge Plug/Cord Level 1 & 2 available per SAE J1772 ©

Vehicle

Existing wiring: capable of worst case drive cycle

*** Multiplication factor (Coincidence factor) varies from region to region and utility to utility.**

When a Plug-in vehicle is Charging, it approximately doubles the household energy load…

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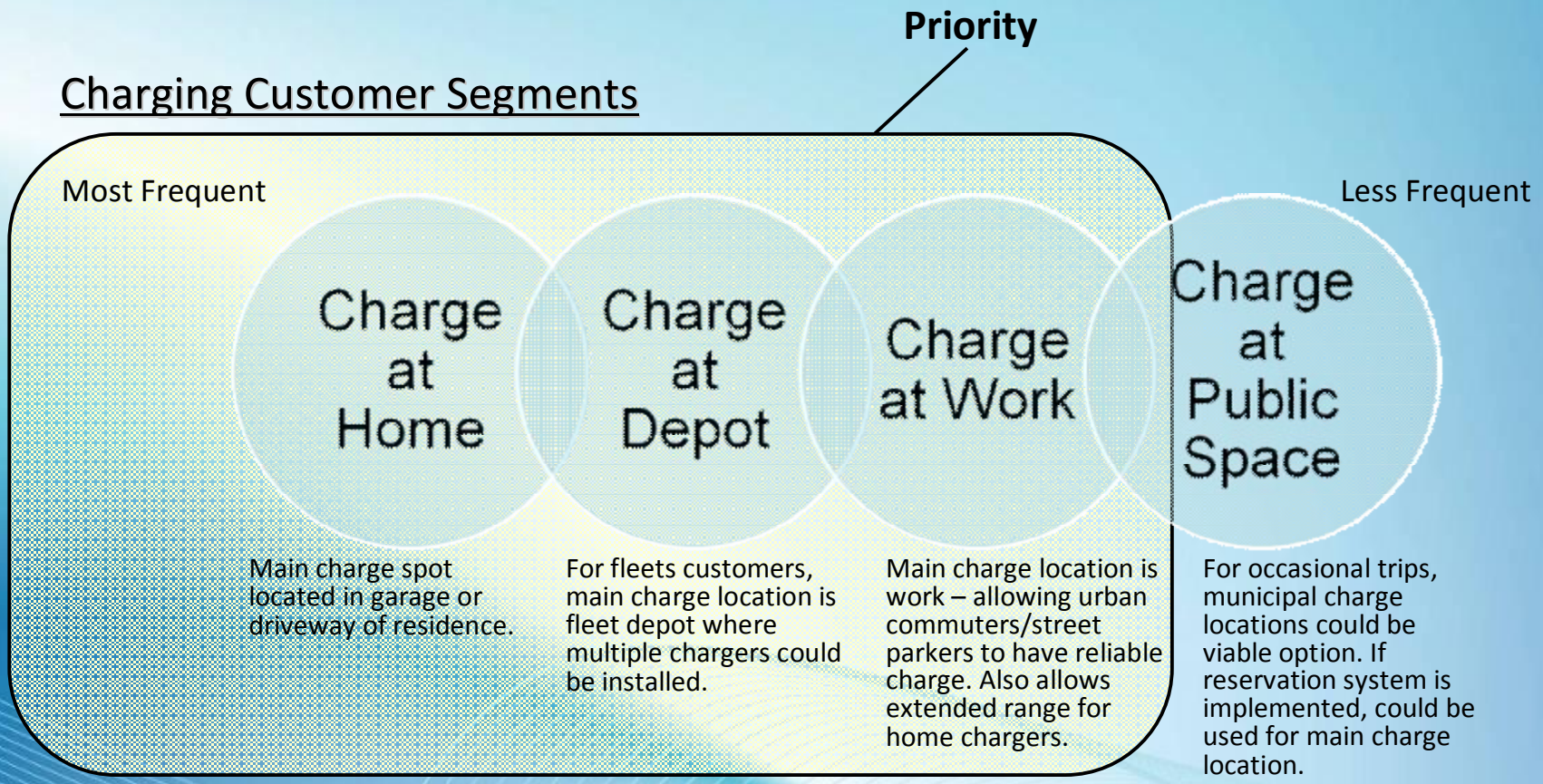
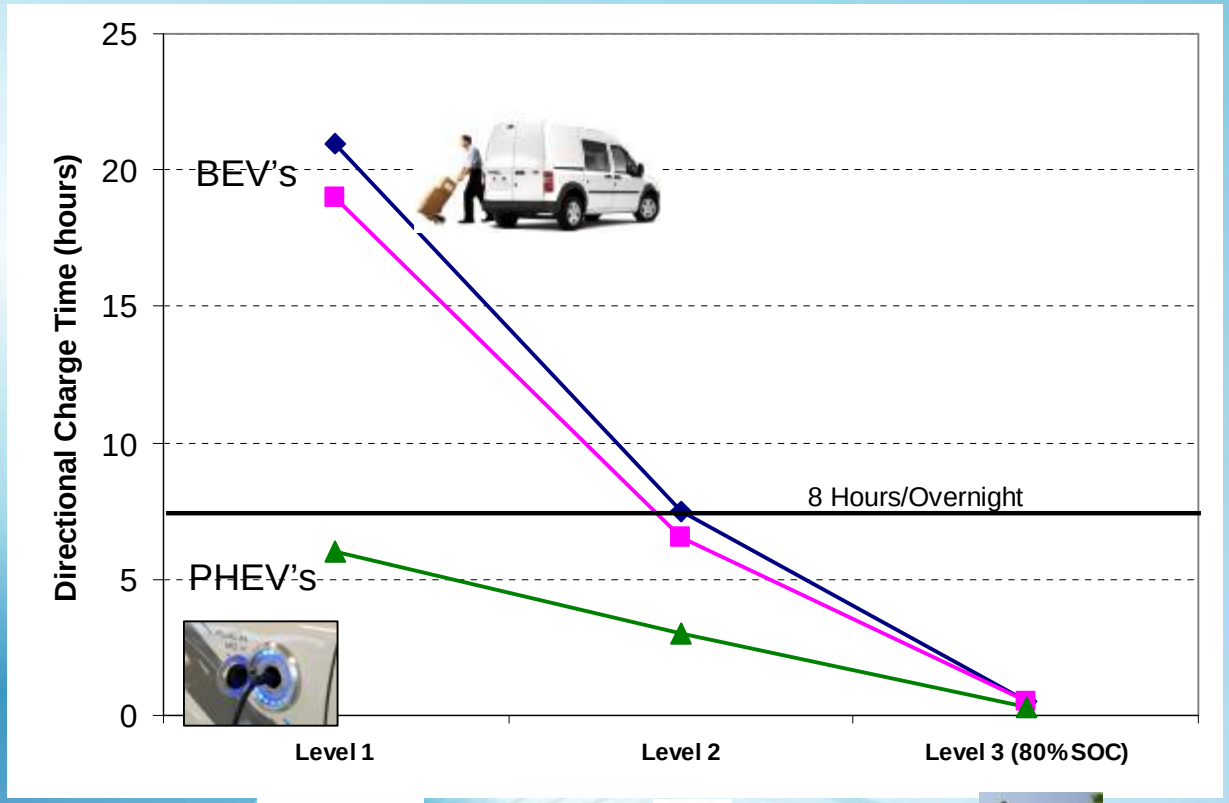
Infrastructure

Charging Customer Segments



Charging Infrastructure is a key enabler to Plug-In Vehicles

Background – Ford Plug-In Vehicle Charging Options



Directional Installation Costs: $0 - $200 **$2,000** **$50,000**

Target overnight charging (less than 8 hours) - base assumption that Level 2 installation will be required for BEV's and optional for PHEV's

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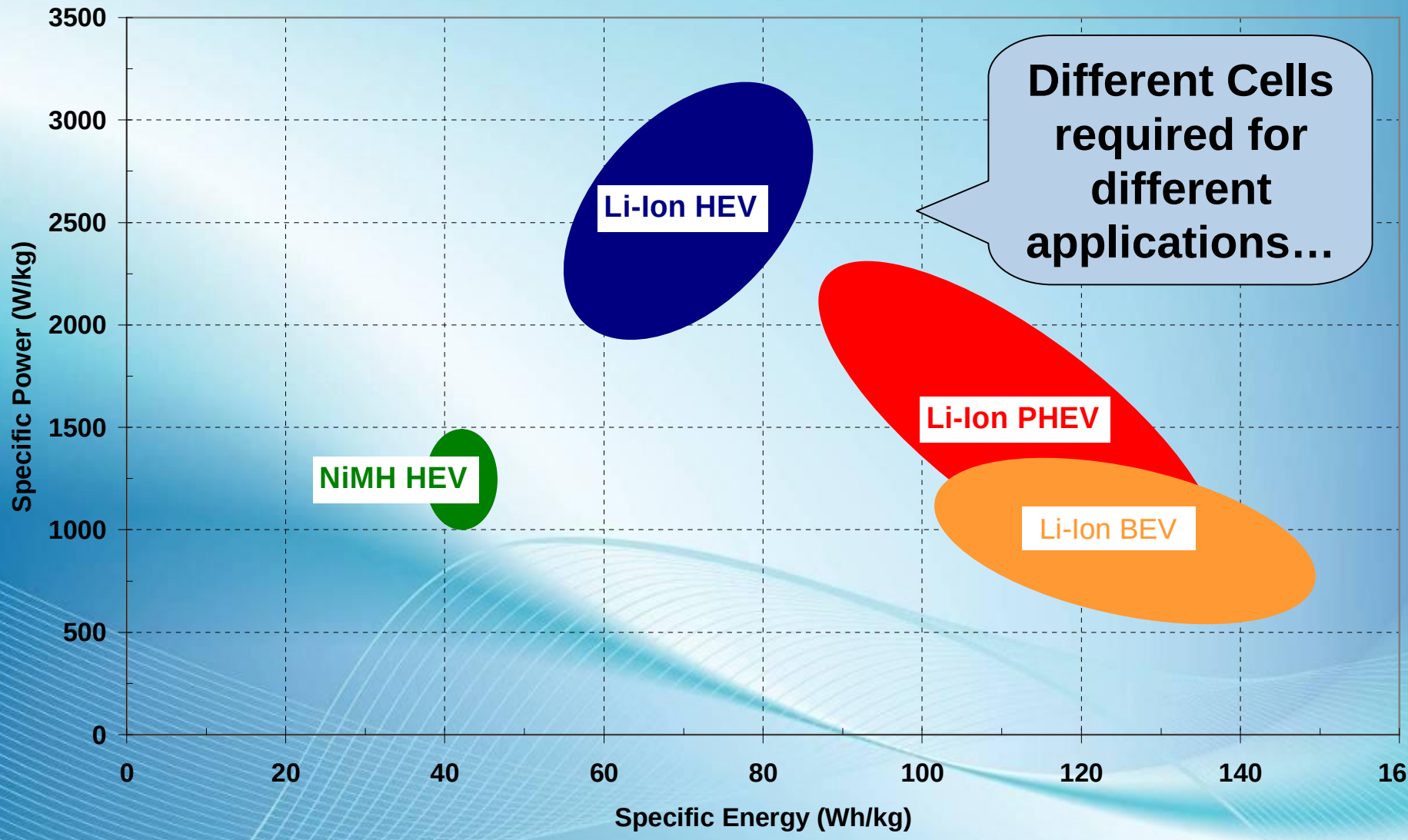
Hybrid Battery Technology Comparison



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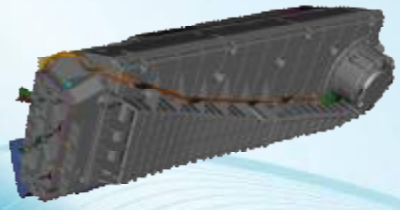
BEV Necessary Battery Technology Evolution

EV Battery
- 23kWh
- 500lbs
- 125 liters

EV Battery
- 23kWh
- 400lbs
- 100 liters

EV Battery
- 23kWh
- 250lbs
- 75 liters

1st Gen



2nd Gen

Future

Goal

Fuel Tank
- 23kWh
- 125lbs
- 60 liters

For weight, size, performance and affordability evolution is required…

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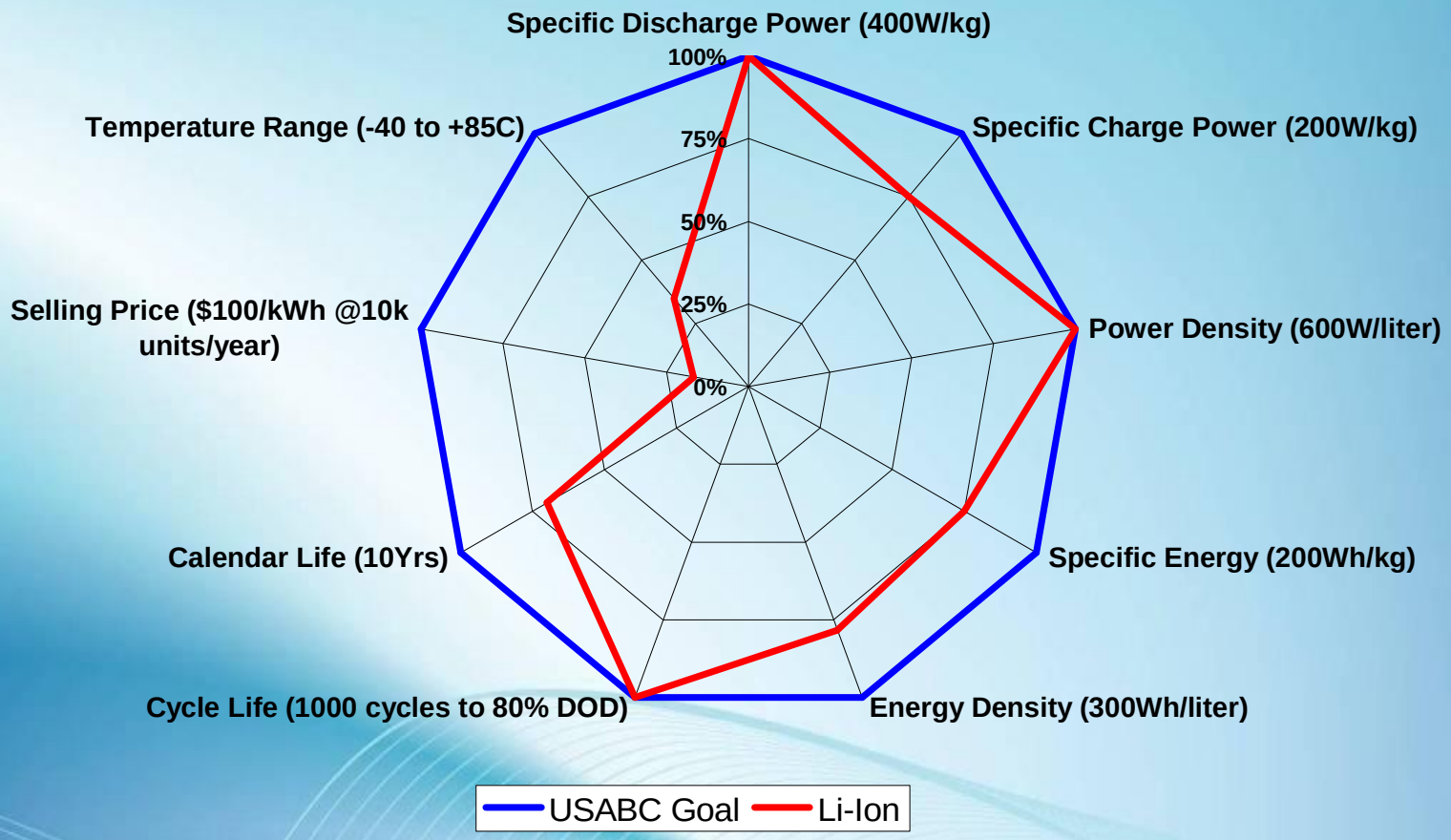
USABC EV Battery Goal Analysis



Calendar Life, Temperature Performance, Energy Density, Real World # Charge/Discharge (2000+) Cycles, and Cost require significant improvements mass market, customer driven products.

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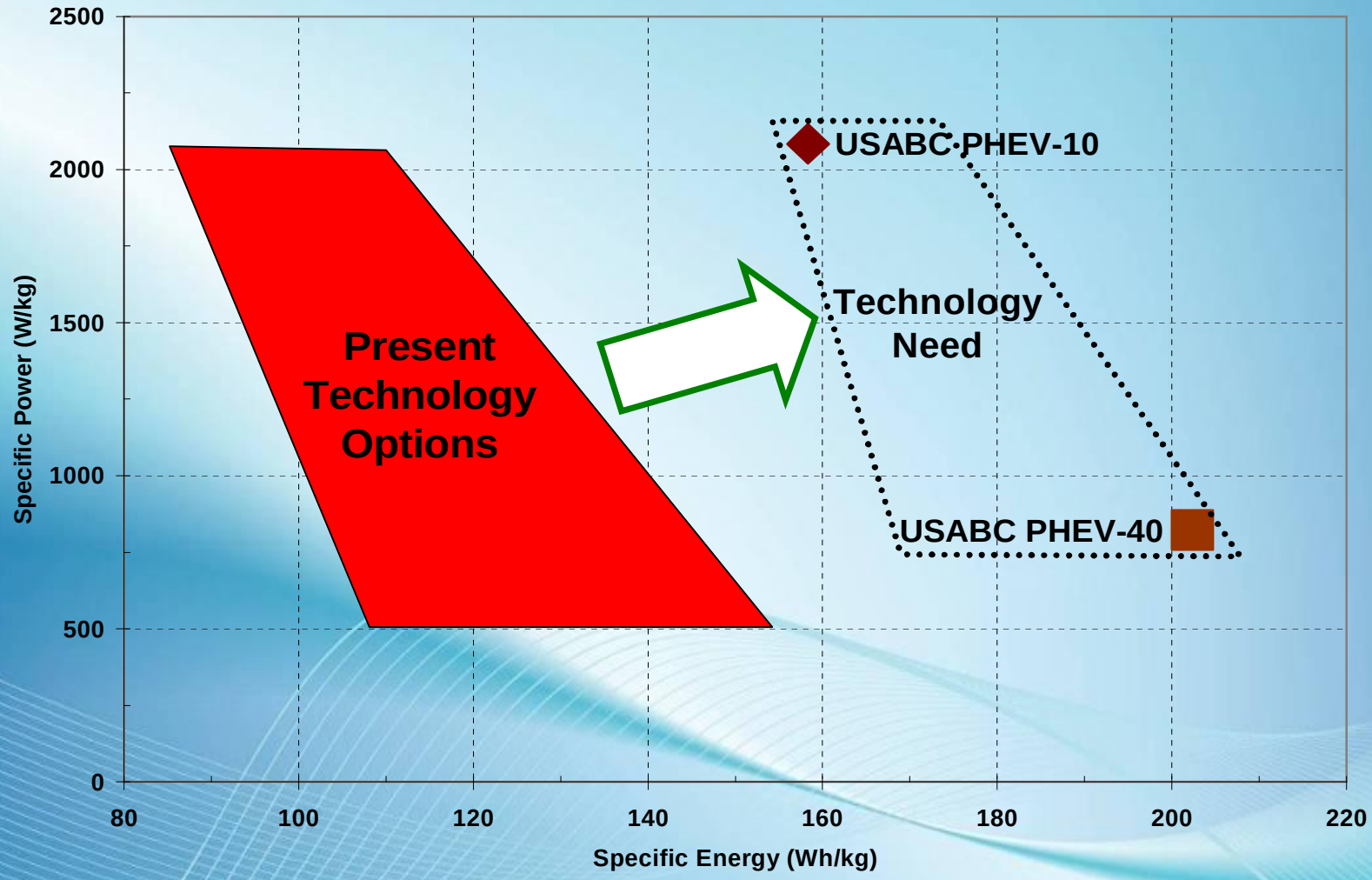
Plug In Vehicle Li-Ion Cell Technology



3 – 4 Cell Technology Innovation Cycles needed for Mass Market, Customer Driven Products

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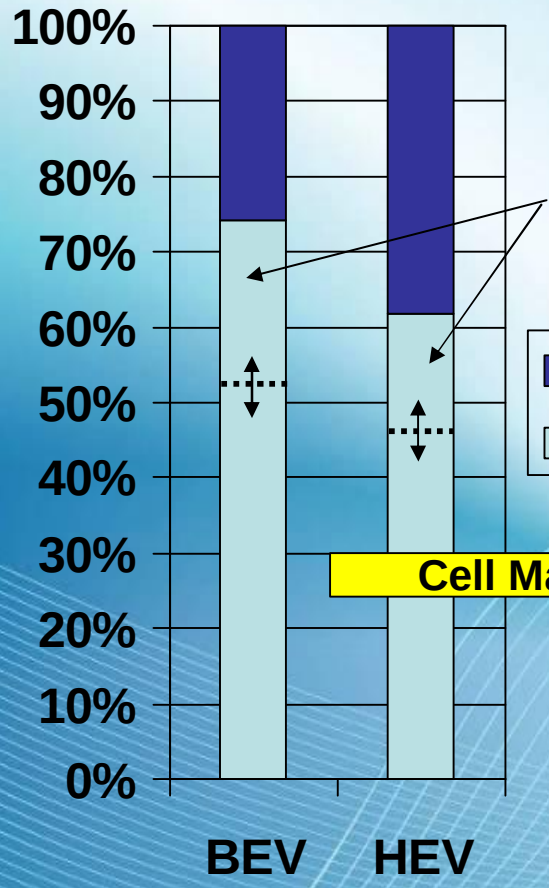
Lithium Ion Battery Cost

- A Lithium Ion Cell (Power for HEV and Energy for PHEV & BEVs) is made up of Cathode, Anode, Separator, Electrolyte, and Structural Hardware (foil, case, terminals, and Header)
- Materials used in both cells are generally the same (recipe is unique)
- Material cost breakdown of a Lithium cell varies slightly with different chemistries
- Current metric for HEV cells is $/kW. Current metric for PHEV or BEV cells is $/kWh.
- Forecast of 2012 industry prices for “cells only” is: $20-$30/kW HEVs and $500-$1000/kWh for PHEVs/BEVs. Range is due to varying assumptions of R&D, capital depreciation, labor, and other markups as the automotive battery industry matures
- Laptop Lithium cell material cost per kWh at high volume (300 mil cells/year) is less than $200/kWh. Automotive qualification for quality and durability adds a premium.

HV Battery Breakdown

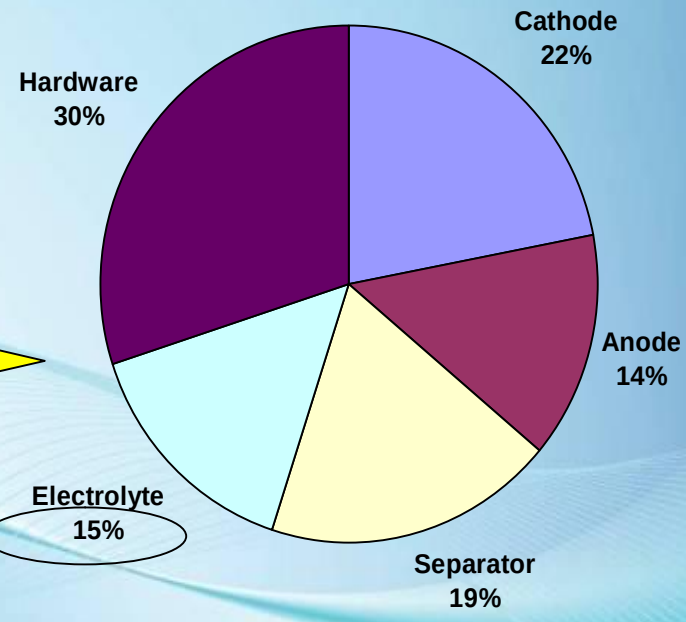
HV Battery Cost Contribution



Depreciation, R&D & other Markups.
Up to 50% of price

System
Cells

Cell Material Breakdown



Lithium: rare earth element analysis suggests lithium supply is available to support needs to 2050

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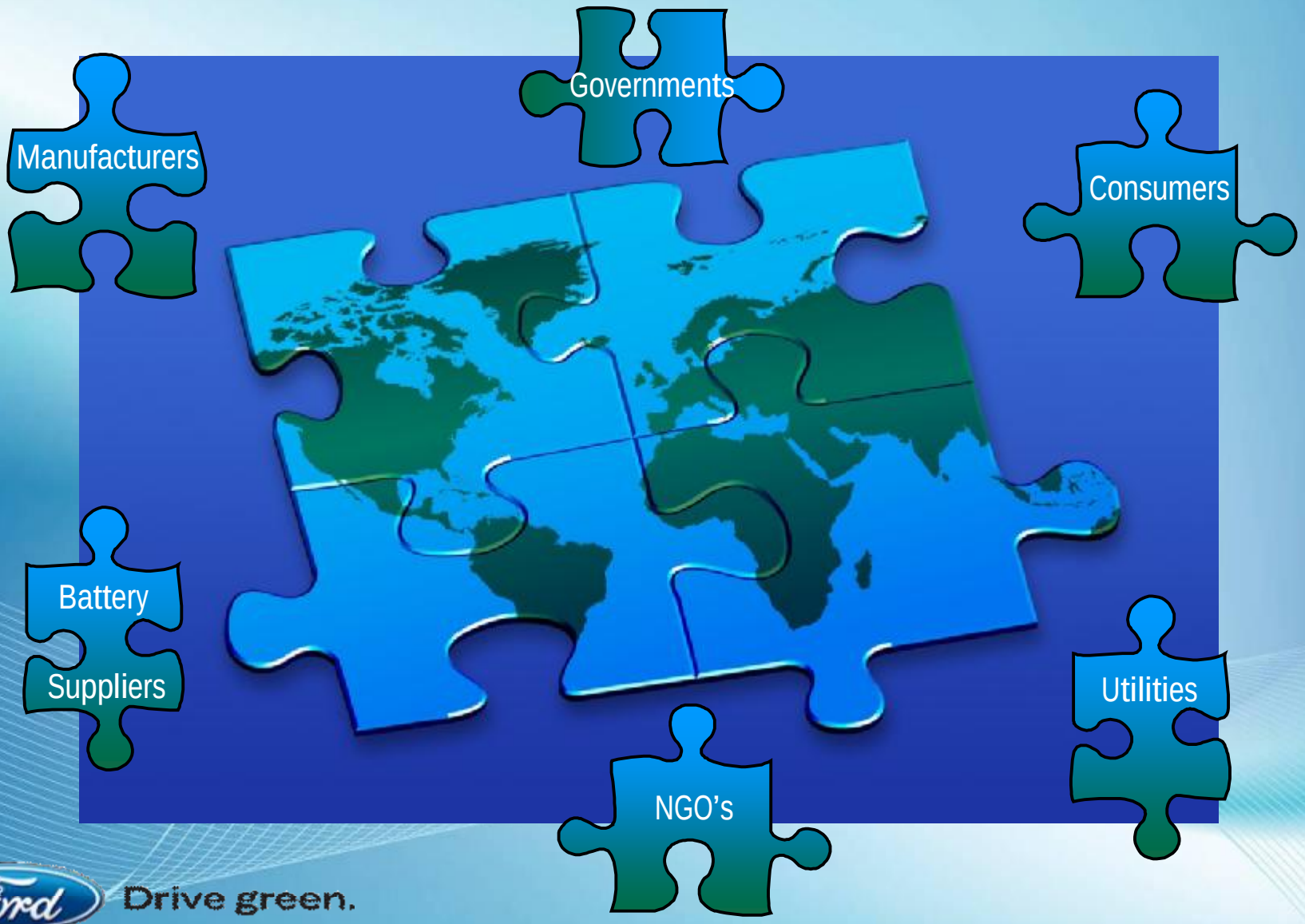
Integrated Approach With Shared Responsibility

The development of a sustainable electrified market will be dependent on close cooperation between many key stakeholders



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