

International AMI Congress
31° March 2009
Congress Center Leipzig (D)



Hybrid and Alternative Propulsion Development Targets of GM

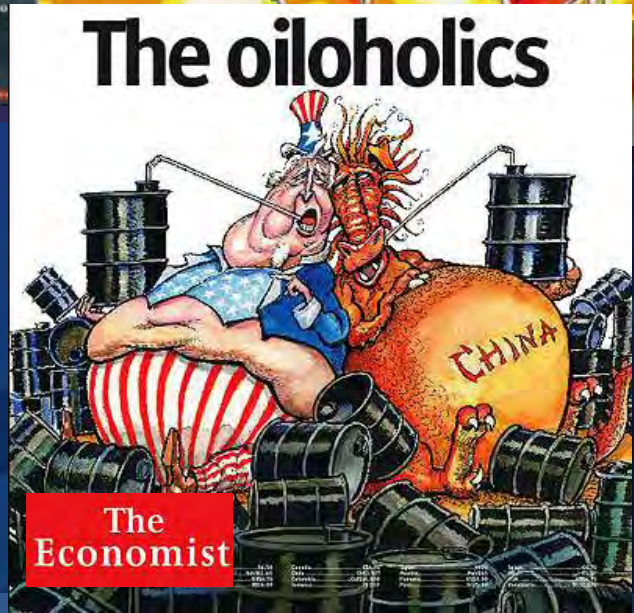
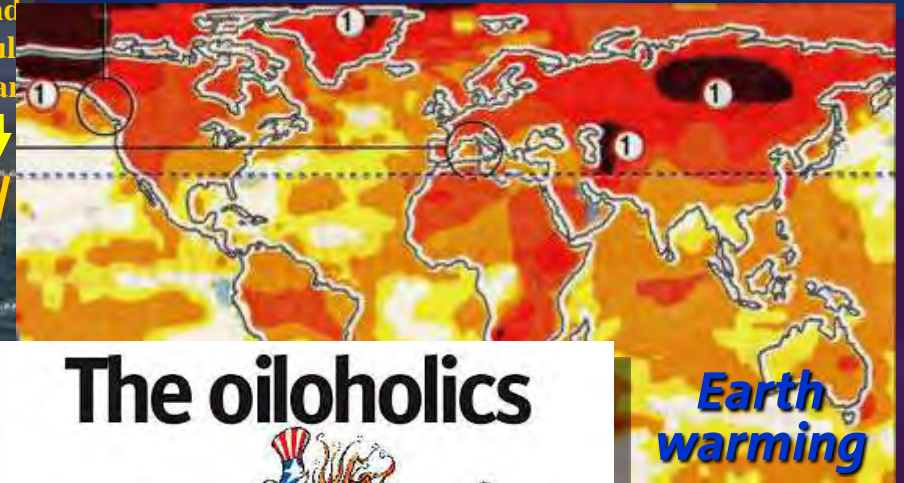
Giovanni Cipolla

Director Advanced Engineering & Site Manager Italy
General Motors Powertrain Europe
Torino, Italy



Automotive environmental challenges

Crude oil price
(last 30 years)



Automotive Growth Opportunity

Mexico

Brazil

Poland

Turkey

Russia

South Africa

China

South Korea

India

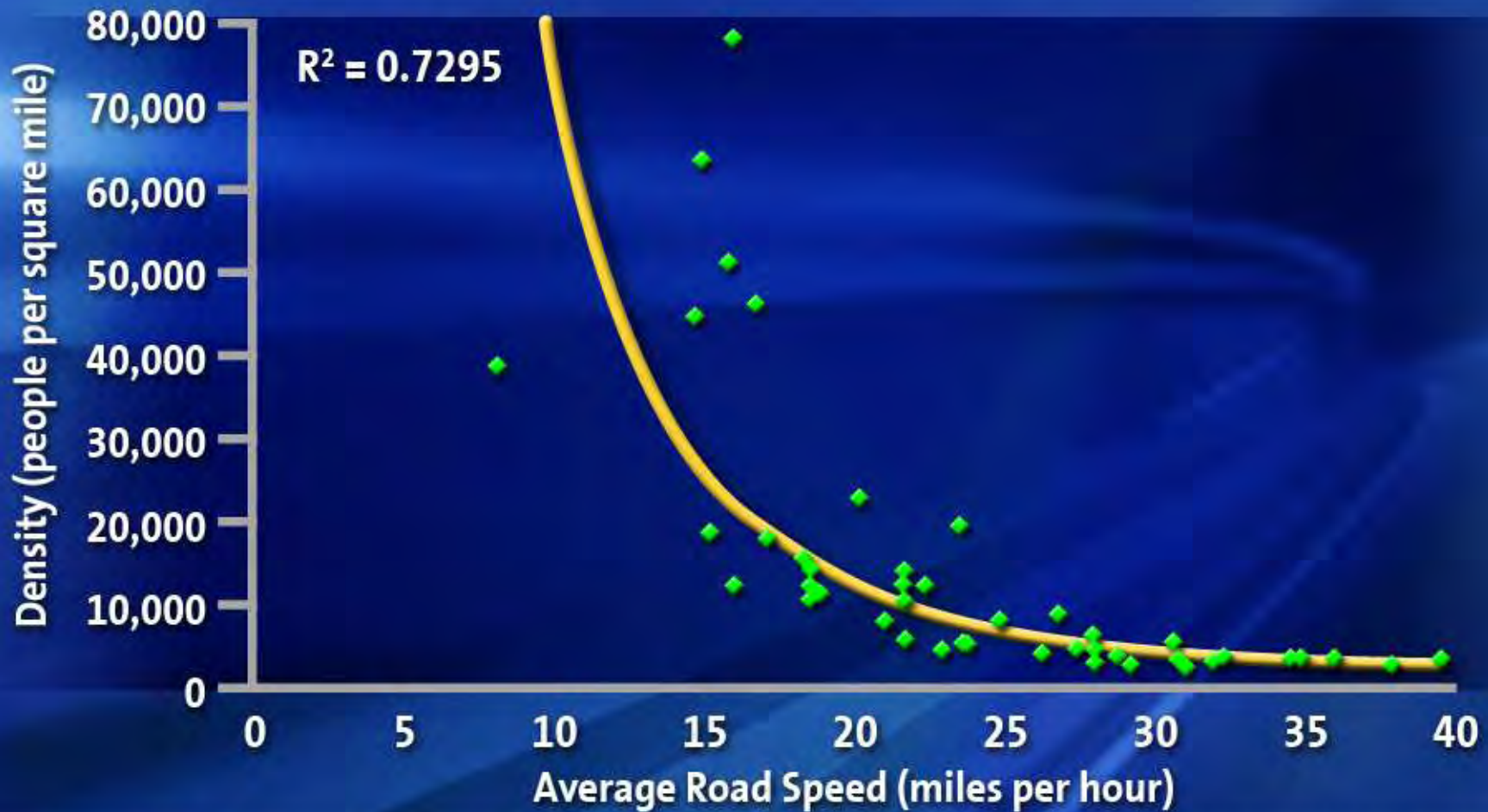
Thailand
Malaysia

70%

of growth from **11** emerging markets



Population Density and Driving Speed



Source: Jeffrey R. Newman, Felix B. Laube (eds), "An International Sourcebook of Automobile Dependence in Cities: 1960-1990" (2002)

Vehicles that drive Themselves

“Boss” project



“Vehicle-to-vehicle” project



Energy Resources: the propulsion options

Energy resources

Oil

Coal

Natural Gas

Biomass

Other Renewables
(Solar, Wind, Hydro)

Nuclear

Energy Carriers

Liquid
Fuels

Gaseous
Fuels

Electricity

Hydrogen

Propulsion Systems

Conventional ICE:
Gasoline / Diesel

Gaseous ICE

ICE Hybrid

Plug-In Hybrid ICE

Electric Vehicle

Fuel-Cell Electric

Battery

Electrification

Evolution of Automotive Propulsion Systems

today

tomorrow

Hydrogen and Fuel Cell Technology



Hybrid Vehicles



Alternative Fuels



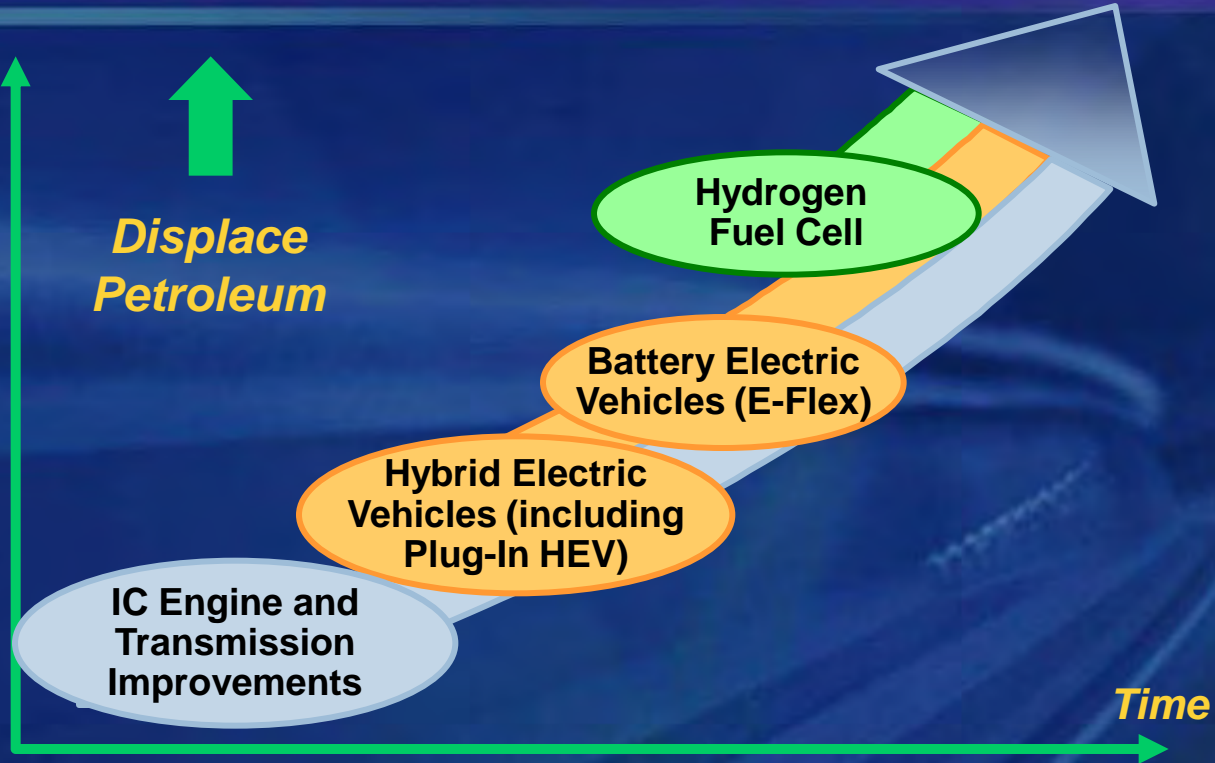
Optimization of Combustion Engines



Advanced Propulsion Technology Strategy

↑
Improved Vehicle Fuel Economy & Emissions

↑
Displace Petroleum



IC Engine and Transmission Improvements

Hybrid Electric Vehicles (including Plug-In HEV)

Battery Electric Vehicles (E-Flex)

Hydrogen Fuel Cell

Time

Energy Diversity

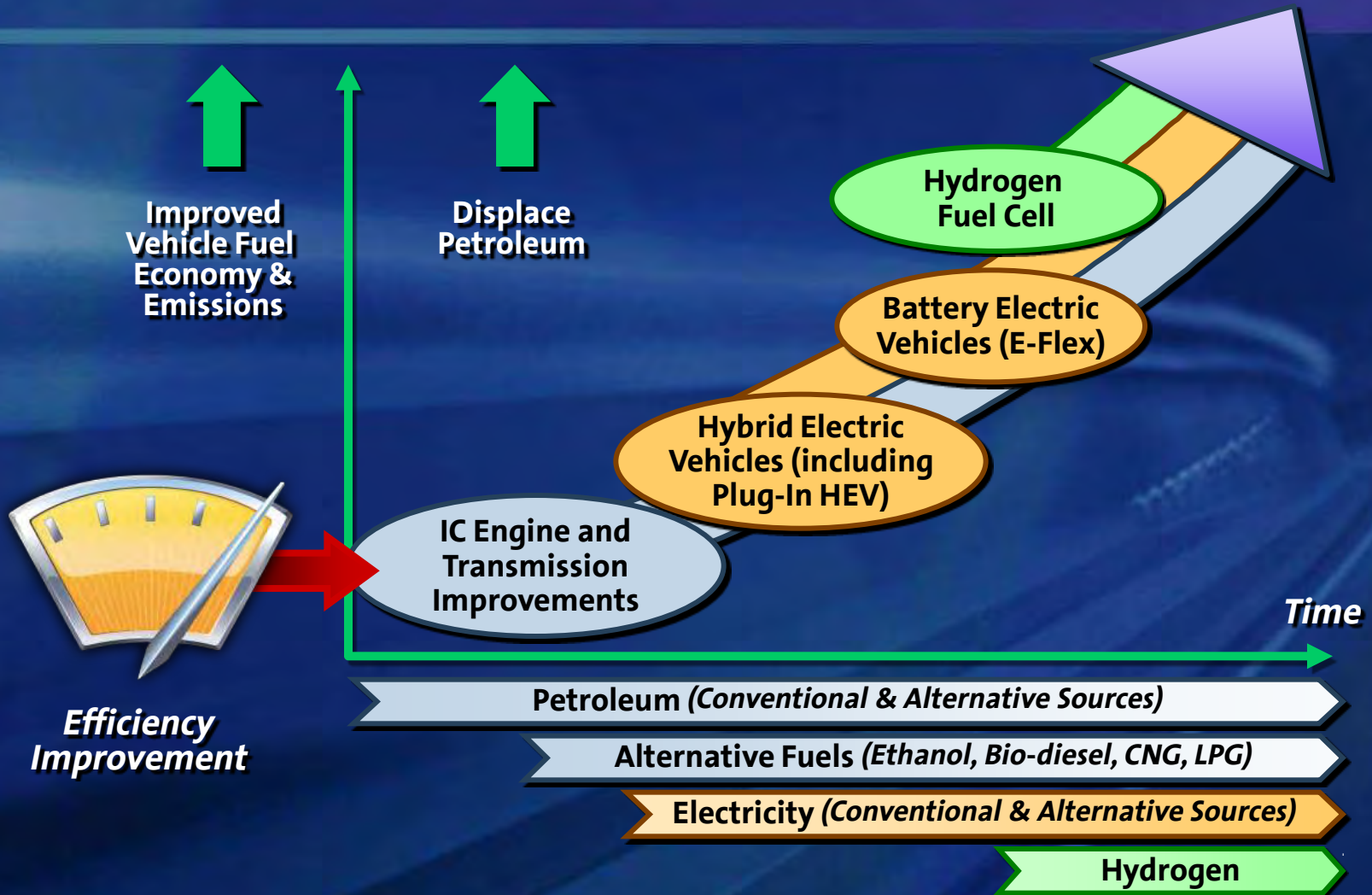
Petroleum (Conventional & Alternative Sources)

Bio Fuels (Ethanol E85, Bio-diesel)

Electricity (Conventional & Alternative Sources)

Hydrogen

Advanced Propulsion Technology Strategy



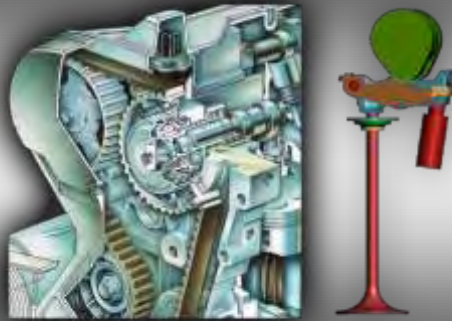
Gasoline Engines

Achieving the Maximum Fuel Economy Potential

Base Engine Technologies

- Modular And Flexible Architectures
- Reduced Mass
- Improved Combustion Technology
- Integration Of Leading Edge Technologies

Cam Phasing, Variable Valve Lift, Active Fuel Management



Port Deactivation with EGR



Spark Ignition Direct Injection



Downsized SIDI Turbo Boosting



HCCI – Homogenous Charge Compression Ignition

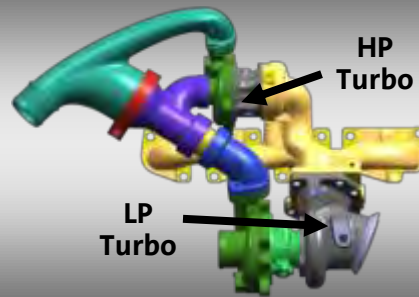


Diesel Engines: Achieving the Lowest Emissions

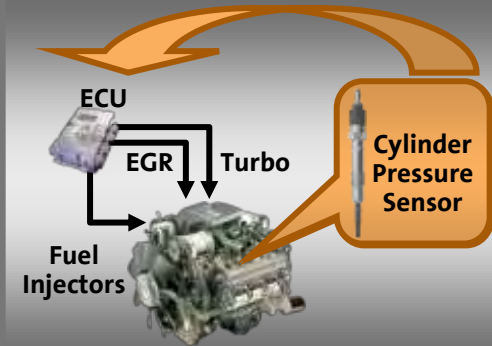
Base Engine Technologies

- High Pressure Injection
- Lower Compression Ratios
- Higher Peak Cylinder Pressure

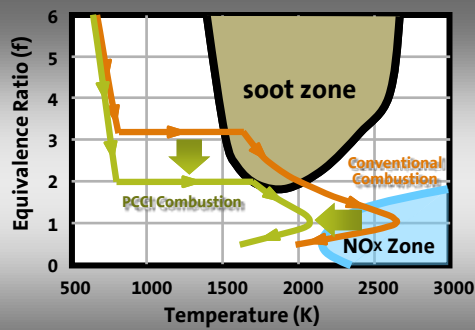
Advanced Boosting with Small Displacement



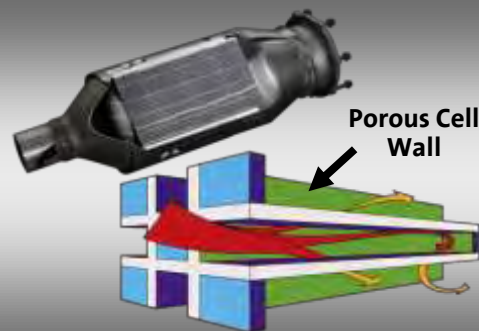
Cylinder Pressure Sensing



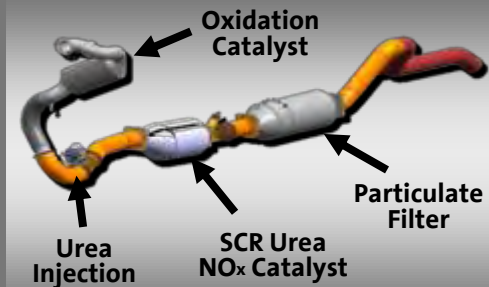
PCCI Combustion



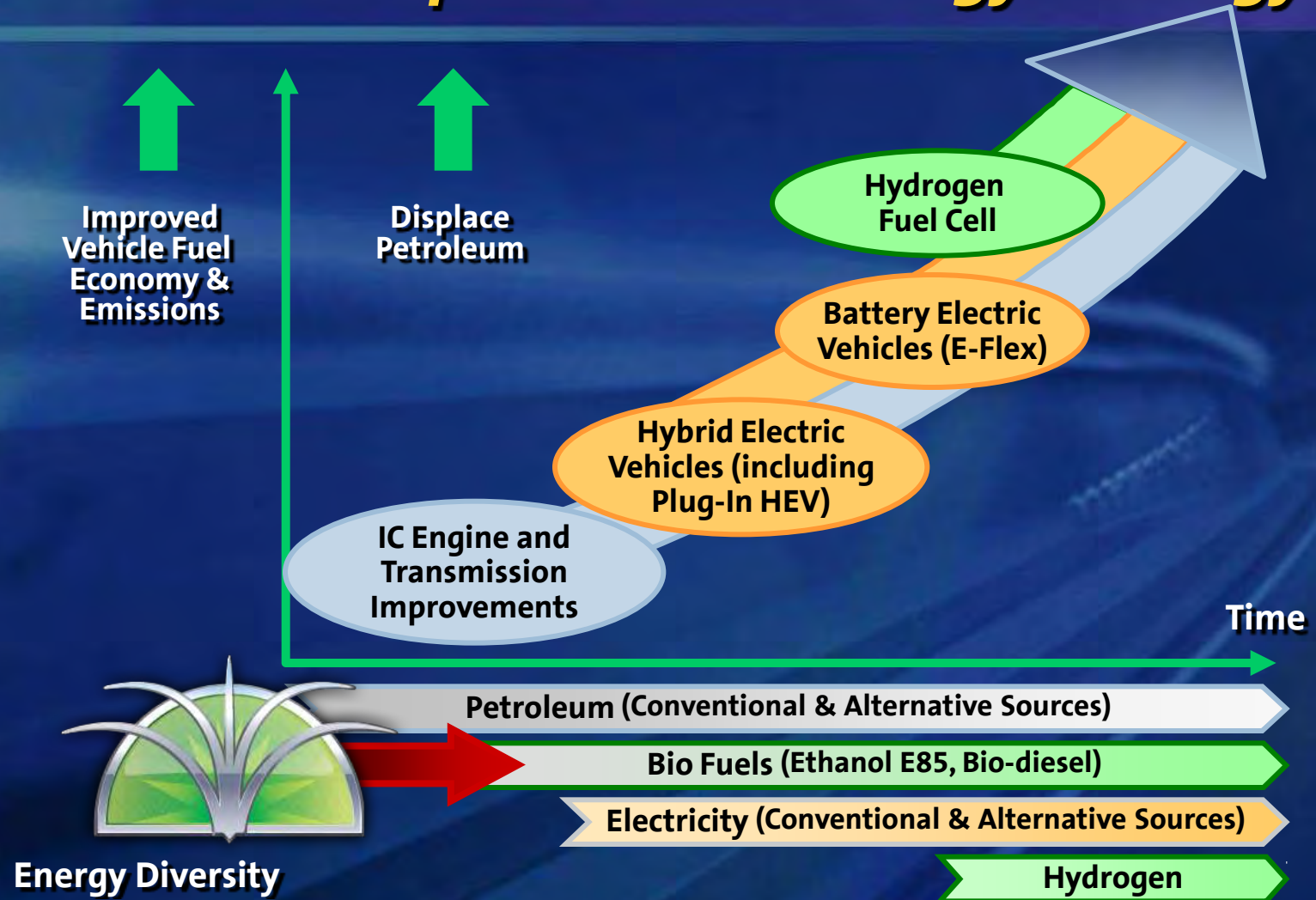
Diesel Particulate Filter



NO_x Aftertreatment



Advanced Propulsion Technology Strategy



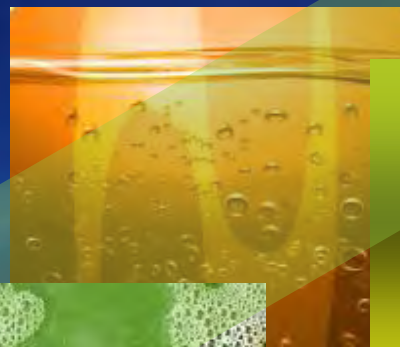
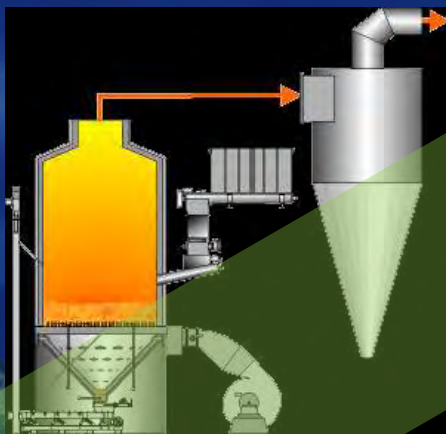
BioFuels for Automotive Powertrains



Biofuels are moving up a technology roadmap

Synthetic Biorefinery

Gasification



Direct Synthesis?



Algae



Cellulosic Bioethanol

Cassava

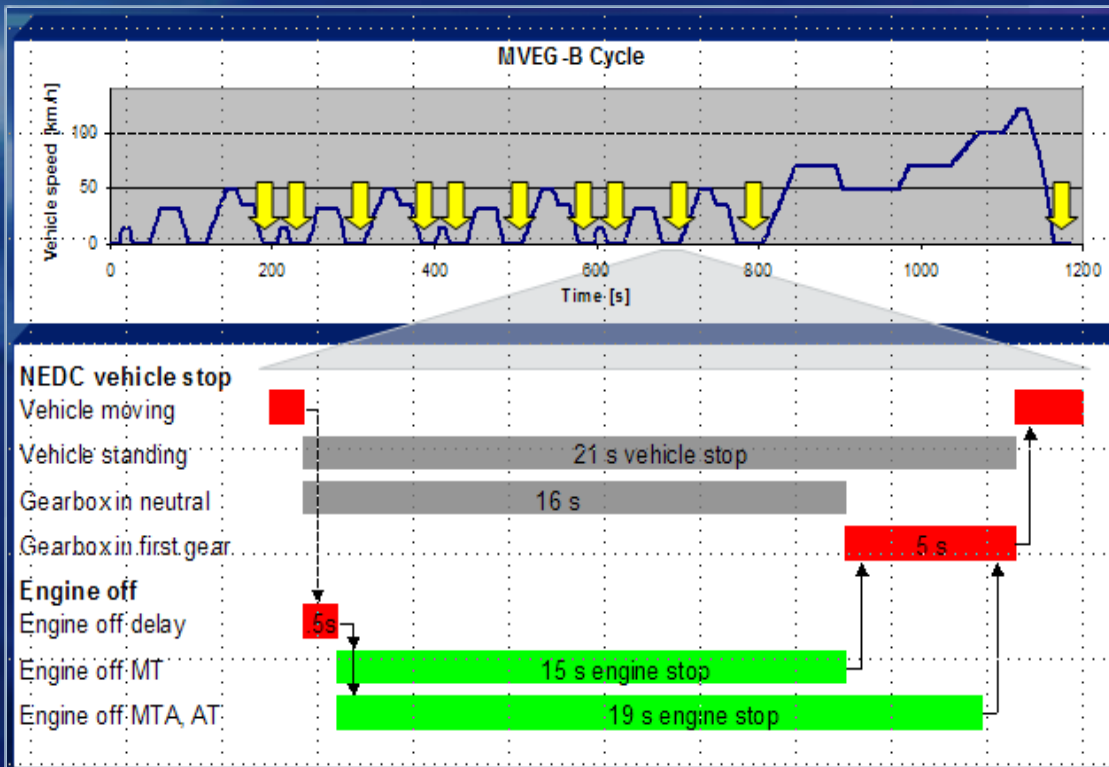


Corn

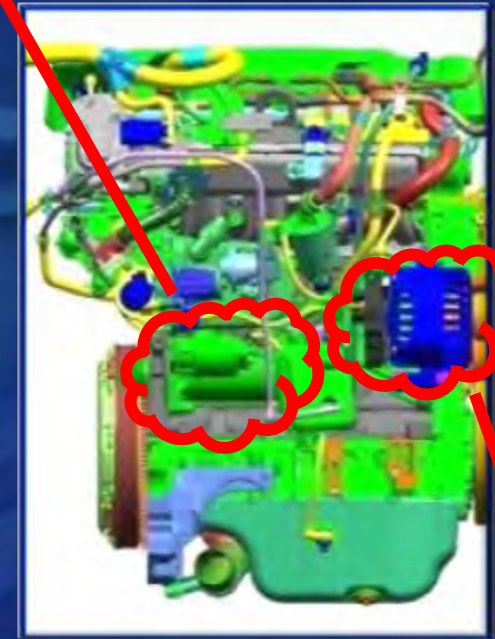
And we have only just begun ...

„Start-stop“ Technology rationales

S&S potential in NEDC

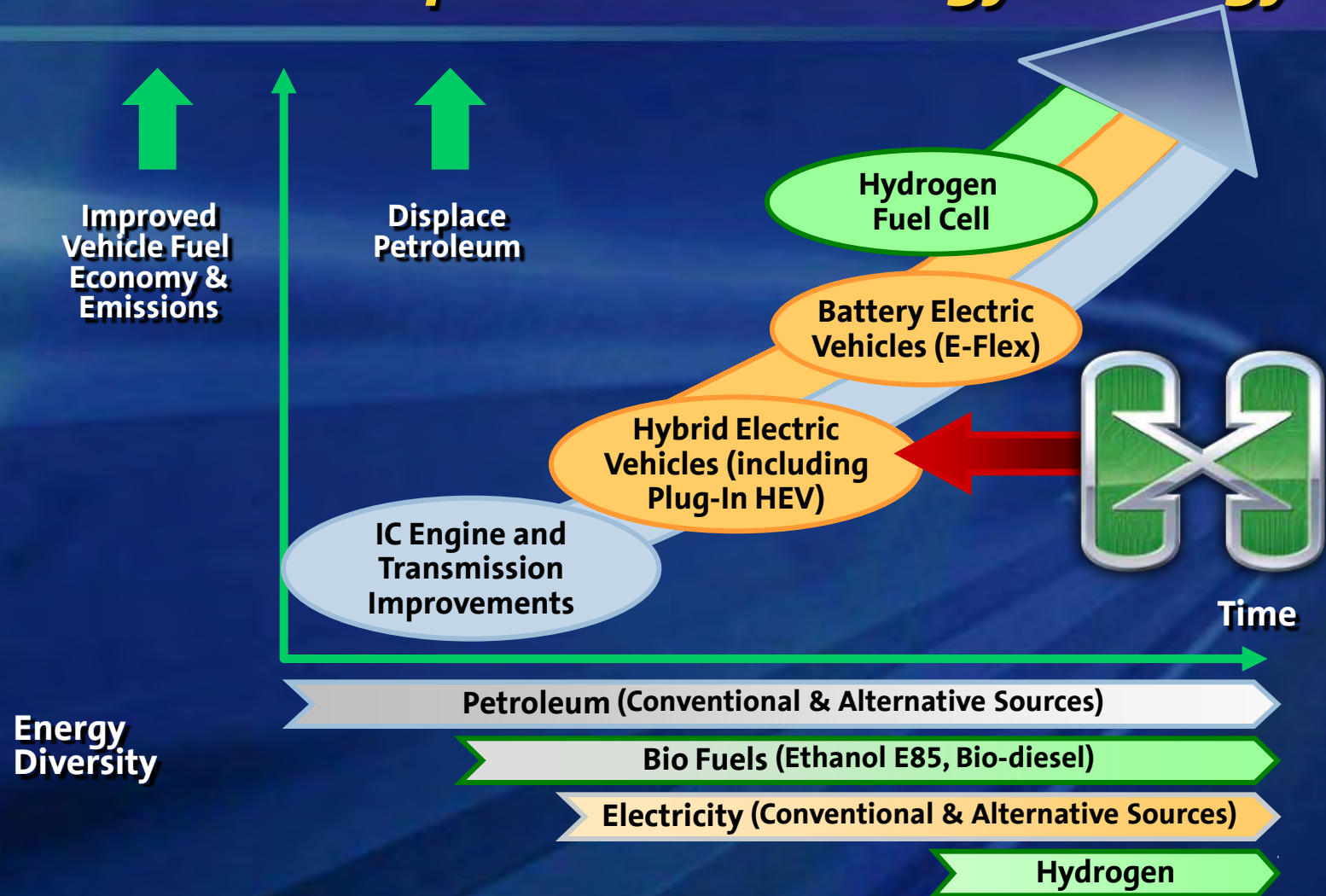


Starter-Based system

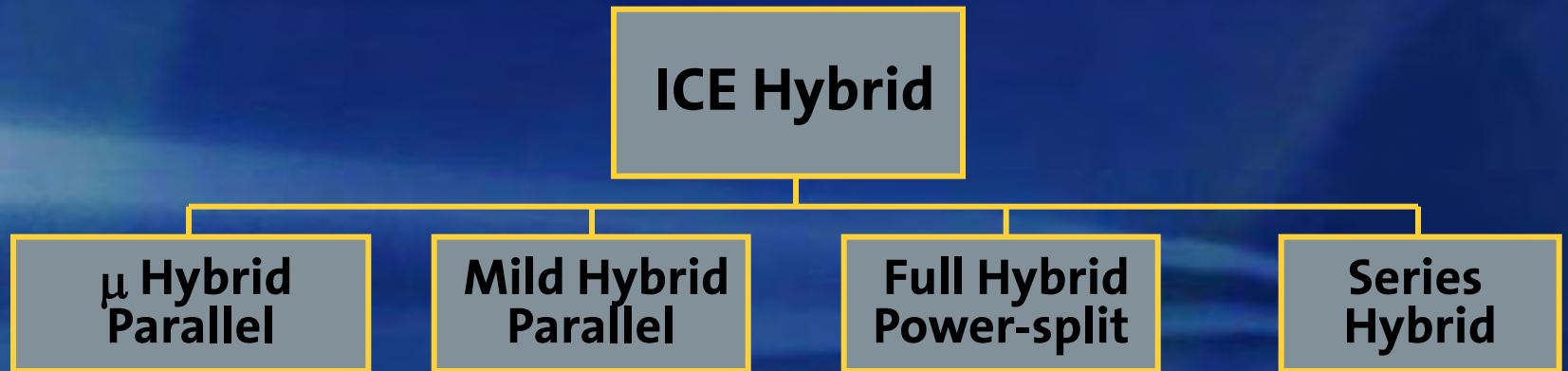


Belted Alternator Starter (BAS)

Advanced Propulsion Technology Strategy



GM Hybrid PT technology portfolio



BAS



BAS+



2 Mode

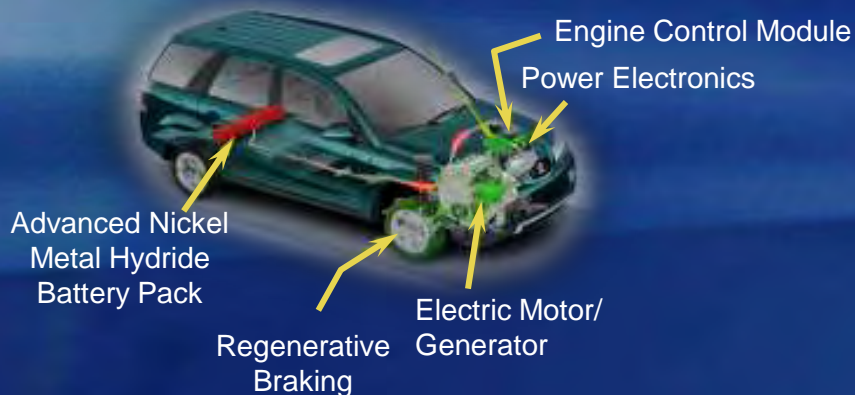


RE-EV



GM Hybrids approach

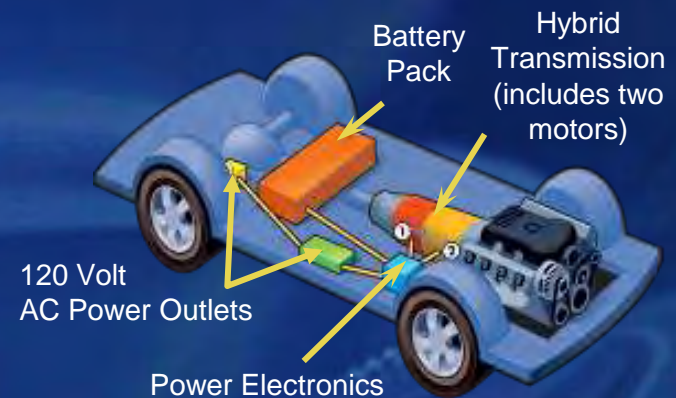
BAS Mild Hybrid



Main features:

- Engine start / stop
- Early deceleration fuel cut-off
- Regenerative braking
- Charging opportunity

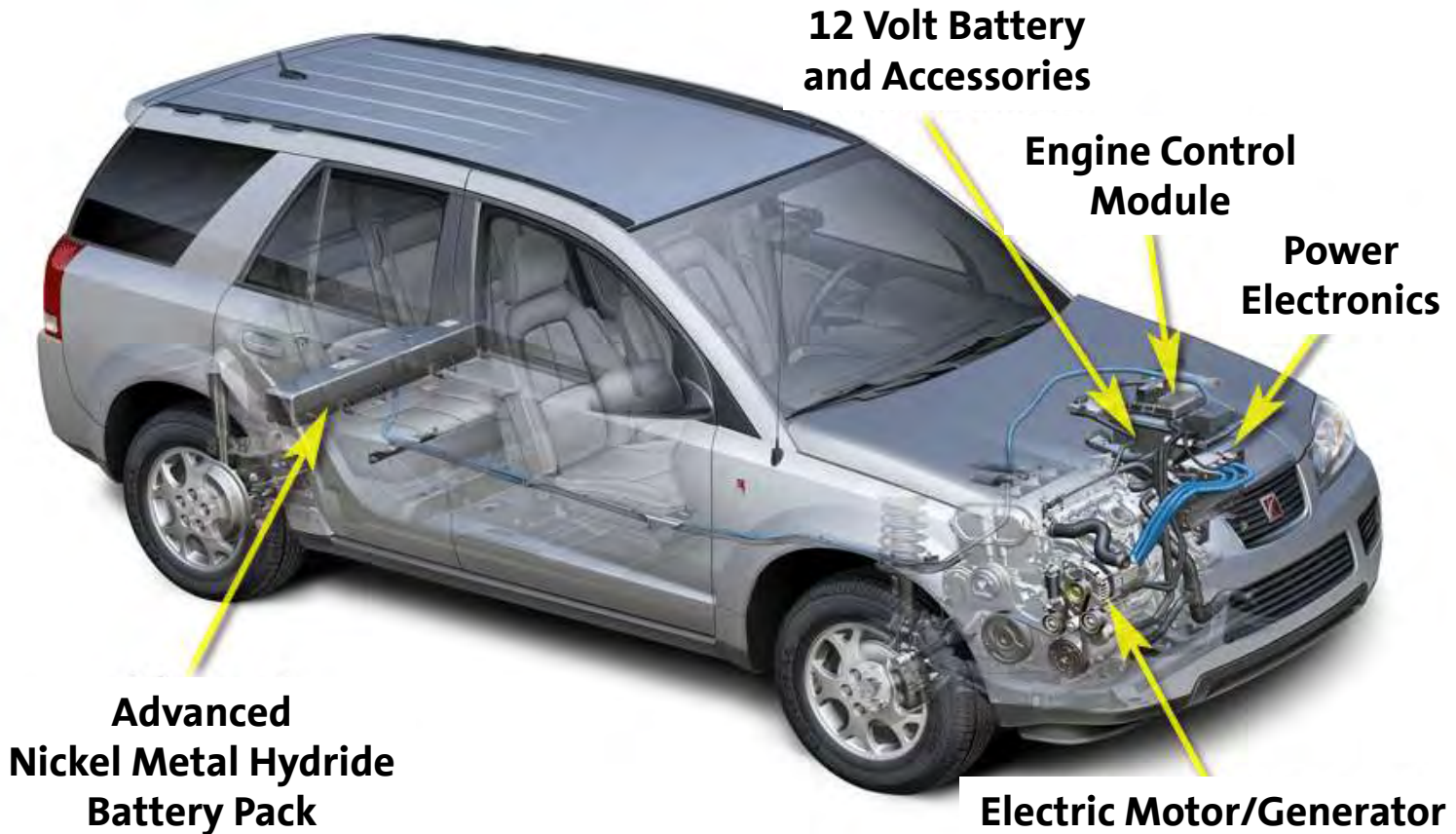
2-Mode Full Hybrid



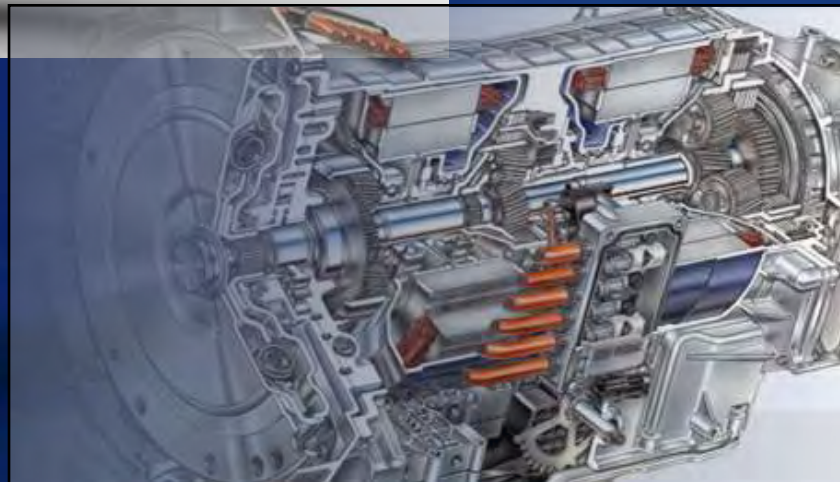
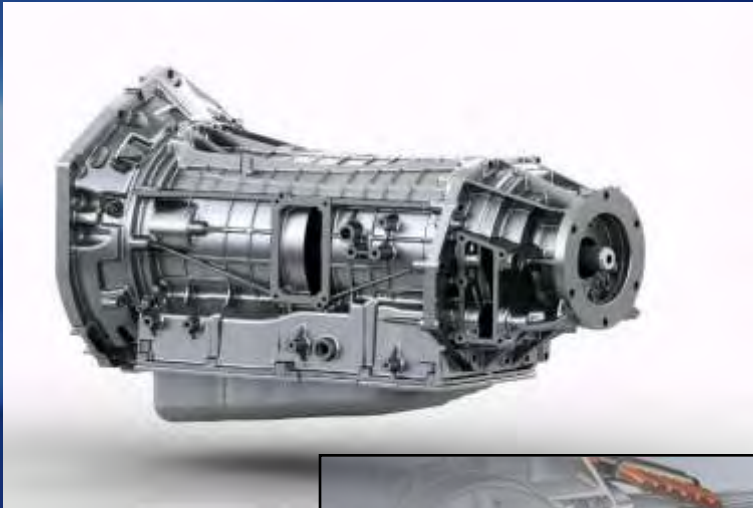
Additional main features:

- Power-split (1st mode)
- ZEV in only-electrical operation
- Enhanced efficiency (2nd mode)
- Performance enhancement

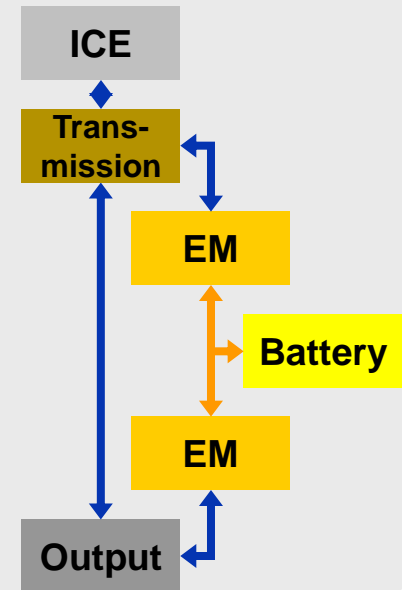
GM Hybrid System for Saturn VUE Green Line



Two-Mode Full Hybrid



power-split

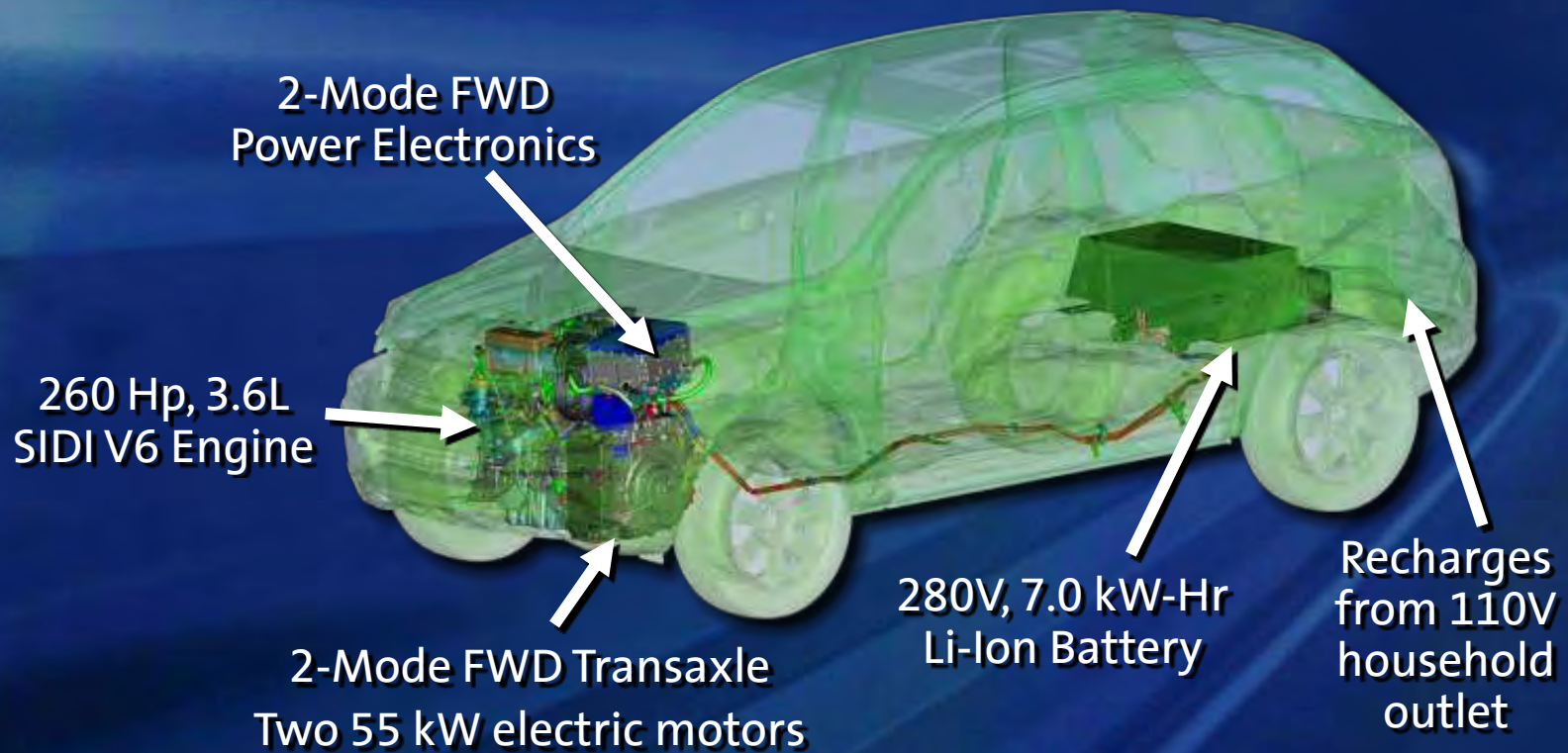


ICE : internal combustion engine

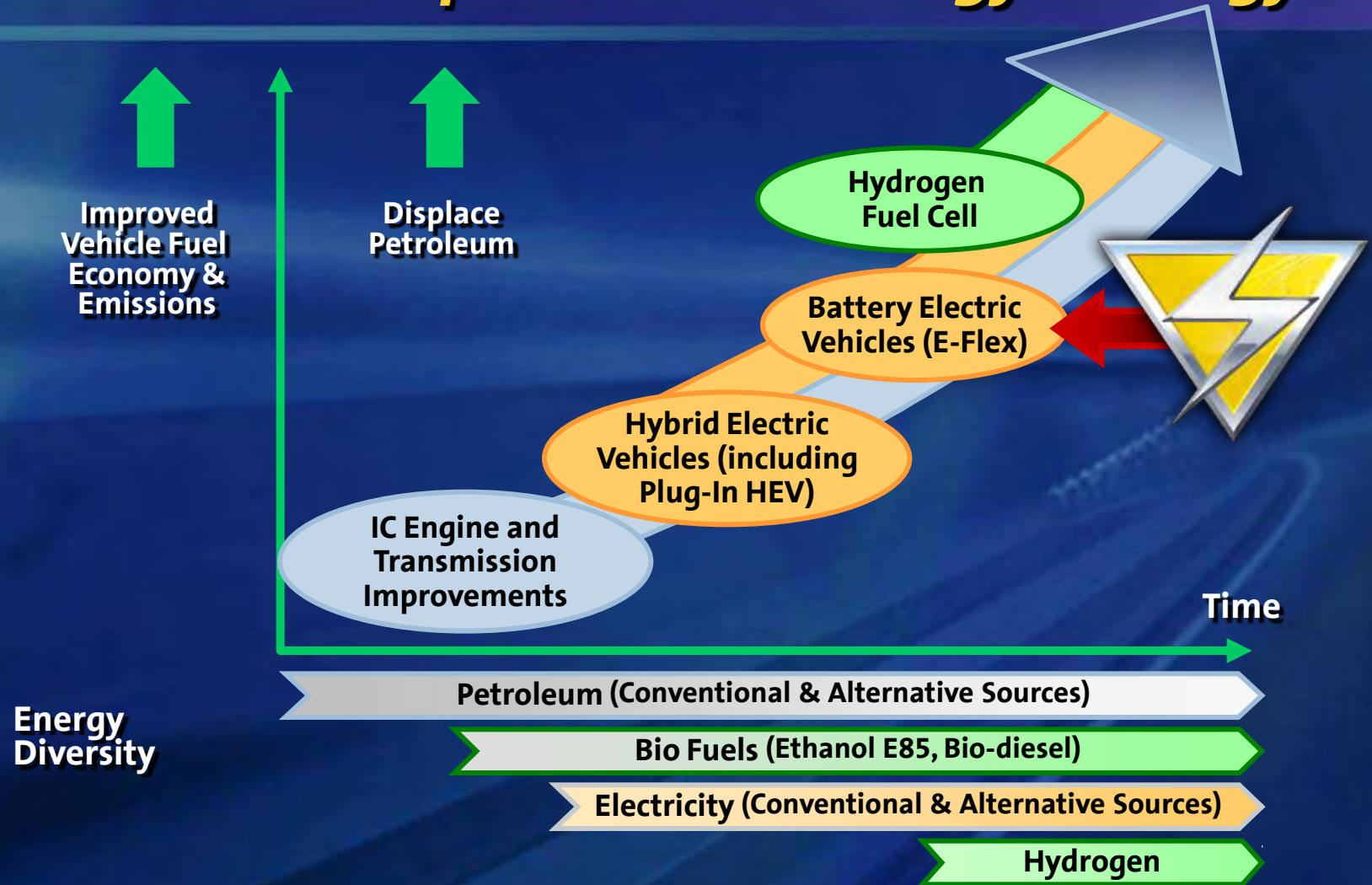
EM : electric motor

Saturn VUE Green Line 2-Mode Plug-in Hybrid

Potential to achieve double the fuel efficiency of any current SUV on short trips



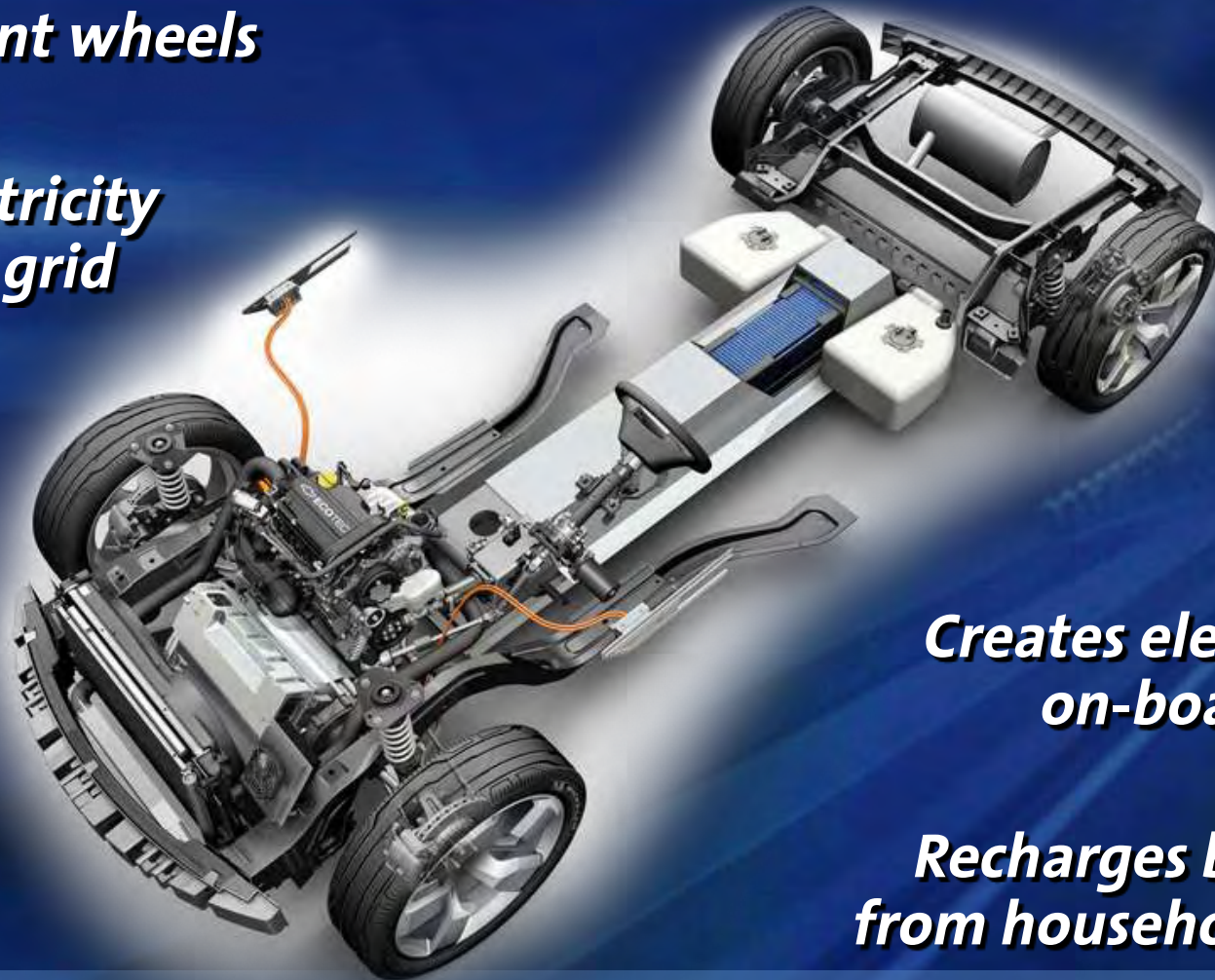
Advanced Propulsion Technology Strategy



Extended-Range Electric Vehicle (E-REV)

Powers front wheels

*Stores electricity
from the grid*



*Creates electricity
on-board*

*Recharges battery
from household outlet*

Chevrolet



- ✓ CO2 emissions less than 40g/Km
- ✓ EV range of 64Km
- ✓ Total range of 700km
- ✓ Lithium-Ion battery pack - 181kg
- ✓ Recharging time from grid: 3 hours
- ✓ Maximum speed 160km/h



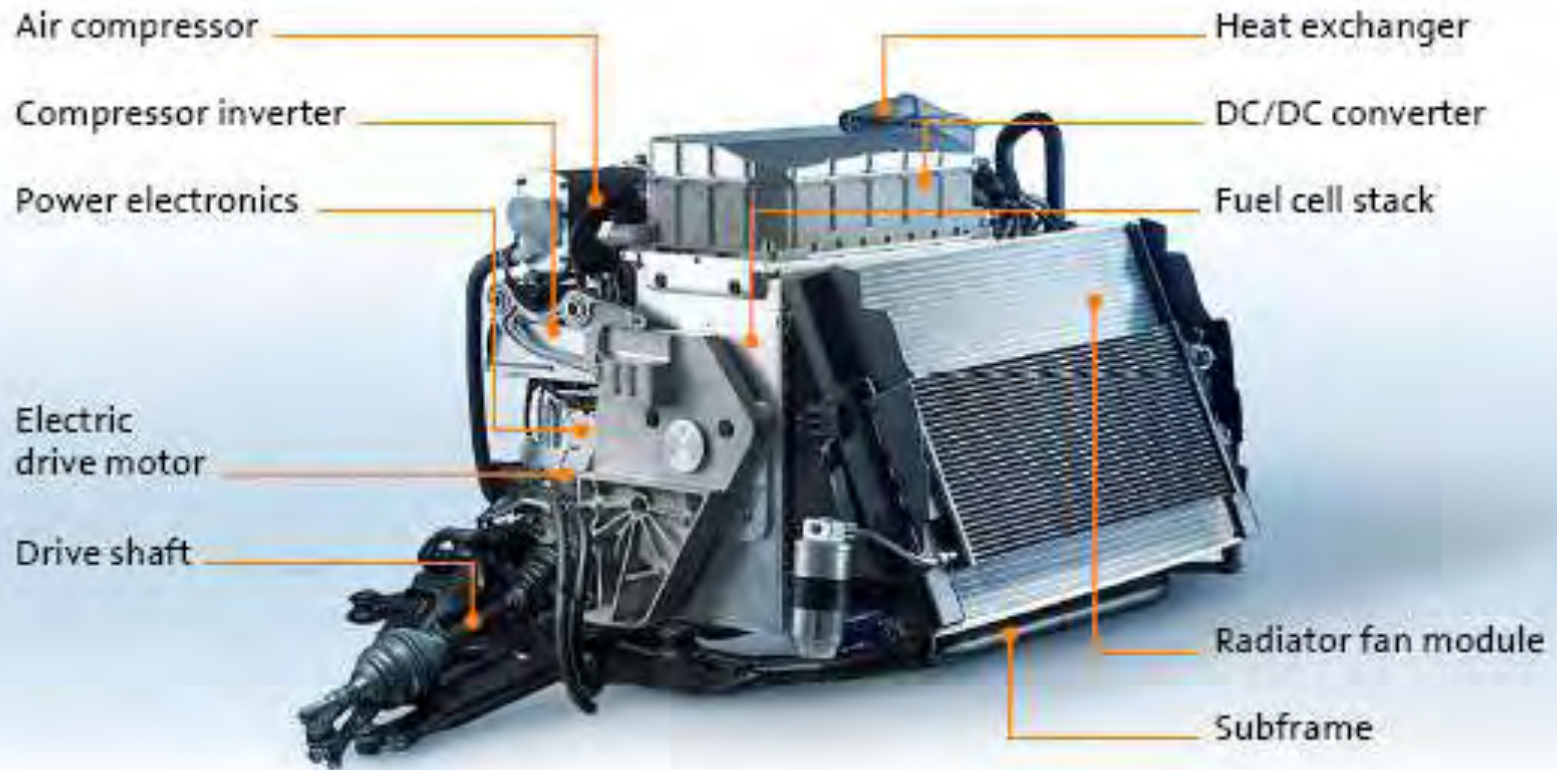
Common Platform for Alternative propulsion options

FLEX

FUEL CELL



Fuel Cells Propulsion Module



EQUINOX FUEL CELL

Project Driveway

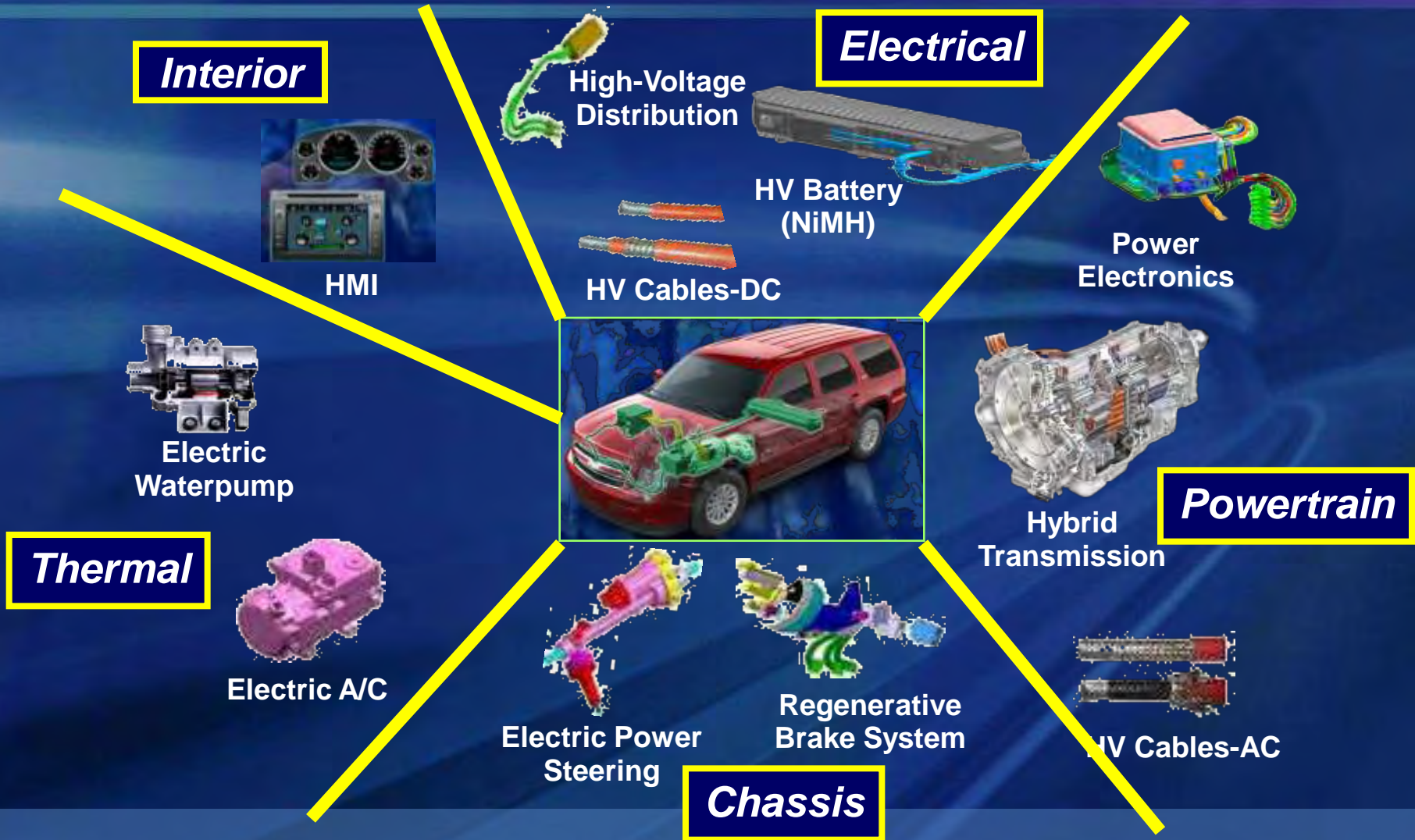
Largest fuel cell vehicle market test

100+ vehicles in the hands of customers

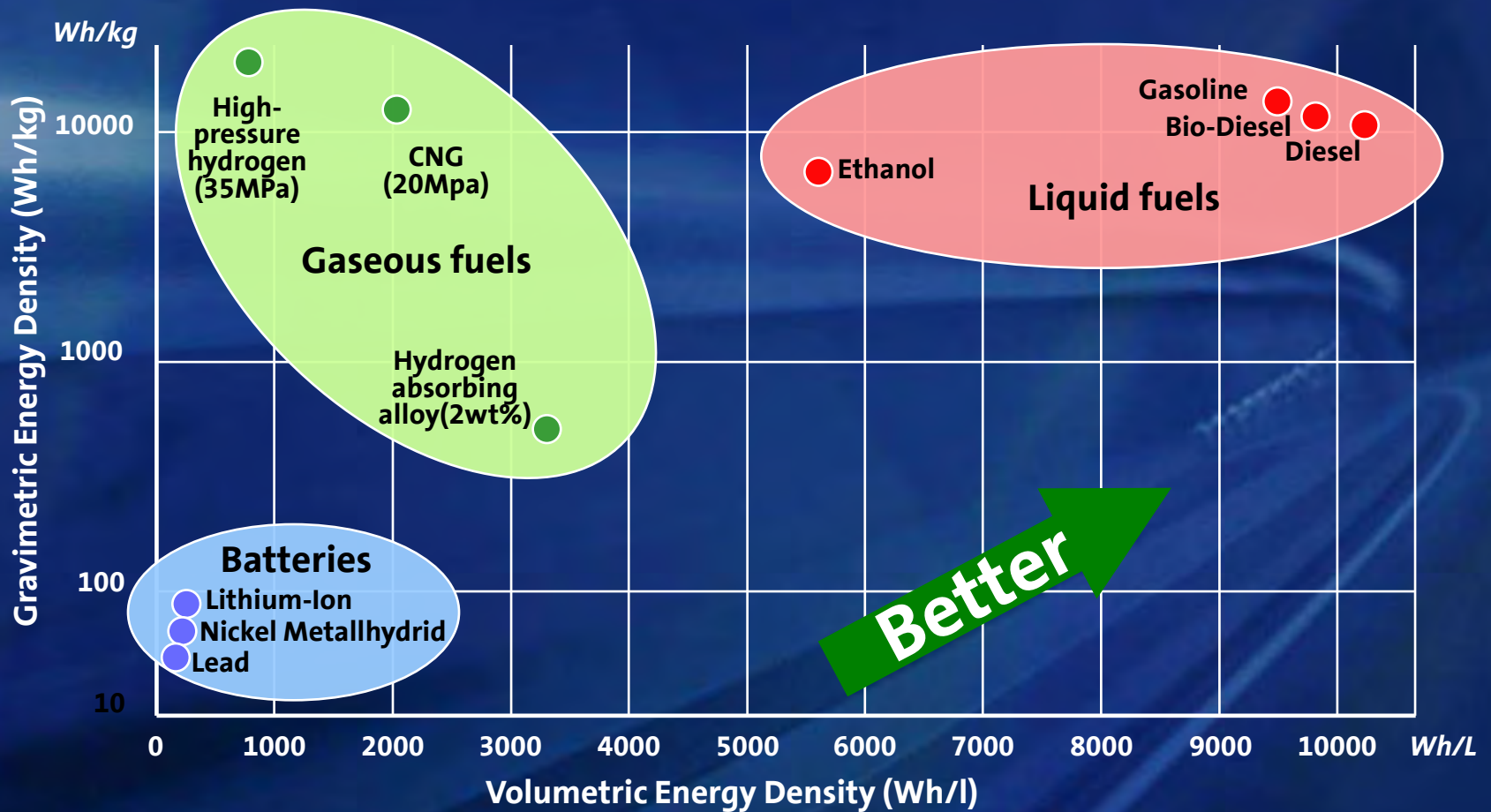
10 in Europe, 7 in Asia



Electrification of the Automobile



Energy Diversity



GM Approach for Powertrain Electrification Final Remarks

- **Top issues of the 21st century, in addition of emissions, are and will be :**
 - ✓ **Earth Warming**
 - ✓ **Energy Diversification**
- **In the development scenario of automotive propulsion systems :**
 - **“Best” Hybrid configurations** consolidation and relevant industrial mass-production development
 - **Electrical drive and batteries** enhancement
 - ... will play growing & remarkable roles in next decades and will be also technology **enablers for future Hydrogen Fuel Cells**
 - ... but **enhanced methodologies and new skills** must be developed
- **Our final goal commitment:**
 - ✓ to make the **automobile more exciting, more functional, more fun to drive** than ever before !