



“Moving Forward with Electrified Vehicles”

12 October 2011

Governmental regulations and incentives, especially in mature markets, are influencing the pace of fuel efficiency and emissions improvement

Regional Drivers of Alternative Fuel Vehicle Adoption

United States

- Corporate Average Fuel Economy (CAFE) standards increasing to over 35 mpg by 2016
- \$7,500 tax credit incentive for manufacturers' first 200,000 plug-in EVs
- State-level standards and incentives (e.g. CA's ZEV program)
- Presidential mandate for clean vehicles and funding support from various federal programs

Western Europe

- Euro 5 (2009) and Euro 6 (2014) standards continuously strengthening emissions requirements for vehicle fleet
- Increased regulatory attention on NO_x emissions from diesel vehicles
- Widespread use of emissions-based vehicle purchase taxes across EU today
- Purchase price subsidies for PHEVs and EVs in several member states (France €5000, UK €2000-5000)

Japan

- Strong federal and regional purchase price subsidies for PHEVs and EVs (up to \$10-20k per vehicle)
- Regional initiatives to deploy smart-grid infrastructure and public charge points
- Federal research grants support development of li-ion battery technology
- Widespread use of high-speed rail for long-distance travel reduces range requirements of plug-in vehicles

Rest of World

- Emission requirements vary between developed (Canada, Australia, South Korea) and developing (Africa, South America, Eastern Europe, South East Asia) areas
- Purchase price incentives for PHEVs and EVs typically only in place in developed areas
- Significant differences in level of electricity infrastructure between regions

India

- Euro 3 emission standards adopted nationwide in 2010, strengthening vehicle emissions requirements
- Poor electricity infrastructure with frequent power cuts in many areas
- Low average cost of new vehicles implies high relative cost of electrified models due to incremental battery cost
- Widespread use of small vehicles (A and sub-A class) today

China

- Euro 4 emission standards adopted nationwide in 2010, Euro 5 to go into effect in 2012
- Authorities are promoting China as a forerunner on electric vehicles. Significant federal and regional incentives available (\$7-9k per vehicle)
- Low average cost of new vehicles implies high relative cost of electrified models due to incremental battery cost

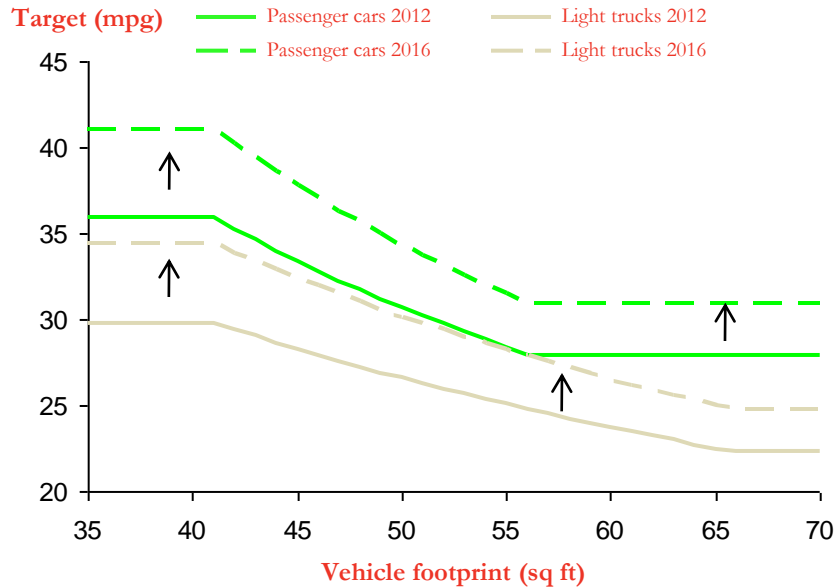
Source: Industry sources

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STELLAR Alliance, LLC

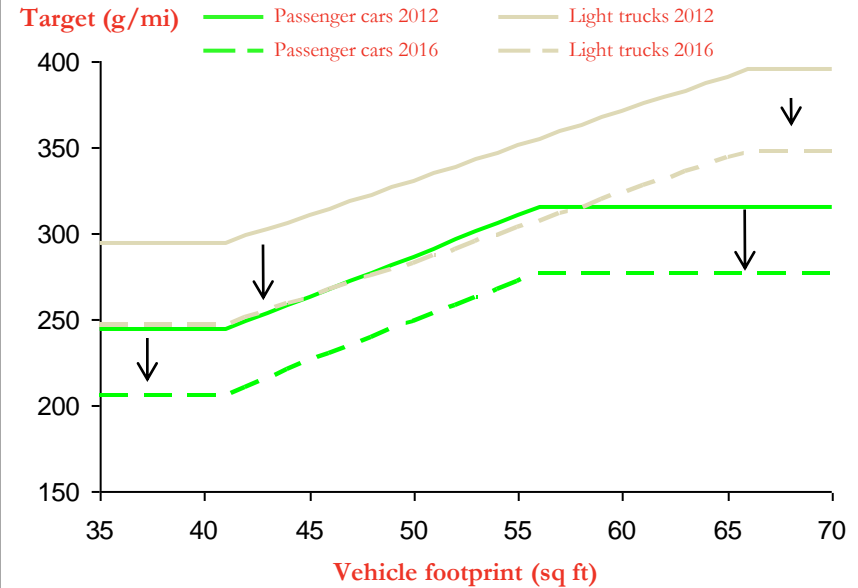
New and pending fuel economy and emission requirements make improving fuel economy more important than ever in the U.S.

Corporate Average Fuel Standards (CAFE)



- Average requirement is raised sequentially from 2012 to 2016 for passenger cars and light trucks by 11-15% depending on footprint
- Fleet-wide average required fuel economy for 2016 estimated at 37.8 mpg for passenger cars and 28.8 mpg for light trucks

Greenhouse Gas Emission Standards (GHG)



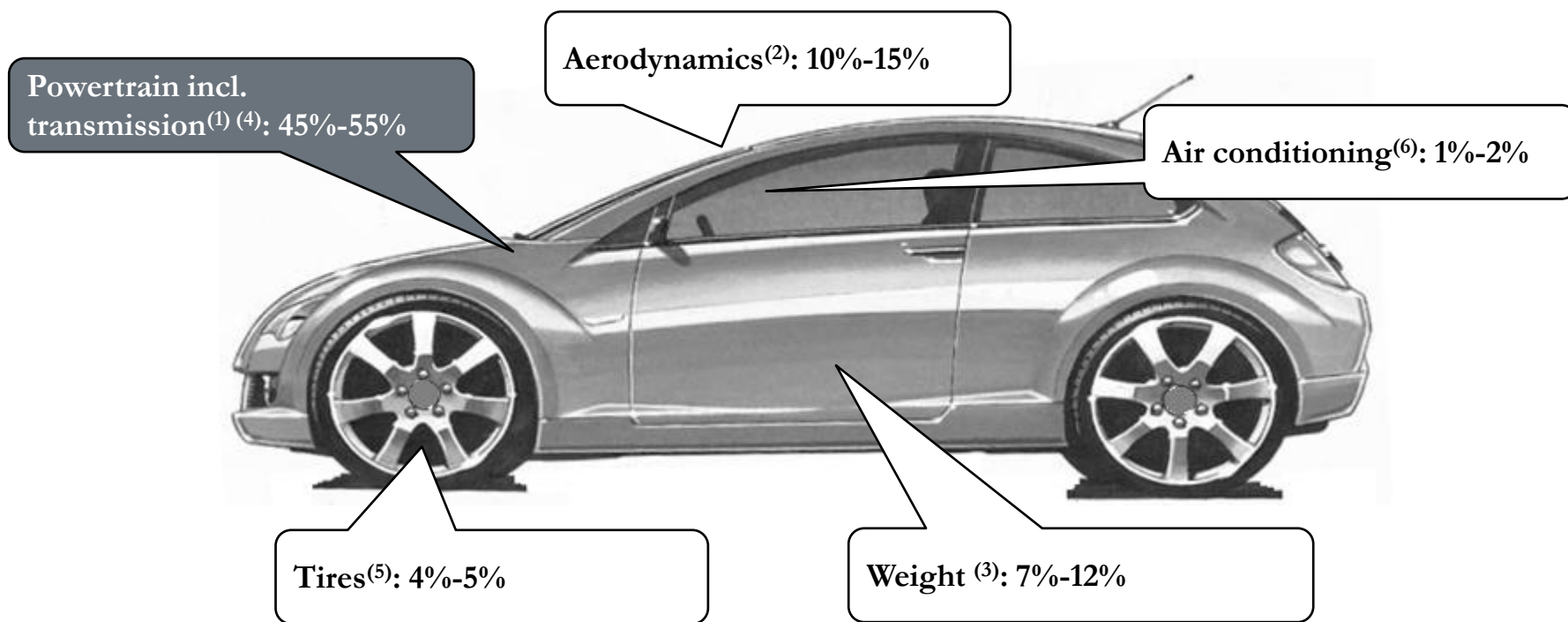
- Average requirement is lowered sequentially from 2012 to 2016 for passenger cars and light trucks by 12-16% depending on footprint
- Fleet-wide emissions compliance level for 2016 estimated at 225 g/mi for passenger cars and 298 g/mi for light trucks

Implications

- Vehicle mix shifting to smaller/lighter vehicles with stronger emphasis on vehicle weight reduction
- Immediate importance of ICE improvements and development of alternative powertrains


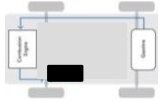

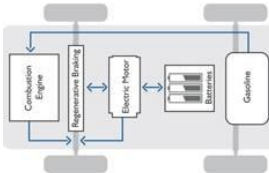

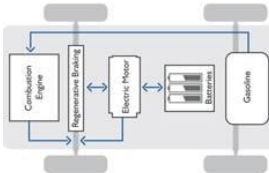

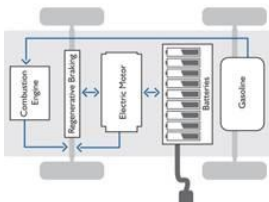


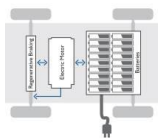
The powertrain's key role in determining fuel economy and CO₂ emissions is the primary reason for the focus on vehicle electrification

Levers to reduce fuel consumption/CO₂-emissions (Fuel consumption reduction potential %)



Note: (1) Base engine: 100kW, 4cyl Gasoline engine; 2) Modern cars have drag coefficient (cw) of ~0.3 (e.g. BMW 1 series); 3) Weight reduction by usage of light weight materials; 4) Piloted gearbox, gearbox ratios optimization; 5) At 56mph average speed; 6) Assuming usage of air conditioning during one third of total usage
Source: TNO, IEEP, LAT, Michelin, Stellar

Vehicle electrification has emerged as a key technology to improve powertrain efficiency and reduce fuel consumption

Technology	Description	F/E Gain	Examples	Schematic
Micro-Hybrid (Micro HEV)	<ul style="list-style-type: none"> Conserves energy by shutting off the engine when the vehicle is idling and automatically re-starting it when the driver releases the brake 	0%-5%		
Mild-Hybrid (Mild HEV)	<ul style="list-style-type: none"> Same as Micro, plus an electric motor assists the engine in acceleration Regenerative braking converts kinetic energy to storable electric energy in a small battery 	10%-15%		
Full Hybrid Electric Vehicle (HEV)	<ul style="list-style-type: none"> Same as Mild, plus can run only on the gas engine or the electric motor powered by a larger battery, or a combination of both Combine electric motor power and engine power in a way that optimizes output to the wheels throughout the operating range 	40%-50%		
Parallel Plug-in Hybrid Electric Vehicle (PHEV)	<ul style="list-style-type: none"> Parallel PHEV: An HEV with a battery large enough to run electric only for a significant distance (10+ miles). Both a regular ICE and electric motor are used as a means of propulsion. Recharge off the grid 	80% - 100% +		
Series PHEV	<ul style="list-style-type: none"> Series PHEV: An EV with a generator on board that turns on when the batteries run low to allow a longer driving range (hence, the term 'Extended Range EV') Recharge off the grid 			
Full Electric Vehicles (EV)	<ul style="list-style-type: none"> Runs solely on battery power Do not have Internal Combustion Engine (ICE) The range is limited by the size of the battery Recharge off the grid 	No Fuel Usage		

Multiple U.S. Government initiatives have been targeted at energy technologies which include vehicle electrification

- **Title XVII of the 2005 Energy Policy Act (EPAct 05) provides broad authority for the DOE to guarantee loans that support early commercial use of advanced technologies (up to \$51 billion)**
- **Amendment to EPAct 05 by ARRA Title IV in 2009 included Section 1705 addressing renewable energy systems, electric power transmission systems and advanced biofuel projects (up to \$32 billion)**
- **ARRA in 2009 included ~\$2.4 billion of grants for advance energy storage and infrastructure projects (i.e. batteries, electrified vehicles, charging stations)**
- **Advanced Technology Vehicles Manufacturing Program, part of the Energy Independence Act of 2007, Section 136 (up to \$25 billion)**
- **Continued tax credit incentives up to \$7,500 for purchase of an electrified vehicle**

Forecasting the direction for vehicle electrification utilizes complex stochastic modeling based on key technology adoption drivers

1

Market Dynamics

- Fuel Prices
- # of vehicle model offerings
- Infrastructure availability

2

Government Regulations

- Incentives
- Emission & Fuel Economy Regulation

3

Technology Advances

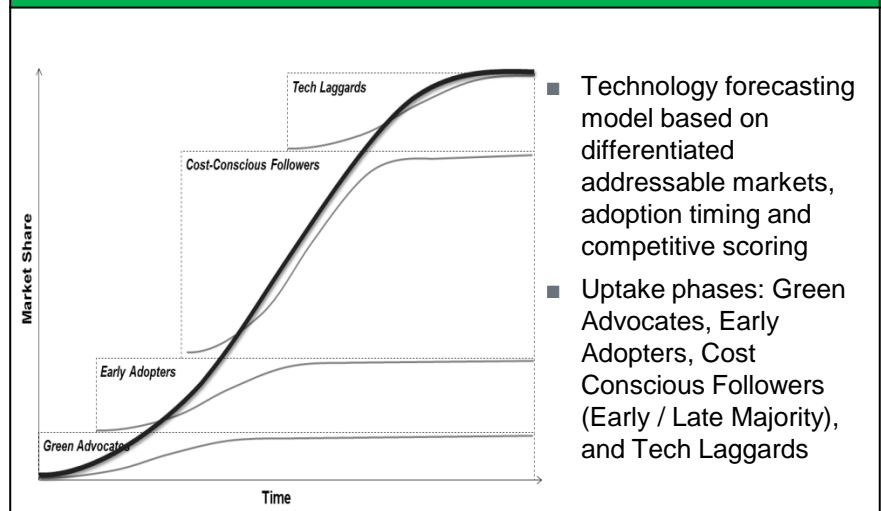
- Technology maturity
- Purchase cost
- Vehicle range
- Utility

4

Customer Perception

- Green / social

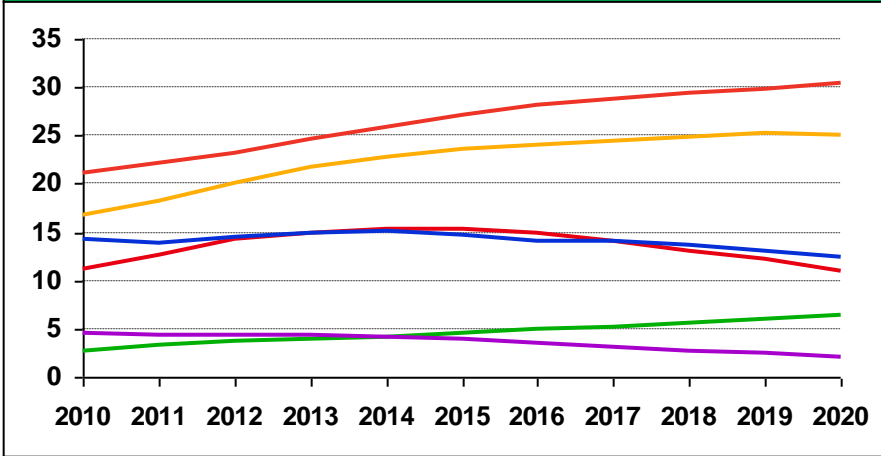
Technology Adoption Lifecycle



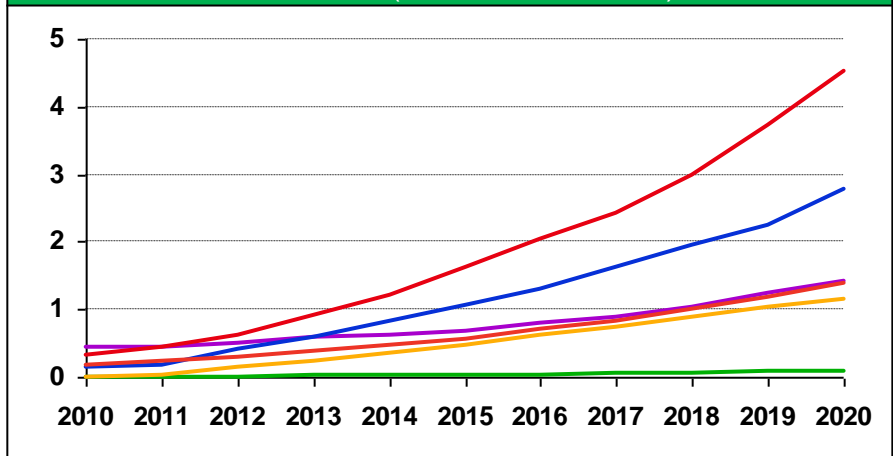
The U.S. is projected to be the largest vehicle market for HEVs, while China will lead in PHEV and BEV sales volumes

— India — Japan — United States — China — Western Europe — Rest of World

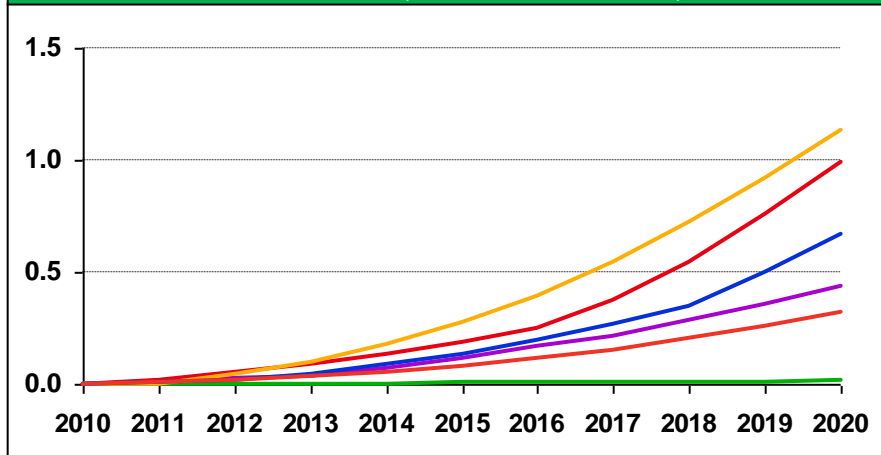
Spark & Compression Ignition Sales (millions of vehicles)



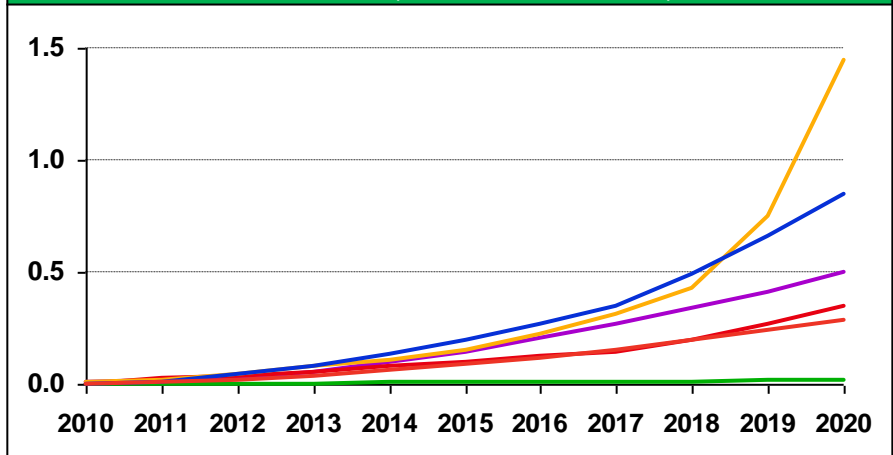
HEV Sales (millions of vehicles)



PHEV Sales (millions of vehicles)



BEV Sales (millions of vehicles)



Summary

Uncertainty about the viability of advanced technologies requires a structured investment strategy to identify growth opportunities while mitigating investment risk

Critical Challenges

- **Competitive demands in the market**
- **Technology direction(s)**
- **Complex trade-offs between technology and operational capabilities**
- **Global capabilities of OEMs, component and material suppliers**
- **Capabilities to meet consumer and governmental requirements**
- **Potential JVs, partnerships or acquisitions**
- **Timing and level of investments**

