
Engine and Transmission Technology Roadmapping: Consequences and Opportunities for Lubricant and Fuels Development

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- **Global trends and themes**
 - Technology roadmapping
 - Consequences and opportunities for lubricants and fuels
 - Conclusions

What's going on



Situation:

- Global automotive industry is undergoing rapid change
- “Mega Trends” are impacting OEMs, suppliers and consumers
- Fuel economy standards, emissions legislation, globalisation, and the rise of emerging markets are creating new opportunities & pressures

Complication:

- Economic downturn is accelerating the changes:
 - After the highs of 2000-2007, slow recovery from 2009-2010
 - Financial distress among suppliers and OEMs is leading to consolidation and constraints on R&D budgets
 - Tailpipe emissions remain important but fuel economy standards and CO₂ dominate R&D budgets and are the major powertrain technology drivers

Industry undergoing rapid change: “Mega Trends” impact consumers, OEMs & suppliers



Macro Economic Environment

- Major markets suffered most in downturn – NA, EU, Japan
- Western sales growth “catch-up” until 2014, “real” growth in China, India & Central / Eastern Europe

Legislation

- Fuel economy, CO₂, safety & end of use legislation increase product cost

Globalisation

- Shift of growth and market power to global institutions
- Regional advantages become a lever for global competitiveness

Model Mix

- More focus on small cars and smaller engines
→ Problem for OEMs who rely on large, premium vehicle profitability

Climate Change Debate

- Growing pressures from CO₂, and emissions reduction targets
- Consumers want clean transport but don't want to pay extra for it
- New technologies add complexity/risk & cost for OEMs and supply chain

Technology Challenges

- Complex road maps with no obvious winning technology
- Shortage of skills and capacity to develop and deliver new technologies

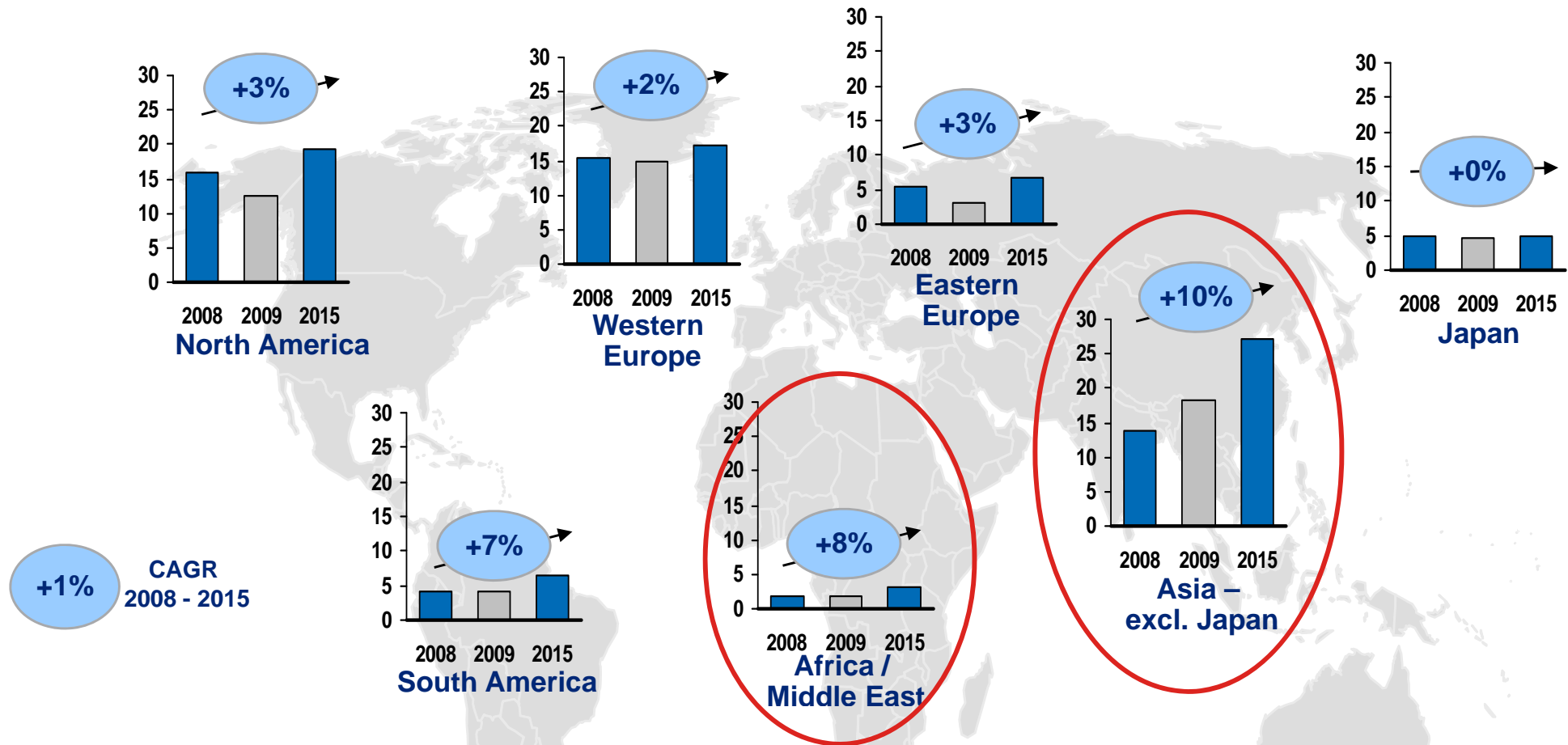
Business Performance

- Growth of low cost vehicles and entry of new OEMs into mature markets
- R&D spend level or rising, despite lower levels of industry profitability

Minimal sales growth expected in EU, USA or Japan: Emerging markets are key to growth

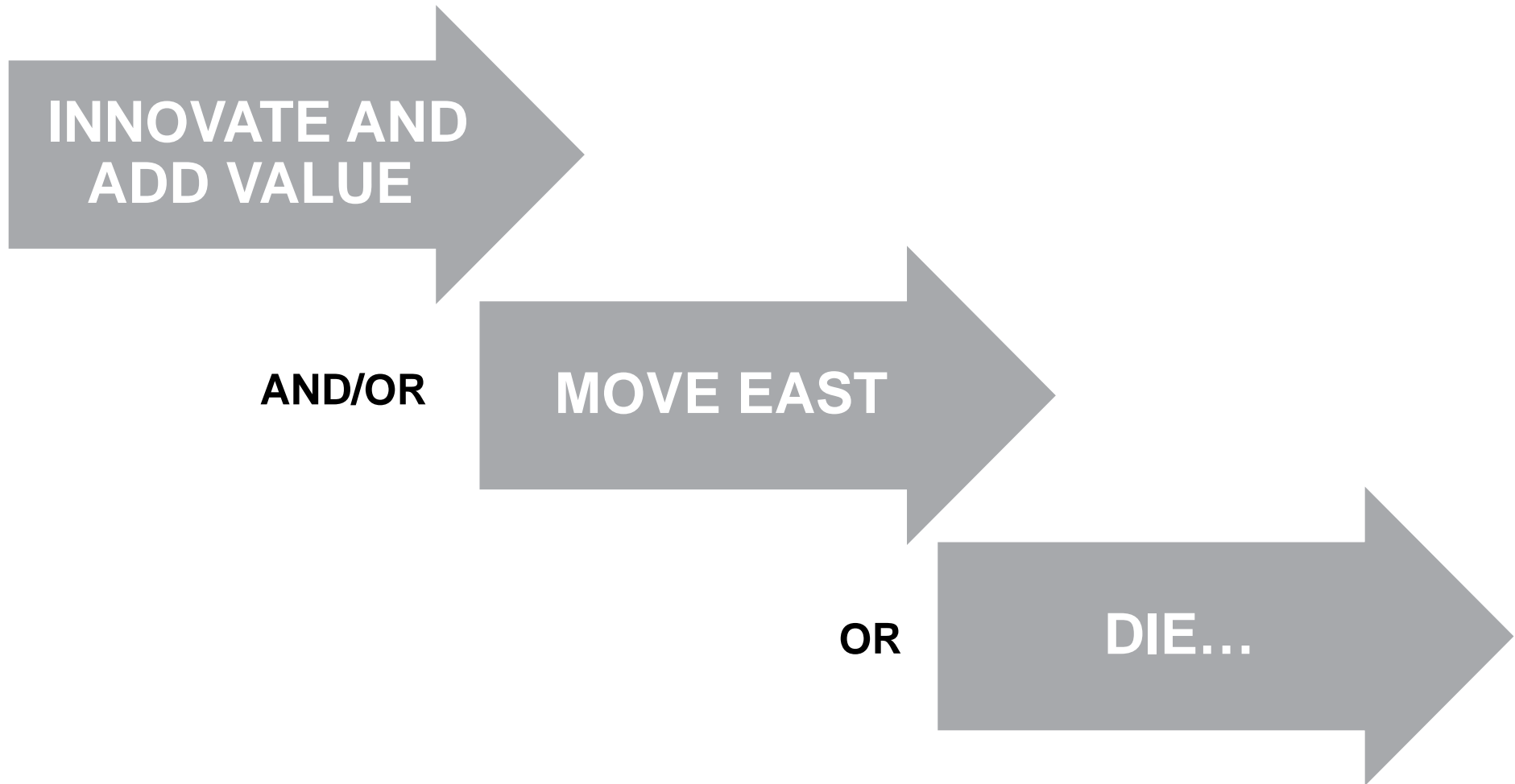


Car sales [million units]



Main winners are China, India and Africa/Middle East
Emerging Asian markets are now larger than North America or Europe

... Resulting in stark choices for OEMs



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Increasing fuel consumption & emissions pressure: Driving development of new powertrain technologies



Legislation

- Taxation: Emissions & efficiency related taxes (CO₂/NO_x)
- Zero Emissions Vehicle (California) benefits
- Incentives: e.g. "Congestion Charge" toll exemption (London)



Competition

- Increasing OEM activities
- Alternative powertrains as a competitive measure
- HEV/PHEV "technology bridge" for future full battery EVs



Conventional powertrain

Energy resources

- Limited resources/supply
- Oil security fears
- Continued increase in consumption
- Increased use of biofuel



Commercial / Society

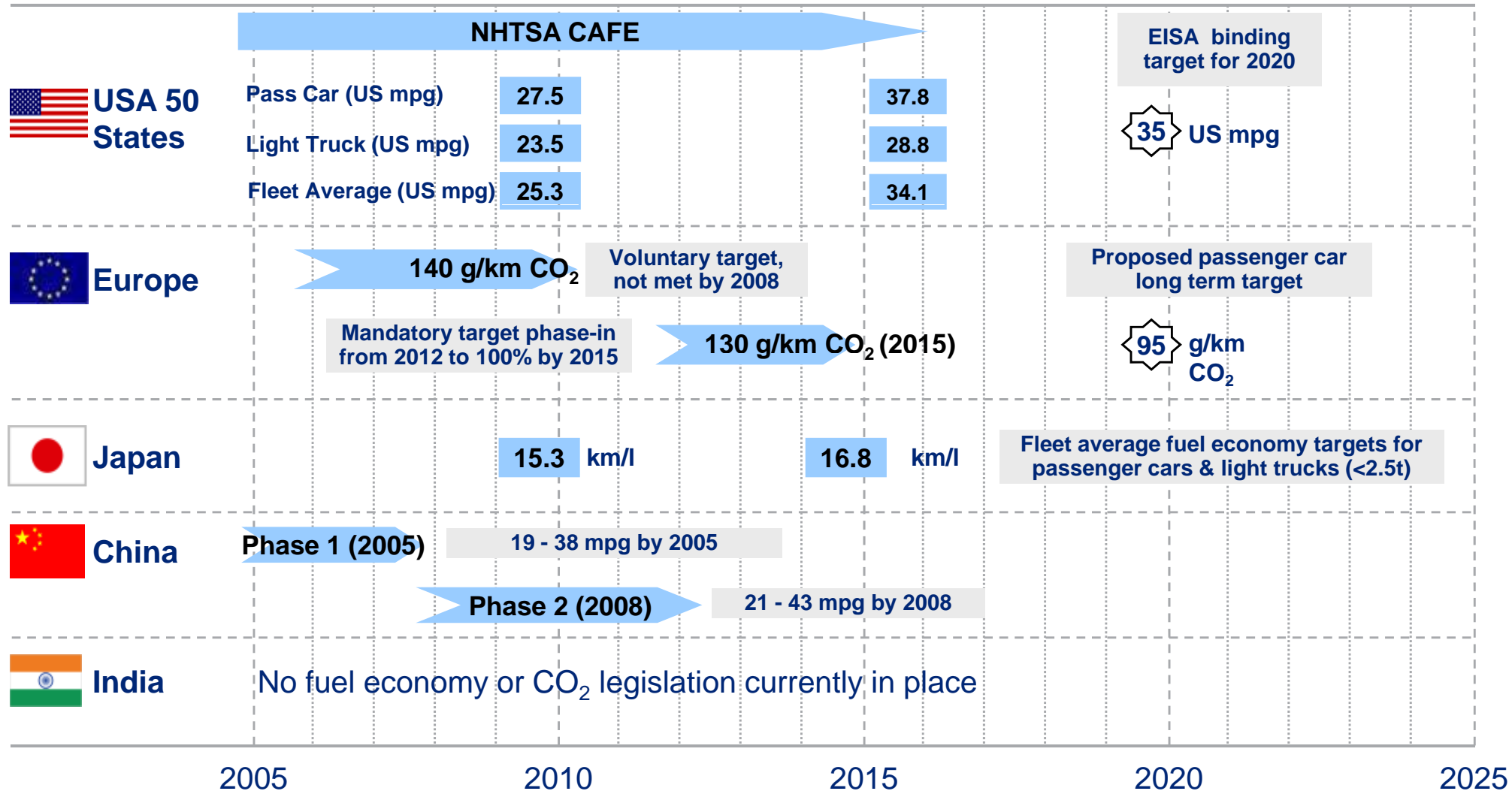
- Cost / value proposition
- Increasing price sensitivity
- Public awareness of climate change and global warming
- Increasing environmental concerns
- Lobbying



For the first time fuel economy and CO₂ legislation is introduced across the world with challenging targets



Fuel economy / CO₂ legislation for light duty vehicles

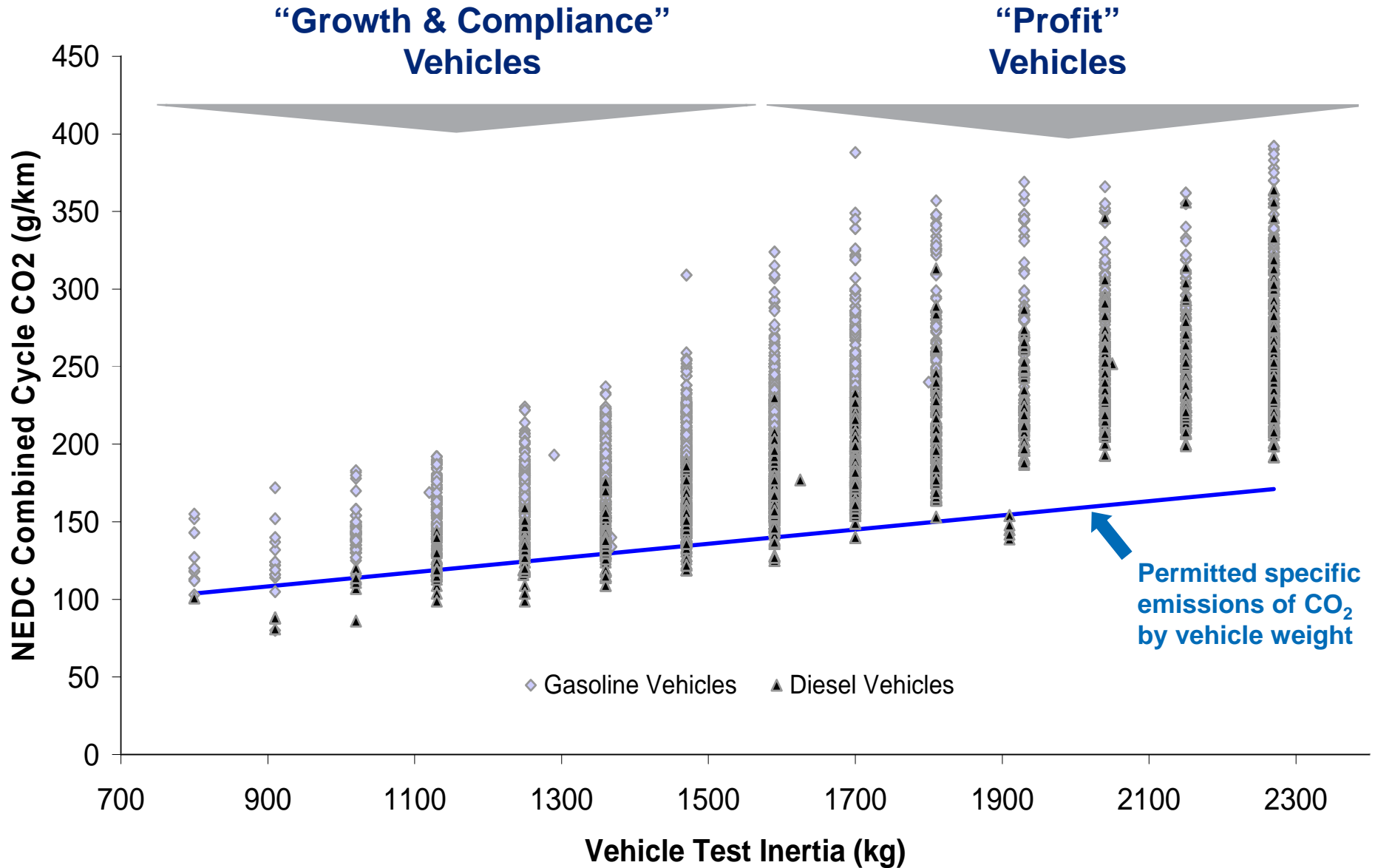


NHTSA = National Highway Traffic Safety Administration CAFE = Corporate Average Fuel Economy, FE = Fuel economy

Source: Ricardo EMLEG database

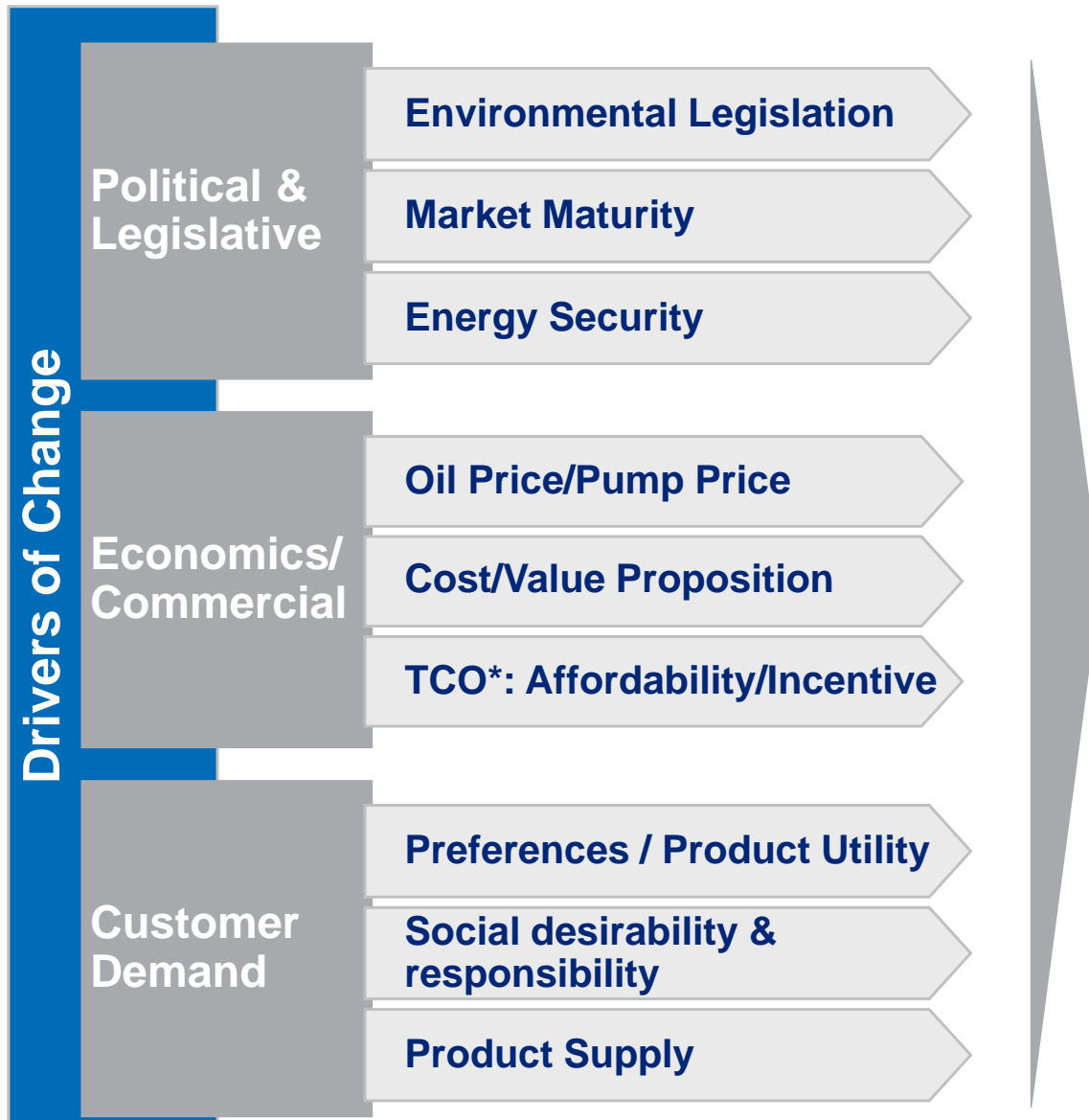
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Most cars in Europe do not meet proposed CO2 standard: The most profitable face greatest challenge



Permitted specific emissions of CO₂ by vehicle weight

Government policy & customer preference: Can be conflicting market drivers



- Diverse market drivers
- Market drivers not necessarily align with legislator views
- Surveys & market research do not always reflect what customers do !
- Economic shifts e.g. \$140/barrel of oil can change both legislative and consumer drivers
- Significant regional variations are always present

*Note: ICE = Internal Combustion Engine. TCO = Total Cost of Ownership

Source: Ricardo Analysis

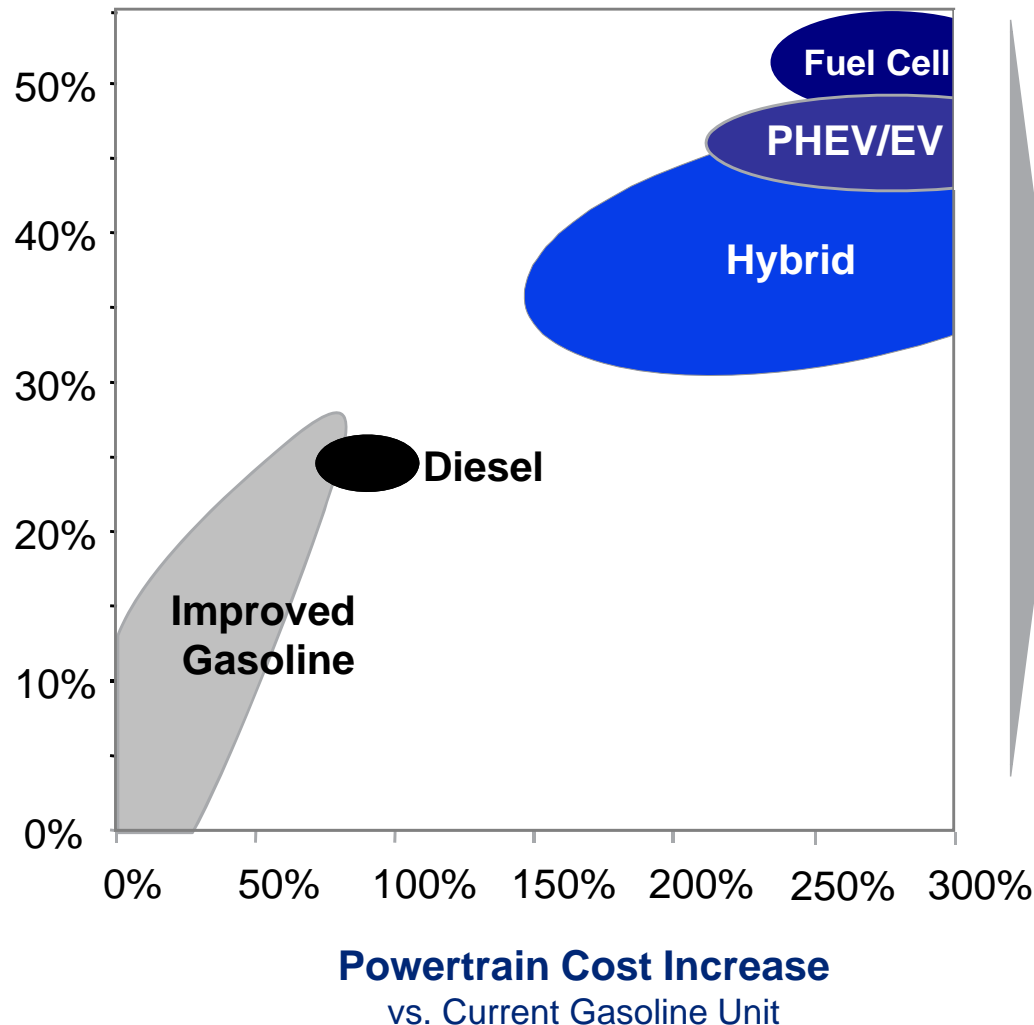
Incremental powertrain improvements are the most cost efficient way to improve vehicle efficiency



Powertrain Cost : Benefit Analysis

CO₂ Reduction

vs. Current Gasoline Unit



Impact

- Continuous improvement of conventional ICEs
- Gasoline closes efficiency gap to diesel
- Hybrids will deliver efficiency benefits, but at significant on-cost
- CO₂ benefits of PHEV/EV depend on renewables content of electricity generation
- Automated transmissions can further improve economy by up to 5% over benchmark manuals
- All technologies must address consumer utility and cost requirements

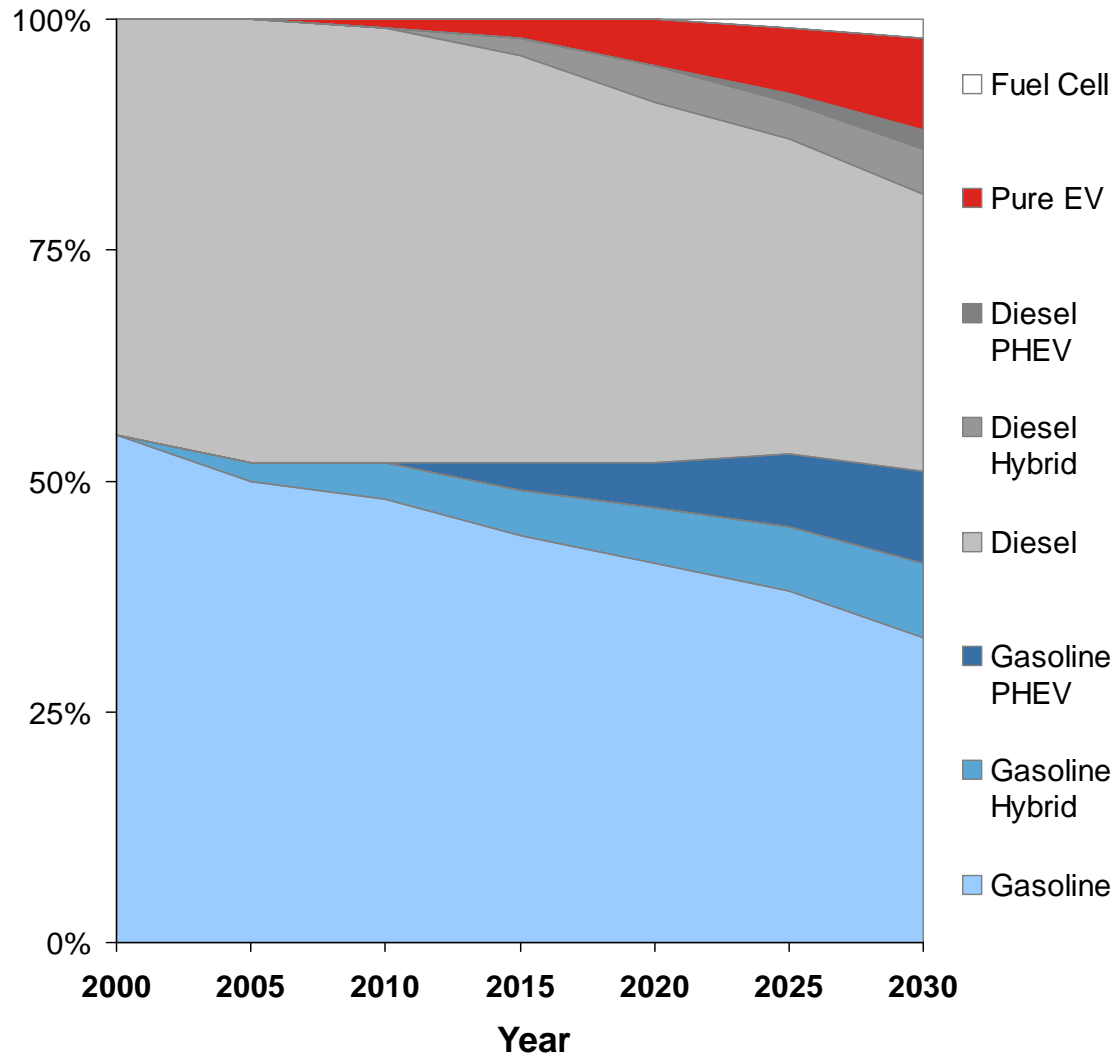
Uncertainty around alternative powertrains: ICE continues to be dominant power source



INDICATIVE

Indicative EU Powertrain Share Forecasts to 2030

Market Share



Consequences

- The powertrain picture to 2030 is uncertain
- Advanced “Conventional” Internal Combustion Engine likely to remain the largest single application
- Hybrid and plug-in hybrid will grow, mainly at the expense of diesel, as emissions compliance becomes increasingly expensive
- Pure EVs will grow from 2012
- Fuel cells start to appear in small numbers from 2025

Transmission production mix is strongly regional; Advanced automation poised for growth



Transmission Production Preferences and Trends (1/2)



- Preference for automatic transmissions, driven by ease of driving & comfort
- CVTs (Continuously Variable) will gain share, led by Japanese OEMs
- DCTs (Dual Clutch) will enter sub-compact segment, as OEMs leverage European technology



- Preference for manual transmissions, moving from 5 to 6 speed
- AMTs likely to grow: Cost effective but with refinement challenges
- DCTs will capture market share, development focus on efficiency, launch performance and cost competitiveness
- CVTs not liked in Europe; technology expected to remain niche



- CVT development driven by Japanese OEM demand and power-split hybrid requirements



- China will remain mainly manual, with automation split between CVT, DCT and conventional automatic

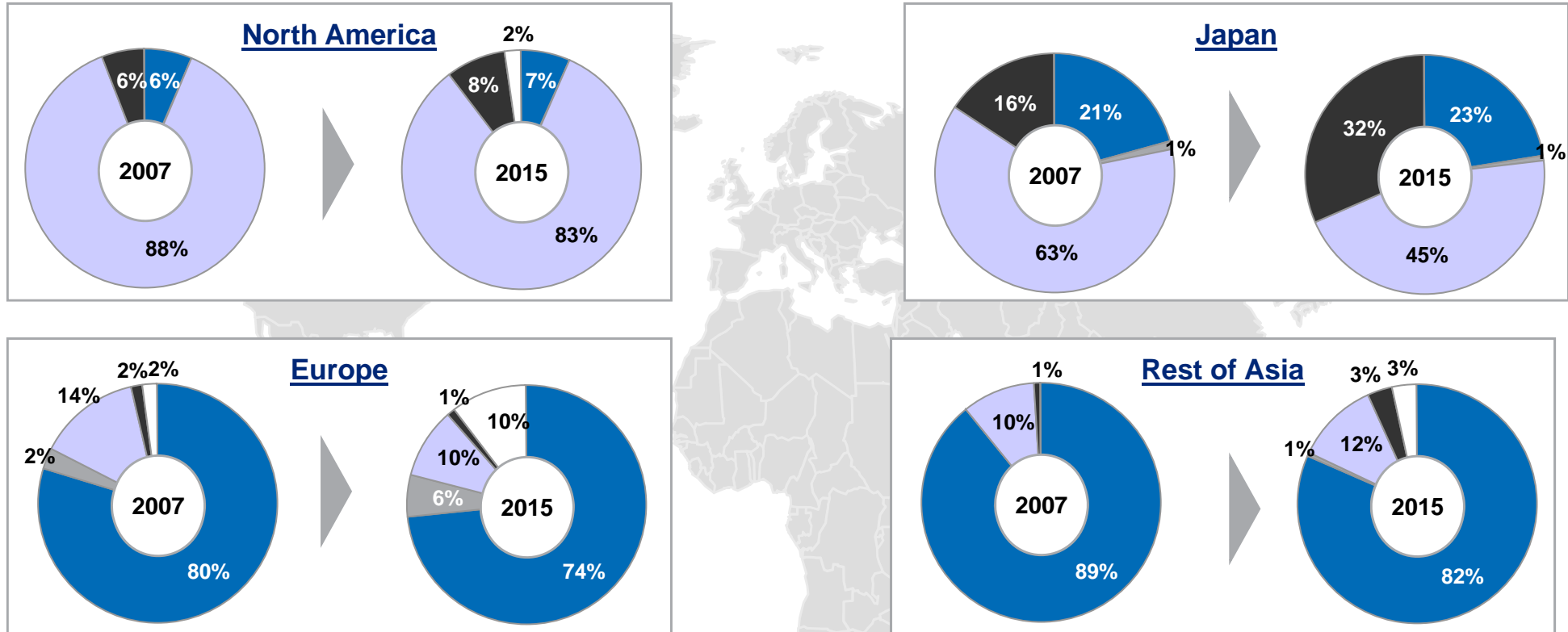


- India will grow demand for lowest cost manual transmissions

Transmission production mix is strongly regional; Advanced automation poised for growth

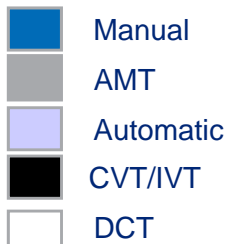


Transmission Production Preferences and Trends (2/2)



***N America & Japan prefer automated transmissions,
while Europe & Asia prefer cost-effective manual***

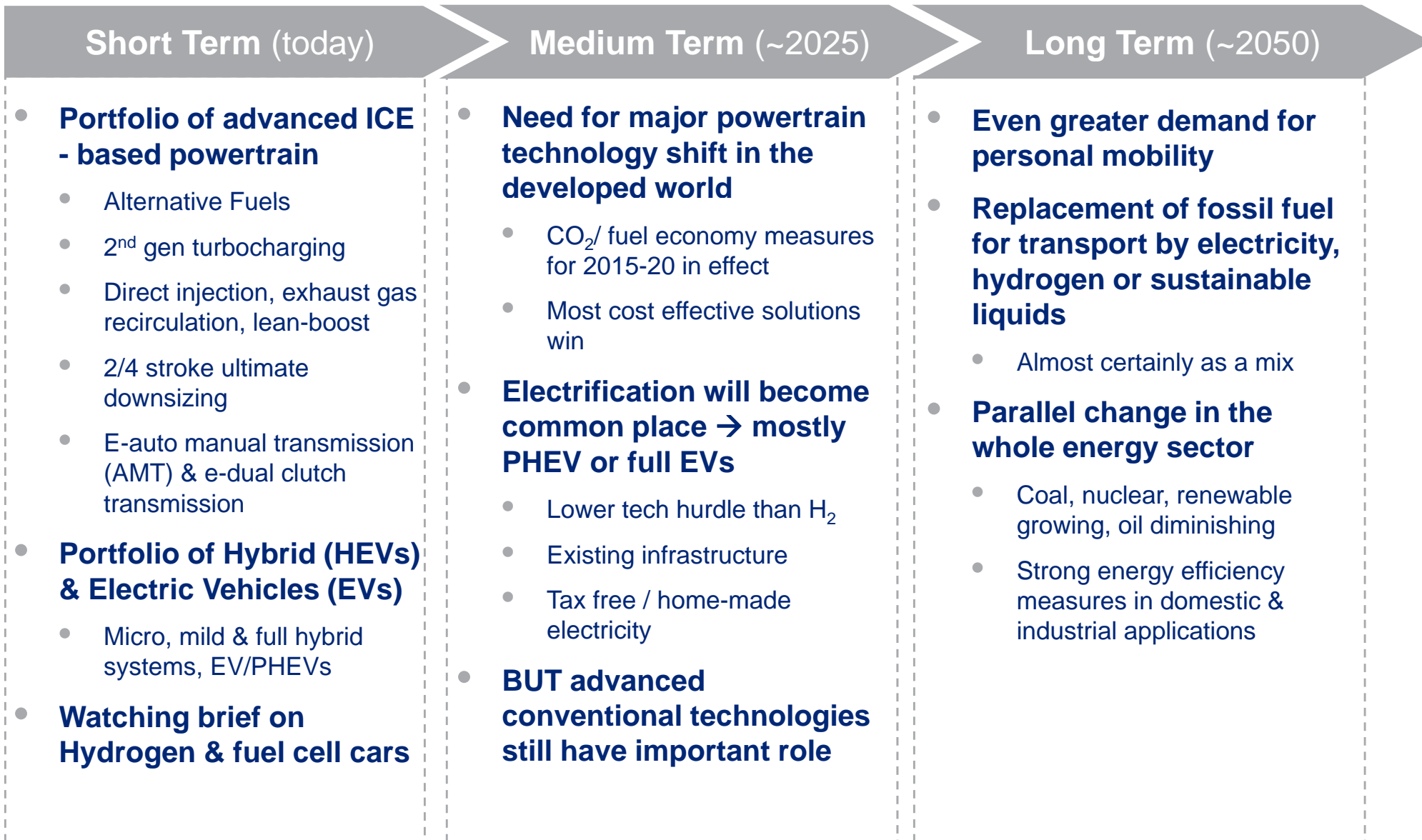
CVT/IVT are set to grow in America and Japan, while EU prefers DCTs



Continuous evolution of technology: No obvious outright winning technology



Powertrain Roadmap



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- Global trends and themes
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 - **Consequences and opportunities for lubricants and fuels**
 - Conclusions

Introduction of advanced powertrains provides opportunities for lubricant, fuel and additive innovation



Gasoline

- Engine downsizing
- Lean operation
- Ethanol blends
- Valve train complexity
- Turbo boosting/ supercharging
- New materials

EBDI[®] “Extreme Downsizing”



Diesel

- Engine downsizing
- Improved fuel injection equipment
- Exhaust gas recirculation
- Aftertreatment for NOx/ PM control
- New materials

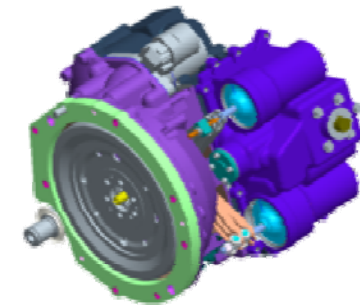
NZED “Diesel for Tier 2 Bin 2”



Transmissions & Hybrid

- Dual clutch transmissions
- Advanced automatic Transmissions
- Start/stop & micro hybrid
- Full hybrid & PHEV
- New materials
- Submerged electrical parts

eDCT[™] “Efficient Automation”



Consequences and opportunities (1/3): Engine lubricants



Engine Lubricants Consequences & Opportunities

Fuel Economy

- Low viscosity and low friction fluids that deliver sustained, significant fuel economy contribution, without compromising engine durability

Emissions System Compatibility

- Delivery of long term engine durability despite pressure to reduce Sulphur, Phosphorus and Ash in the lubricant

Varying duty cycle engine protection

- Downsizing and boosting – higher thermal stress on a smaller oil charge
- Hybrids – long life oils in engines that run intermittently, infrequently, or with a very different duty cycle

New Materials

- Conventional additives might not be optimised for new materials (e.g. DLC)

Consequences and opportunities (2/3): Transmission Lubricants



Transmission Lubricants Consequences & Opportunities

Stepped Automatic Transmissions

- More gears, higher power density
- Fluid solutions to reduce torque convertor and actuation losses, and to prevent fatigue

DCT

- Wet clutch performance with manual transmission performance
- Compatibility with submerged electronics and seal materials
- Fluids to deliver high torque transfer combined with appropriate clutch friction characteristics

CVT

- Fluids optimised for future generations of CVT
- Lower viscosity, better air release, and electronics compatibility

Hybrids

- High performance fluids for future hybrid optimised transmissions
- High dielectric strength with excellent viscometric properties

Consequences and opportunities (3/3): Fuels



Fuels Consequences & Opportunities

Advanced Diesel Fuel Injection

- Intolerant to deposits → requires cleanliness additives to ensure long term power, fuel economy and emissions compliance
- Enhanced lubricity additives to cope with higher pressures and new materials
- Higher injector operating temperatures → potential need for new bulk fuel stability additives

Biodiesel

- 1st generation → Additives for stability, cleanliness and cold flow properties
- 2nd generation → Potentially specific solutions for cold flow and continued treatment with lubricity additives

Fuel Economy/ Emissions Systems

- Fuel borne catalysts for diesel particulate filter regeneration may offer better compromise on fuel economy/DPF performance

Consequences and opportunities: Issues and concerns



Issues & Concerns

Fuel Economy

- Future may require mandatory delivery of FE over vehicle lifetime
- Fluids delivering FE will become an integral part of the delivery system

How do we ensure the correct fluids are used over the vehicle lifetime ?

Emission System Compatibility

- Need to formulate for
 - Long oil life
 - High fuel economy
 - Hardware durability
 - Emissions system compatibility
- Requires compromise

How do we deliver the best compromise for stakeholders ?

Co-development & value generation

- Formulating for advanced hardware is expensive
- Increasing requirement for co-development by fluid & hardware developers
- Need for early engagement

How do we ensure the system value of these high value fluids is shared fairly between stakeholders ?

- Global trends and themes
- Technology roadmapping
- Consequences and opportunities for lubricants and fuels
- **Conclusions**

- The principal drivers for hardware evolution to 2030 will be emissions containment and fuel economy improvements driven by the demand for GHG reduction
- Technology roadmapping studies indicate that hardware changes will occur incrementally, resulting in a mix of solutions with no obvious outright winners
- The predominant powerplant for the foreseeable future will be the ICE supported by increasingly sophisticated transmissions
- Performance challenges offered by the introduction of advanced hardware will provide opportunities to create value for fluid developers, marketers and OEMs
- Early collaboration and hardware/fluid co-development will be essential to ensure maximum value and benefit to all stakeholders