



**Electrified Propulsion: A Perspective on HEV Technology
and Market Acceptance for Automotive Powertrains**

Agenda

- ▶ Exploring the IC Engine's Success
- ▶ Drivers for Change
- ▶ Reality Check
- ▶ The Prognosis

Conventional Engines: Why are they so successful?

1876 Nicolas Otto develops 4-stroke, spark-ignition (SI) engine



1892 Rudolf Diesel develops 4-stroke, compression-ignition (CI) engine



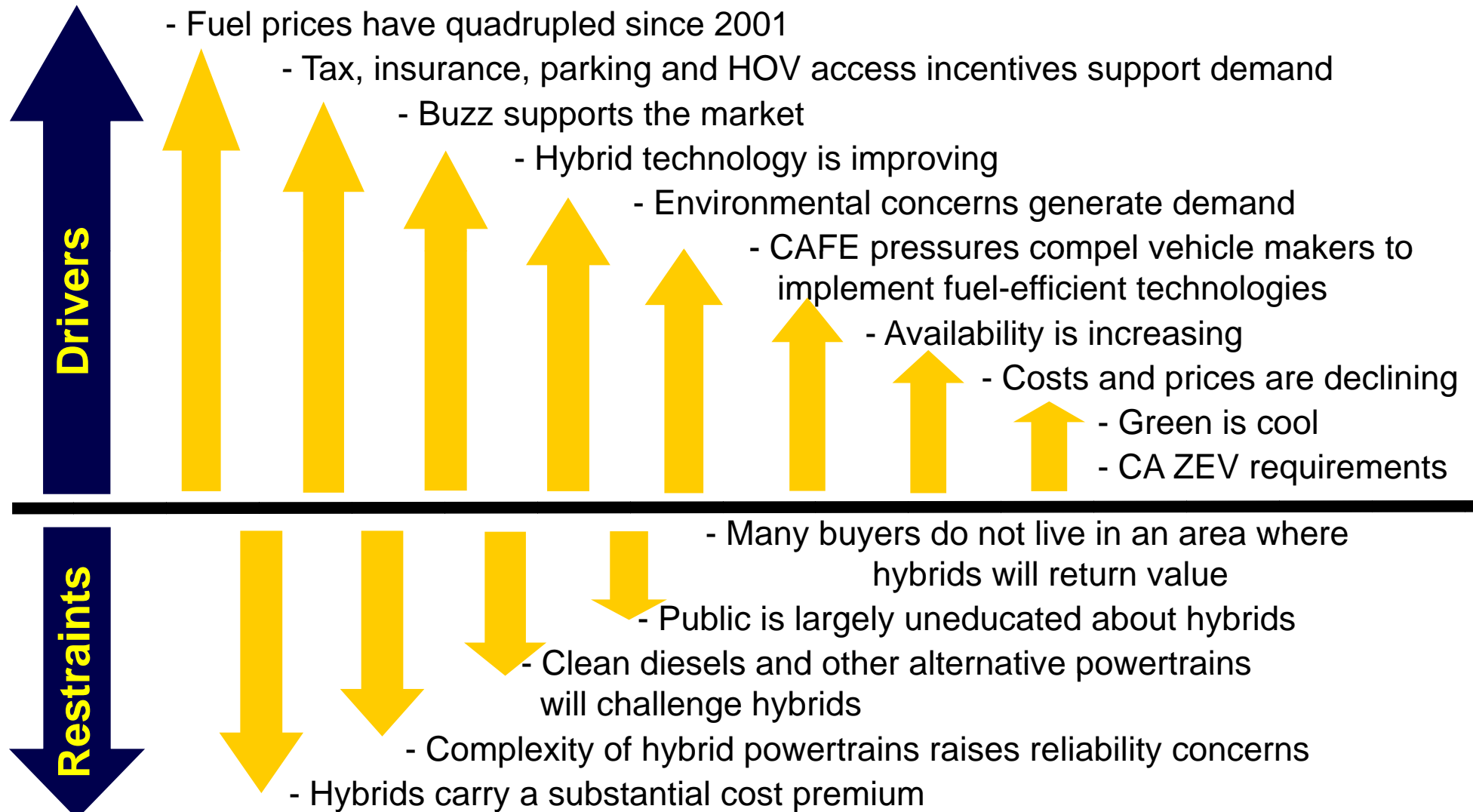
After 100+ years, these are still the primary powerplants of choice for personal mobility

- Low cost density (<\$30/kW)
- High power density
- Robust, versatile
- Matched to 'cheap', available fuel
- Near-zero emissions
- Historically efficient enough

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Regulatory and market drivers outweigh restraints, resulting in a forecast for growth

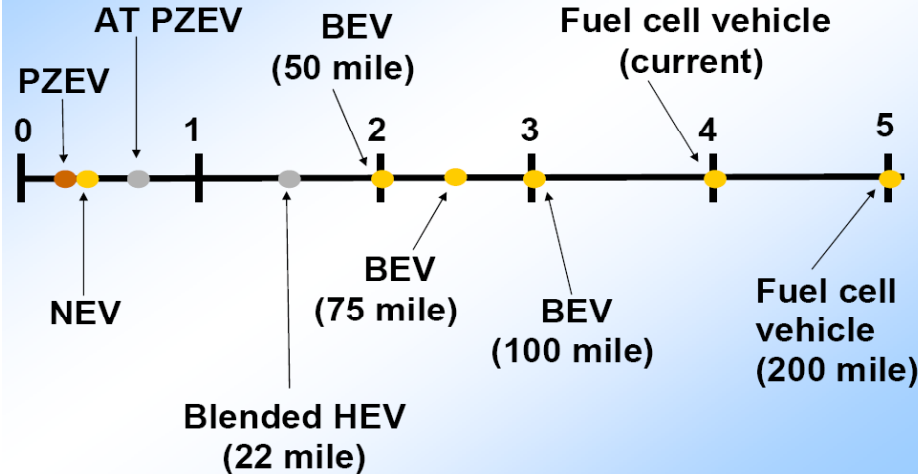


Regulatory Drivers: ZEV Rules Drive High Levels of Electrification

Model Years Minimum ZEV Requirement

- 2009 → 2011 11 %
- 2012 → 2014 12 %
- 2015 → 2017 14 %
- 2018 → 16 %

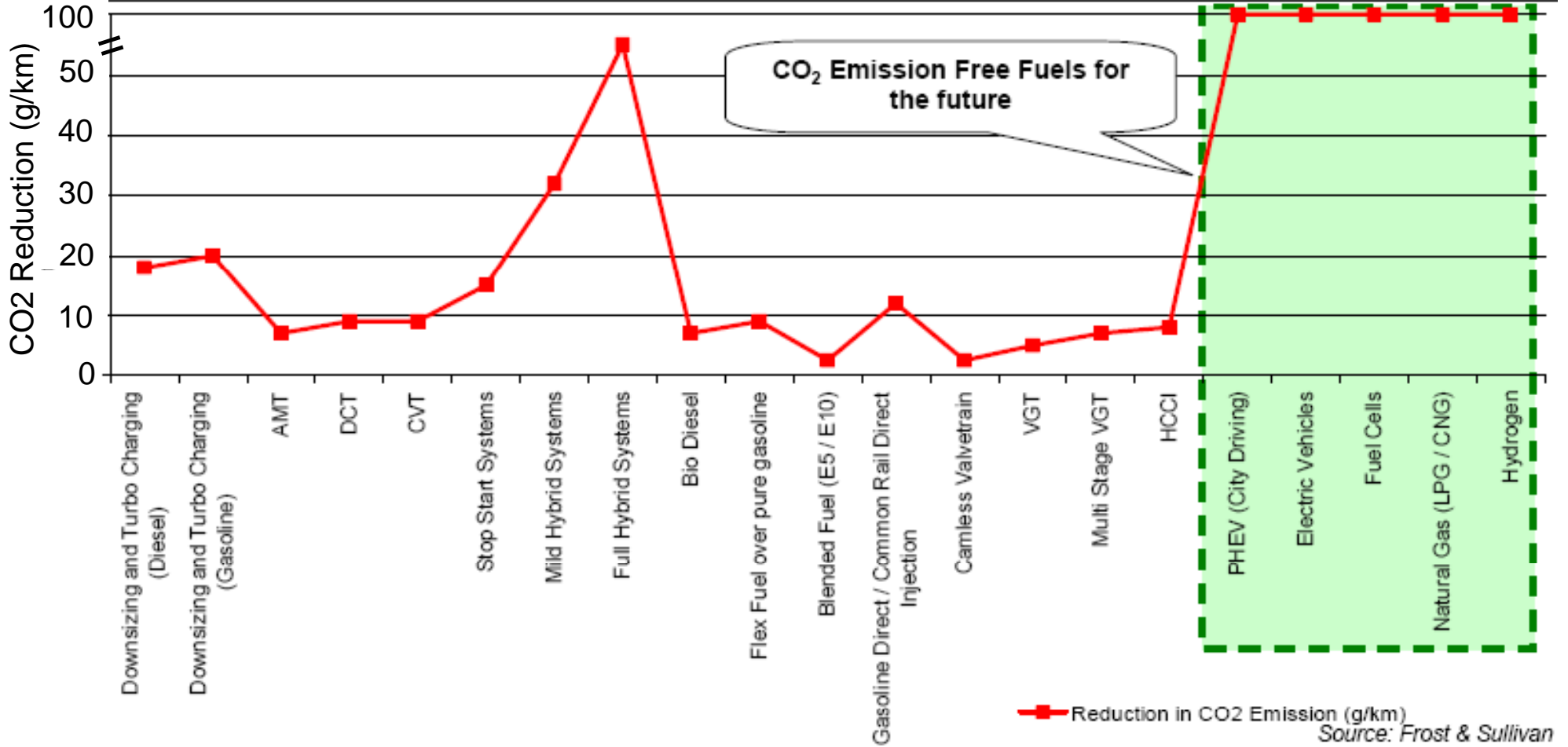
Credit Per Vehicle



1 Chevy Volt \approx 3 Toyota Prius'

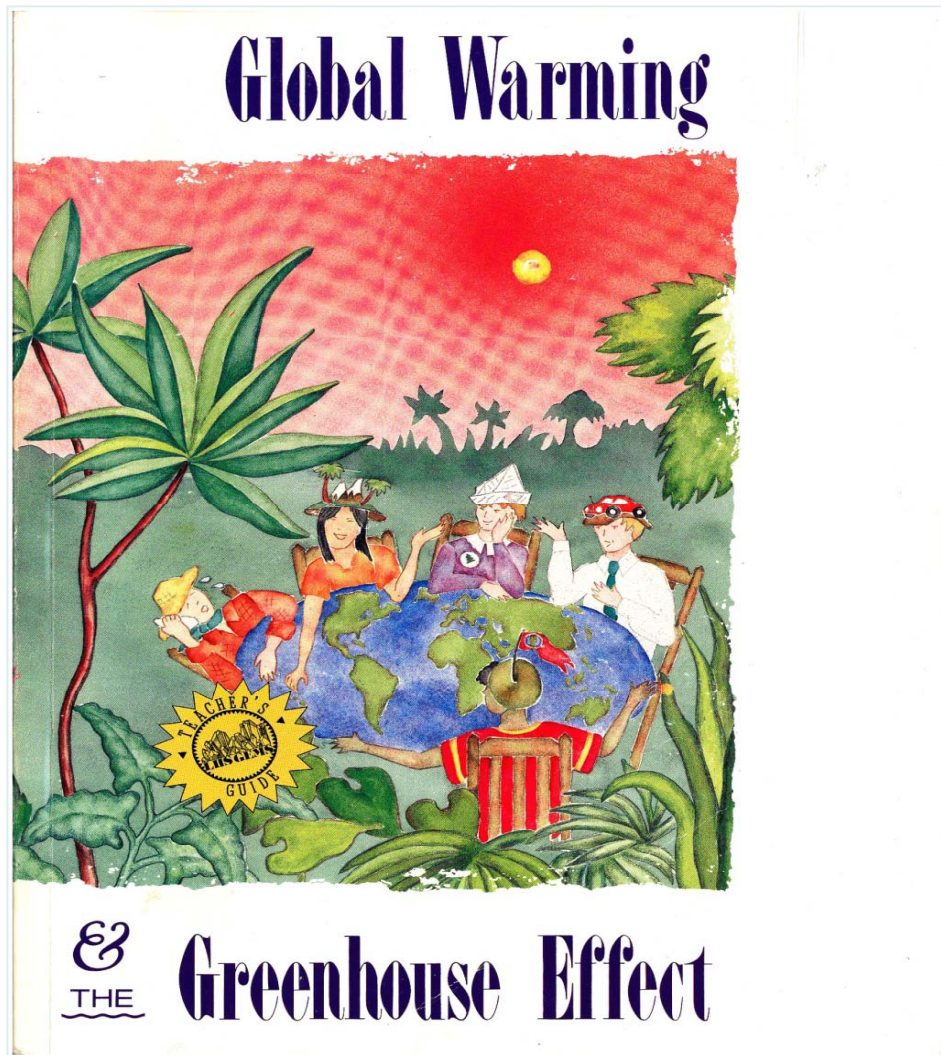


Environmental Drivers: HEVs Offer Strong Reductions in CO2



In pure EV mode, environmental concerns are removed from the equation

Societal Drivers: Young Buyers are being "Rewired"



- Junior High textbook being adopted in US science programs
- First published in 1990
- Gas-burning autos are not positioned favorably
- Today's grade school students are tomorrow's buyers

Market Drivers: Industry Leaders are Publicly Committing to EV Propulsion



"...Ford's turnaround plan revolves around more and more electrification, both hybrids and battery electric vehicles"
-Alan Mulally, CEO of Ford Motor Company

"The EV is real. It's here. And before long - when curbside charging stations are as ubiquitous as parking meters – it won't seem all that complicated, either."
-Carlos Ghosn, CEO of Renault-Nissan



"We're going to make electric motors, power electronics, and batteries core technologies at GM. Then we can mix and match and do all kinds of electric vehicles."
-Tom Stephens, Vice-Chairman of General Motors

Technology Drivers: EVs Enable Dramatic Vehicle Design Freedom

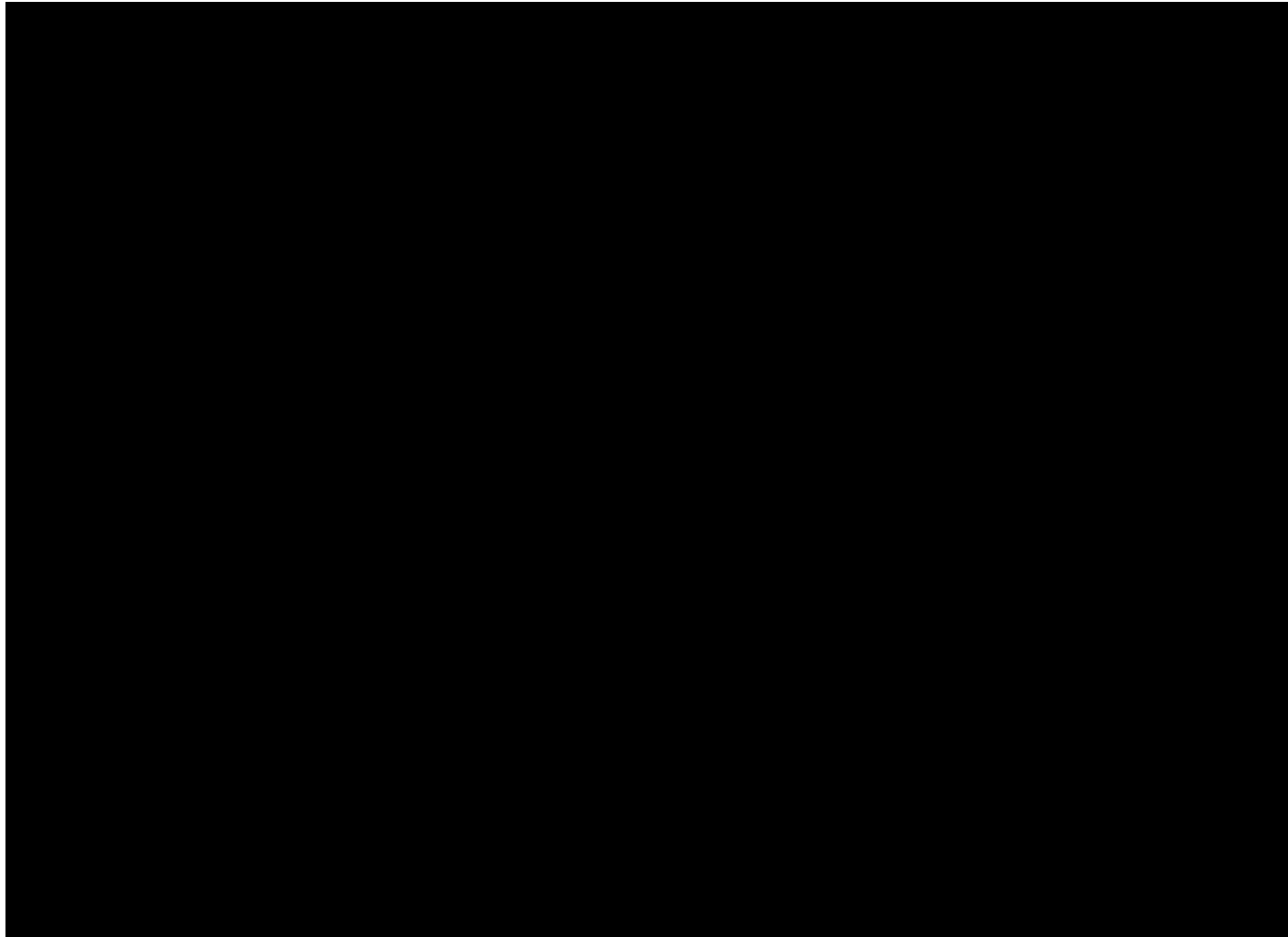


Engine compartment with current V6 powerplant



Engine compartment with 150kW Electric Powertrain Module

Performance Drivers: EVs are Fun to Drive



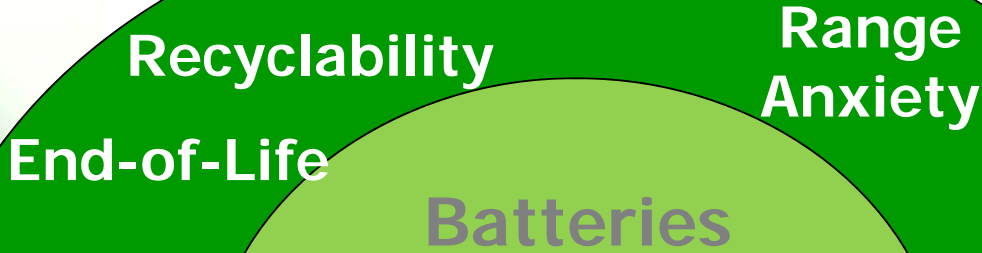
*Prototype
Dodge
Circuit EV
with 190kW
motor +
single speed
gearbox*

*2009 Dodge
Challenger
with 372
bhp, 5.7L
Hemi V8 + 6
speed
manual*

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Reality Check



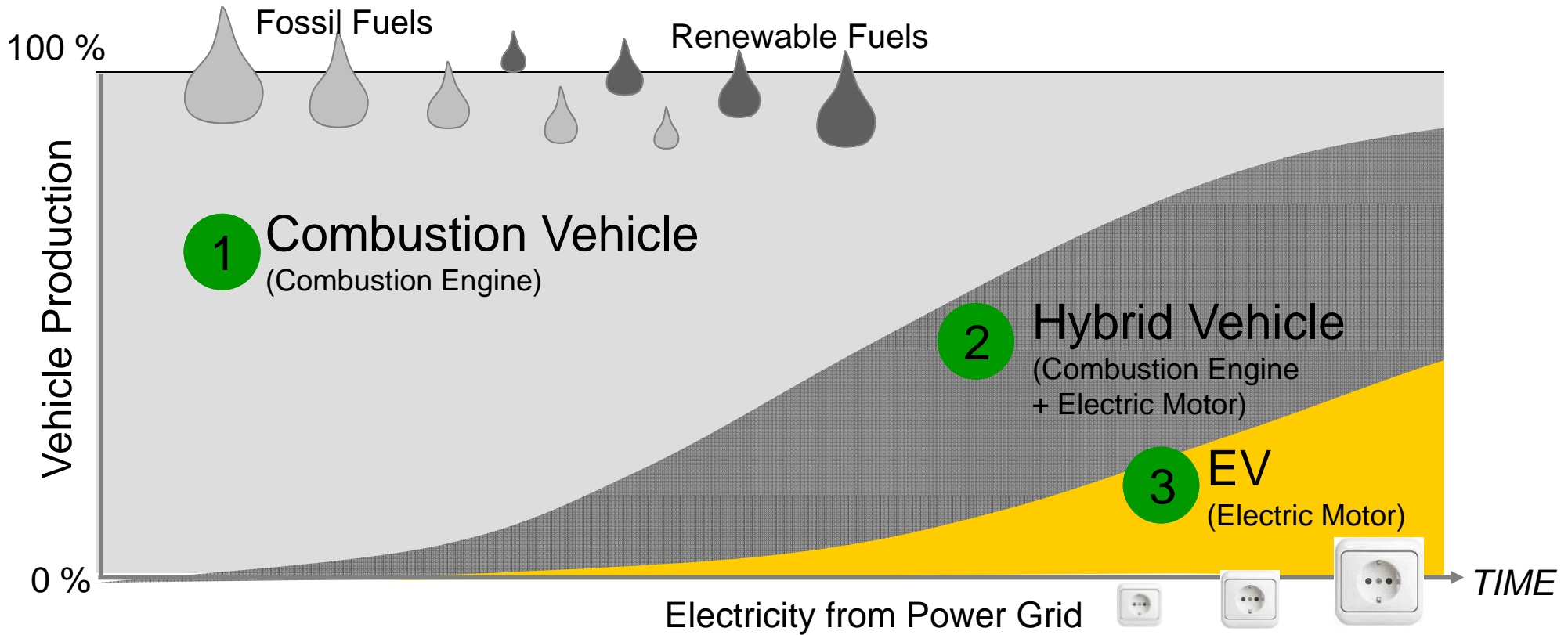
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Global Market is Migrating Towards EVs

ZERO EMISSIONS

- 1 Improve efficiency of conventional powertrain (short and mid term)
- 2 Back up combustion engine by electric motor (mid term)
- 3 Emission free electric vehicles (EV) (long term)



Projected HEV Penetration into US Market Sales

	2010	2015	2020
HEVs	5.5%	7.6%	11.8%
EVs (inc. RX)	0%	1.4%	3.5%
Total	5.5%	9.0%	15.3%

Strong HEV growth in specific market segments driven by private/public incentives and increasing consumer demand

