An OEM's Perspective on Fuel Economy Technologies and Future Sustainability

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Go Further

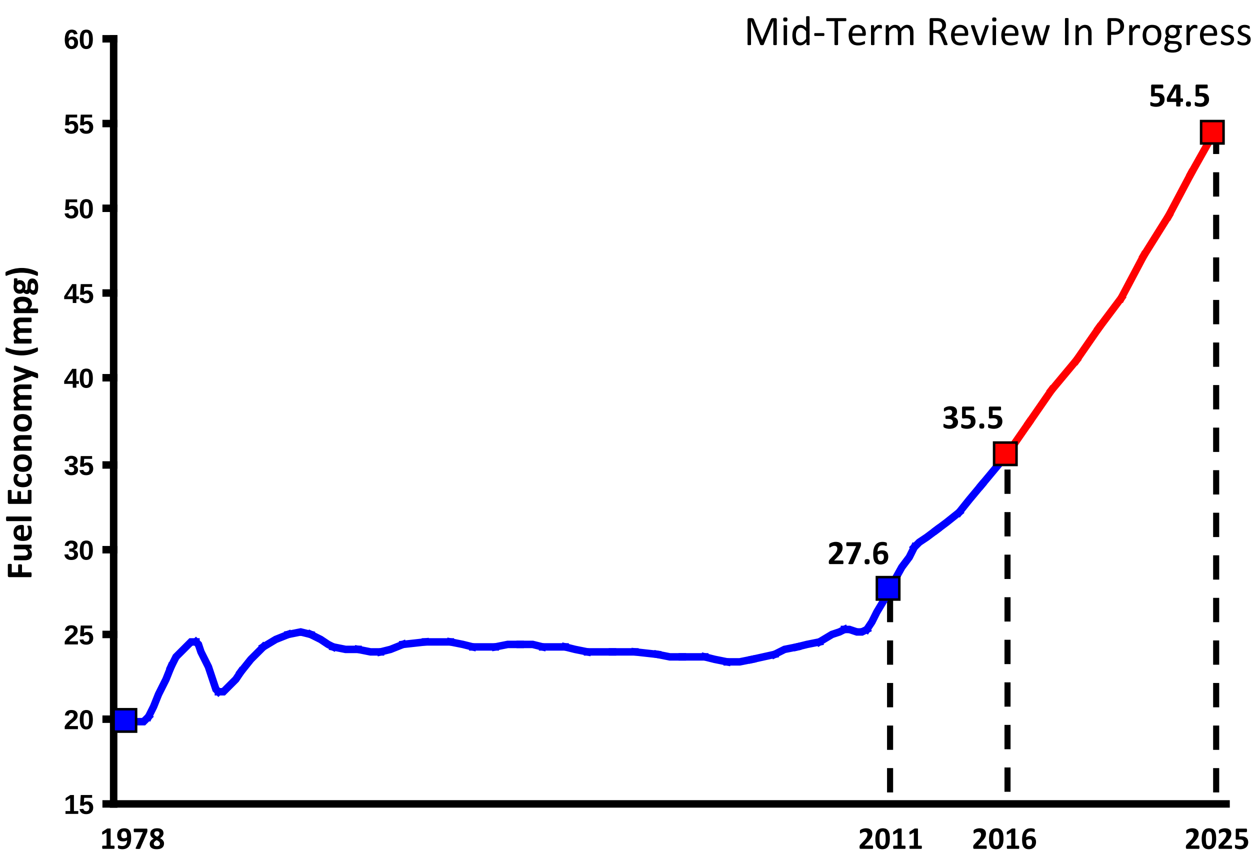
Automotive/Petroleum Industry Forum
"Fuel Economy - How Do We Get There?"
April 19, 2016
Dearborn, Michigan

Outline

- Current Regulations / Requirements
    - Fuel economy / CO_2
    - Balancing requirements
    - Technology costs / Customer value
- Sustainability – Well-to-Wheels - Beyond Regulations
- Sustainability – Multiple Opportunities
    - Vehicle
    - Fuel
    - Usage
- Summary / Conclusions

U.S. Fuel Economy Regulations

U.S. CAFE Requirements

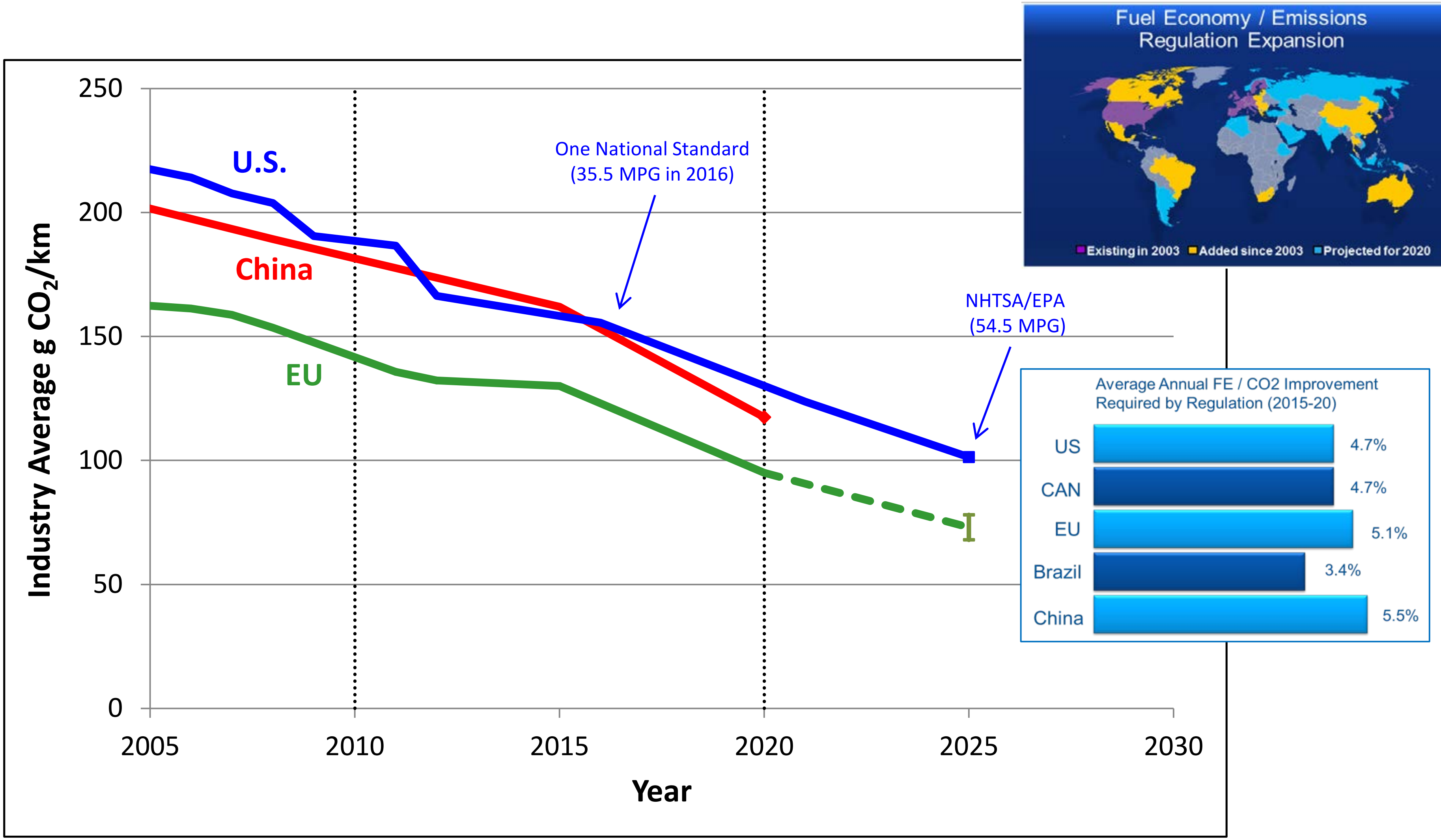


- By 2011, Fuel economy increased ~40% since the beginning of CAFE
- CAFE requires a further 30% uplift by 2016
- The 54.5 mpg target equates to more than a 95% increase over 2011

ONP = One National Program

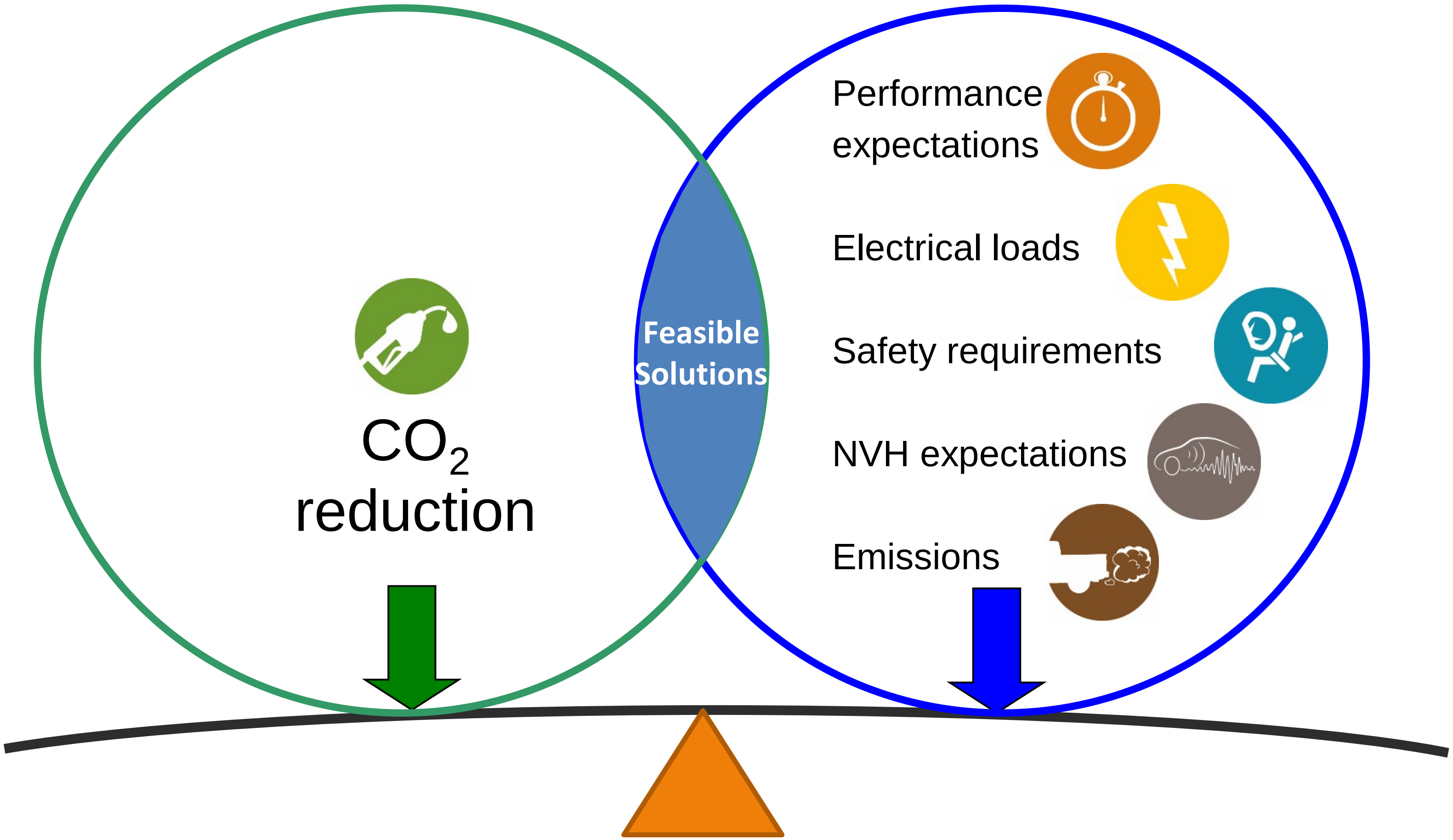
Compared to 2011, CAFE needs to increase by more than 95% to reach 54.5 MPG by 2025… significant year-over-year improvements are required.

Global CO_2 Regulations



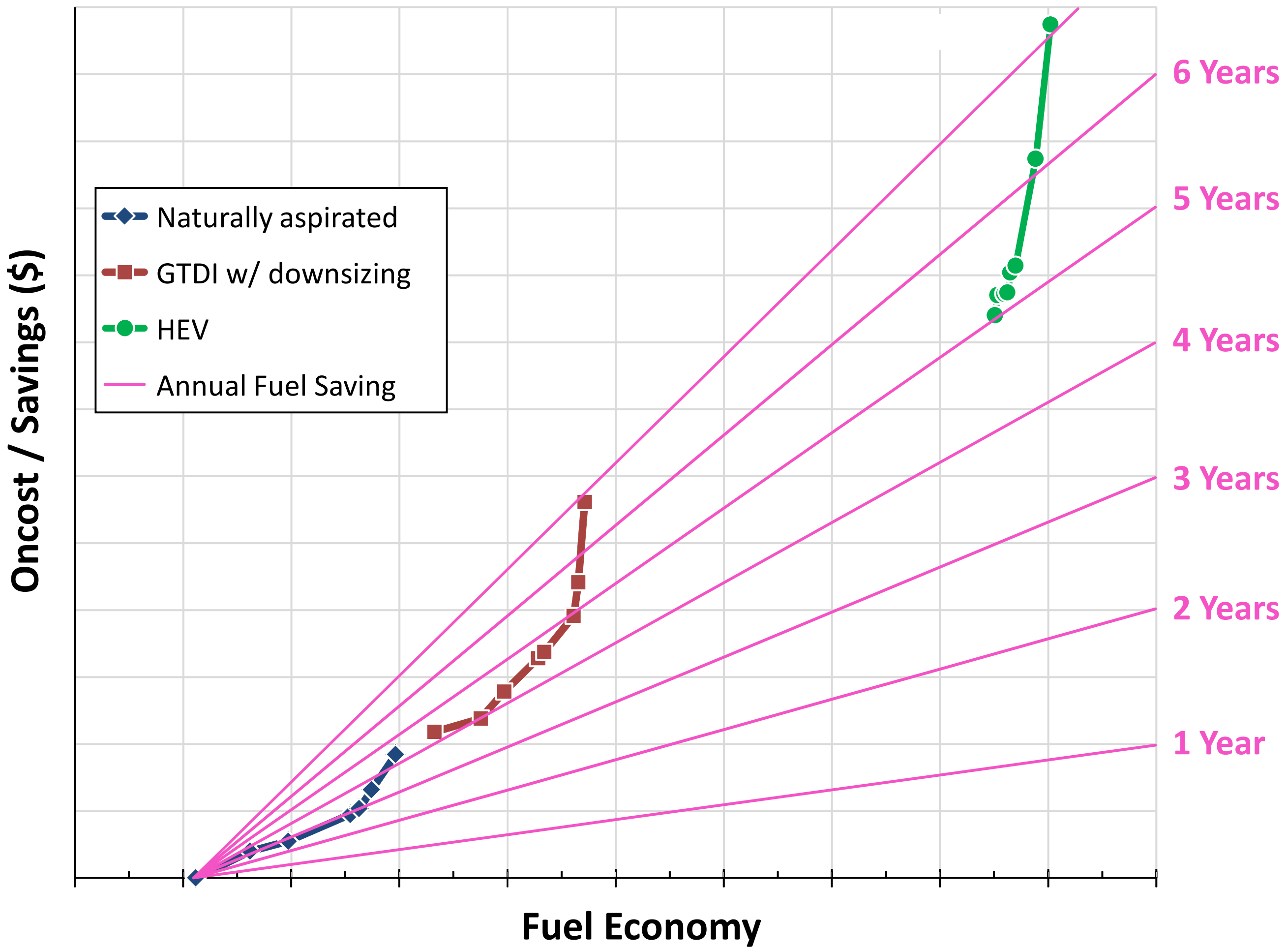
The current global regulations require aggressive year over year CO_2 reduction requiring a very rapid pace of advanced vehicle technologies development.

Balancing Competing Requirements



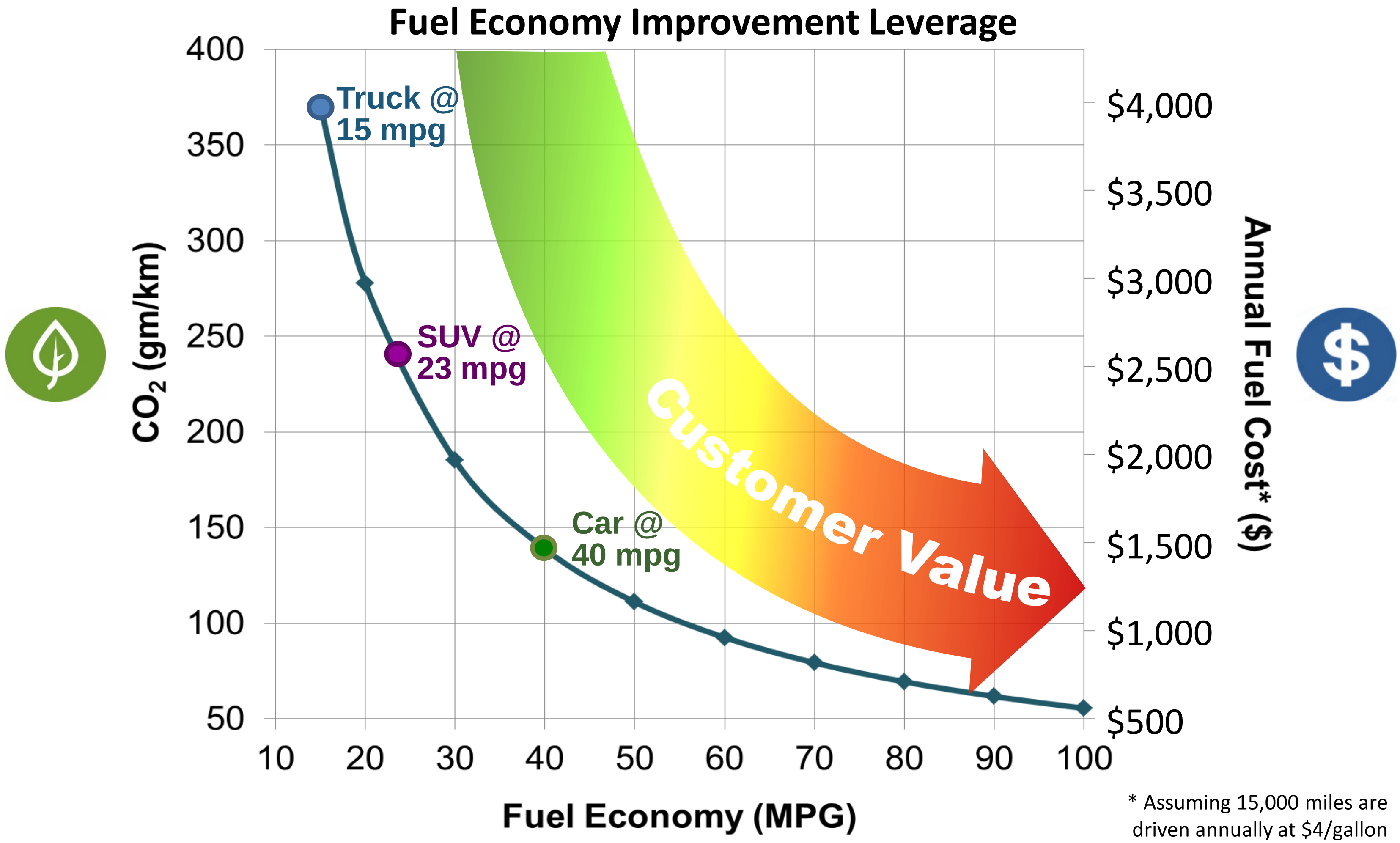
Balancing CO_2 reduction requirements and increasing customer expectations constrains the feasible solutions zone, requiring an integrated approach.

Increasing Technology Costs



Though costs are additive, technology benefits are not in most cases, and the costs increase much more rapidly than the fuel economy benefits.

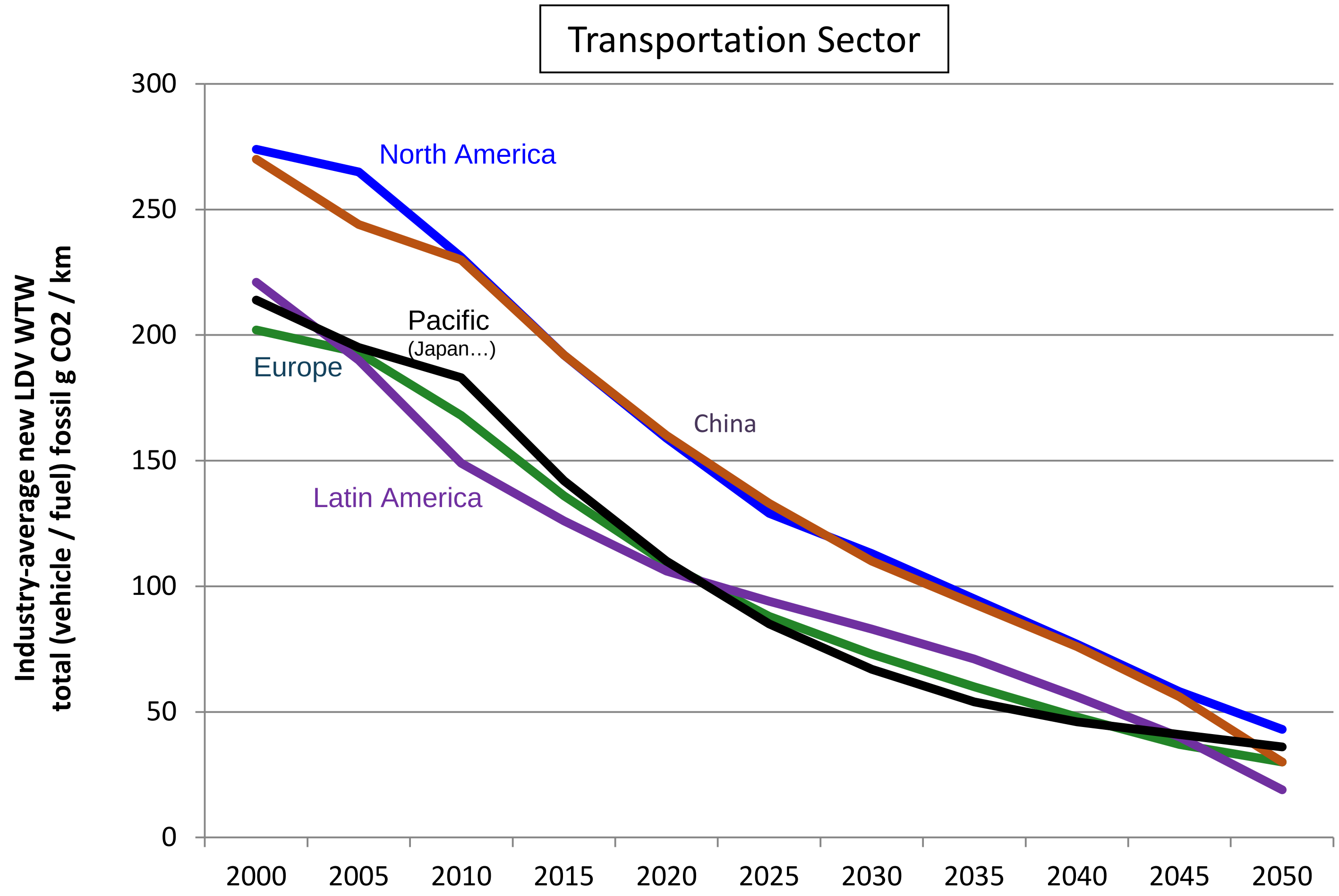
Decreasing Fuel Economy Savings



* Assuming 15,000 miles are driven annually at $4/gallon

As Fuel Economy improves, customer fuel savings decreases, and the willingness to pay for further incremental increases diminishes…while product costs increase.

Sustainability – CO_2 Glidepath – Well-to-Wheels



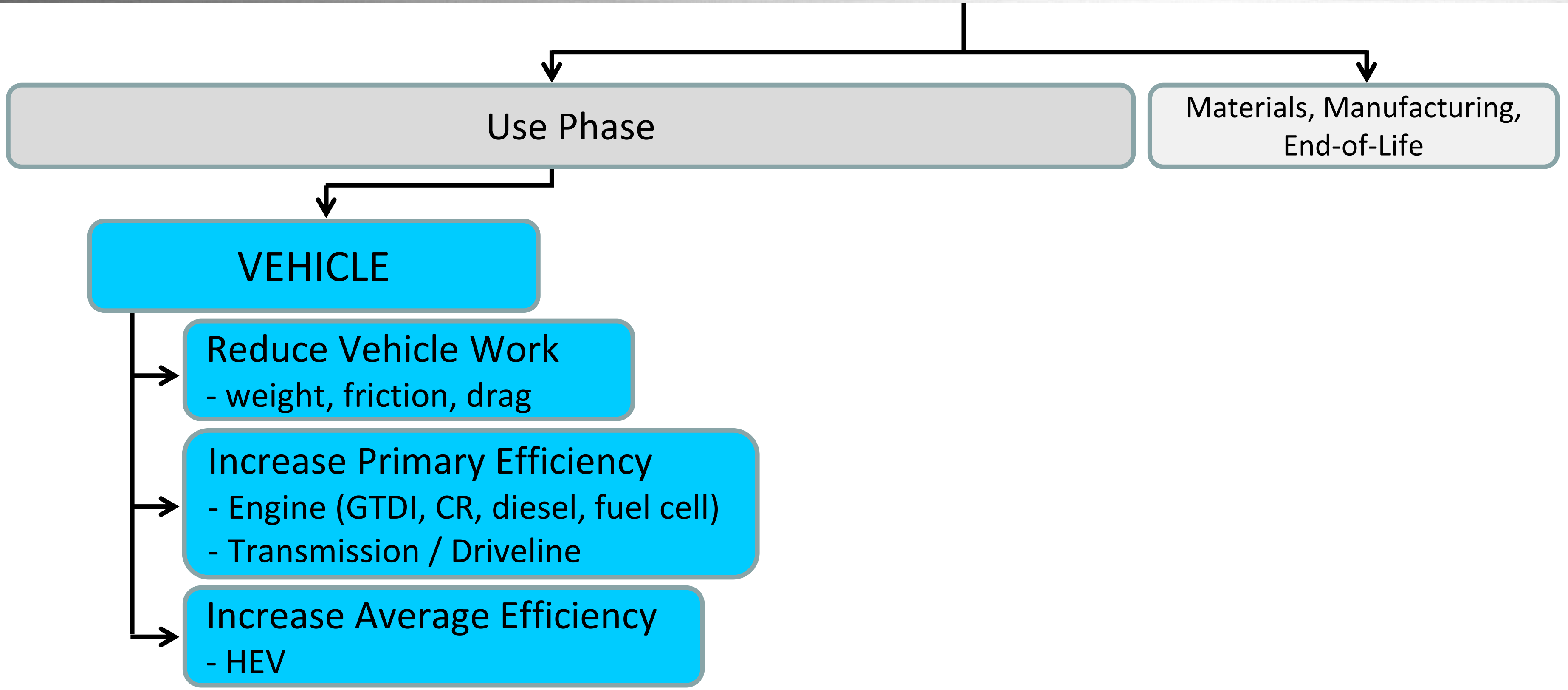
Beyond vehicle-only (Tank-to-Wheels) regulations, stabilization of CO_2 concentrations in the atmosphere at 450ppm will require large reductions in emissions, for all sectors.

Sustainable Transportation – Areas of Focus

- Use Phase
  - VEHICLE
    - Reduce Vehicle Work
      - weight, friction, drag
    - Increase Primary Efficiency
      - Engine (GTDI, CR, diesel, fuel cell)
      - Transmission / Driveline
    - Increase Average Efficiency
      - HEV
  - USAGE
    - Reduce Miles Travelled
    - Smart Mobility Technologies
  - FUEL
    - Properties (Octane, etc.)
    - Liquid Fuels
    - Gaseous & Liquefied Fuels
    - Electricity
    - Hydrogen
- Materials, Manufacturing, End-of-Life

Sustainable LDV transportation requires actions on multiple fronts: Vehicle | Usage | Fuel

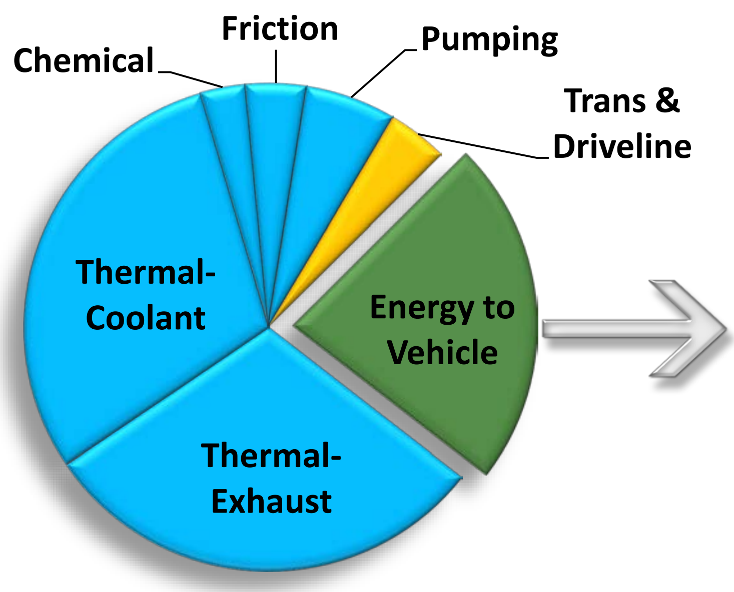
Sustainable Transportation – Areas of Focus



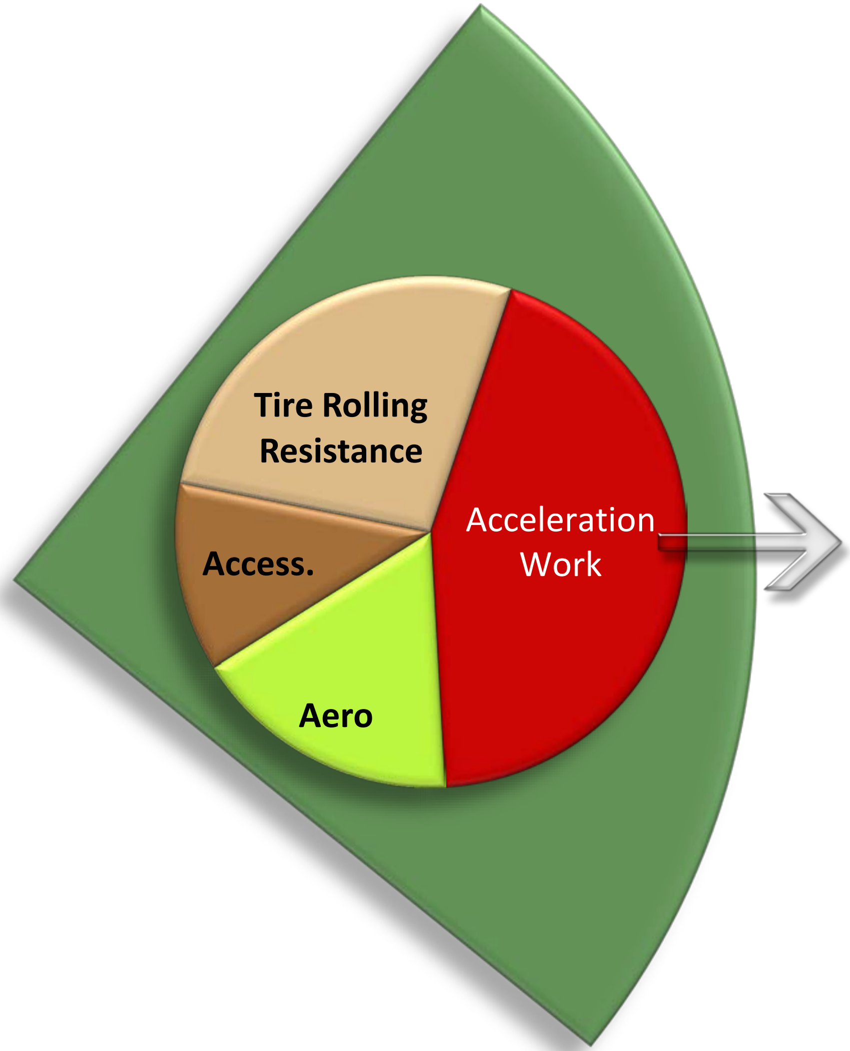
Sustainable LDV transportation requires actions on multiple fronts: Vehicle | Usage | Fuel

Conventional P/T & Vehicle Energy Distribution

Powerpack Energy Available

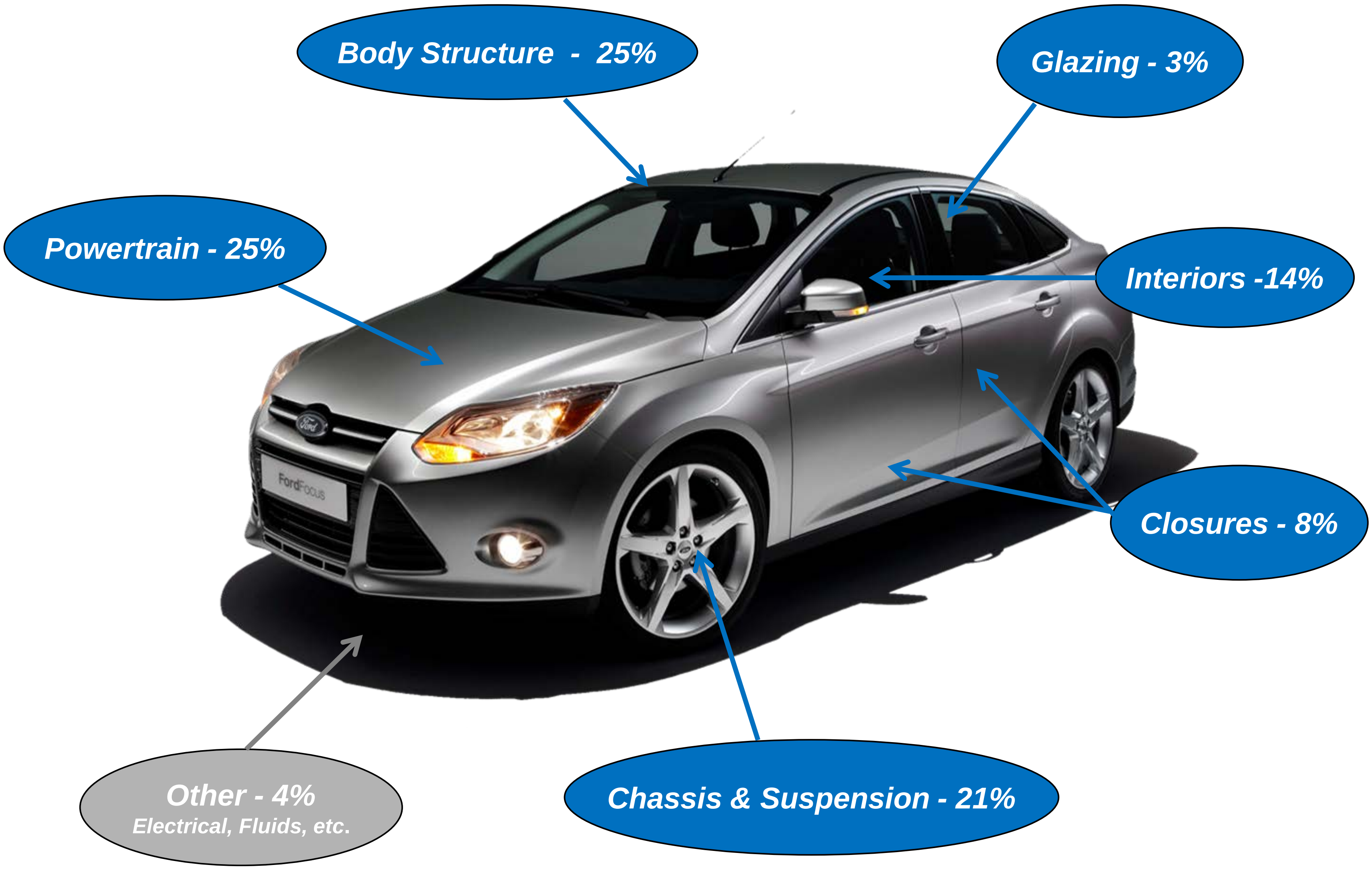


Energy Consumed



Vehicle technologies continue to be developed to increase the fraction of converted energy available for propulsion, by improving efficiency and reducing system losses.

Weight Distribution – Typical Sedan



Body structures, Chassis, and Powertrain provide the most significant opportunities for weight reduction.

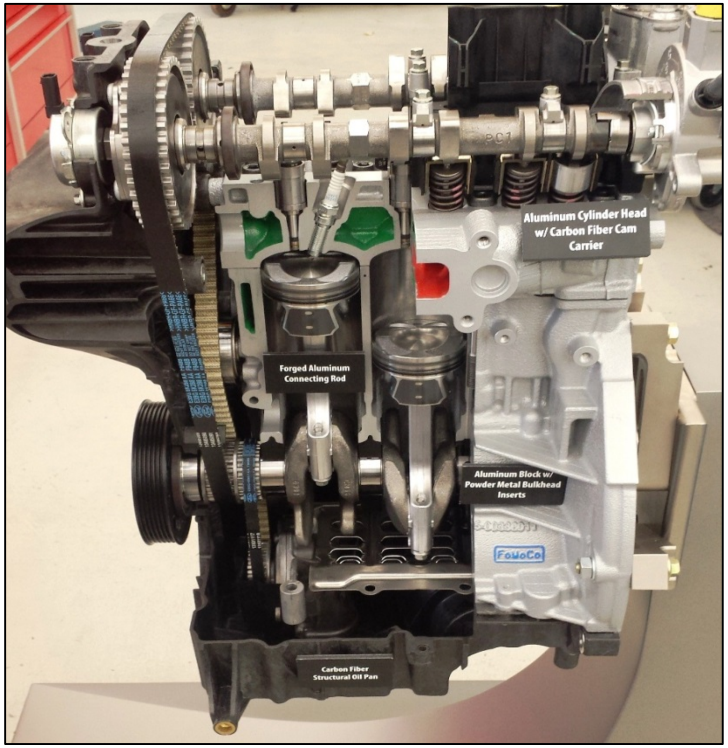
Lightweighting - Vehicle

Go Further

Although most of the weight reduction announcements have focused on advanced materials for the vehicle body and chassis…

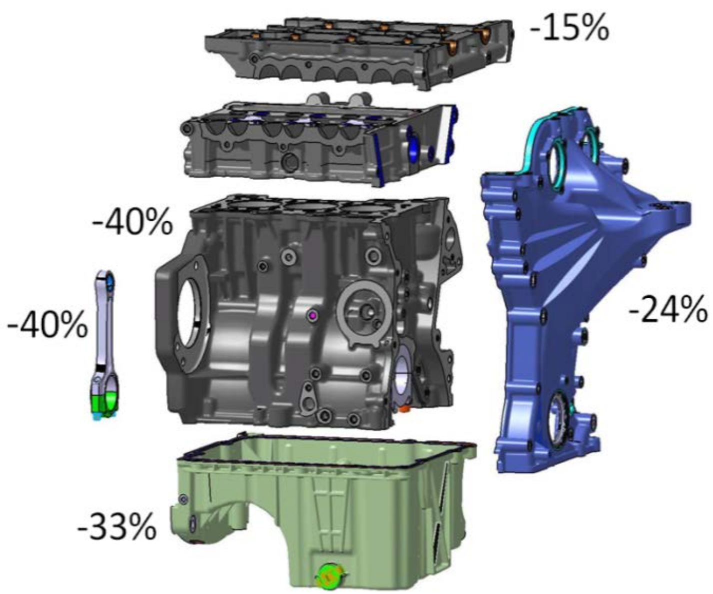
Engine Weight Reduction

1.0-liter EcoBoost Concept



Goal:

Target key engine component areas to maximize weight savings and ongoing improvements in EcoBoost power density.

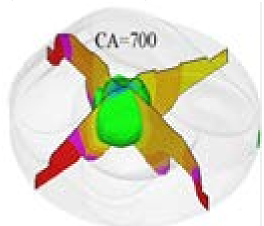


…incorporating innovative ideas with future materials and technologies into the core engine structure can also offer substantial weight reduction opportunity.

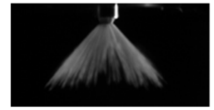
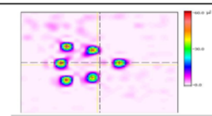
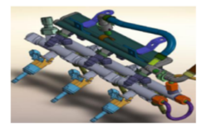
Advanced S.I. Engine Technologies

Combustion

- Improved fuel economy
- Reduced NOx emissions
- Advanced direct injection systems required

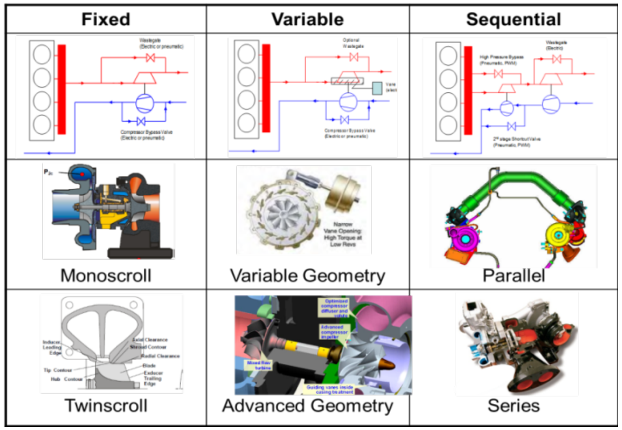


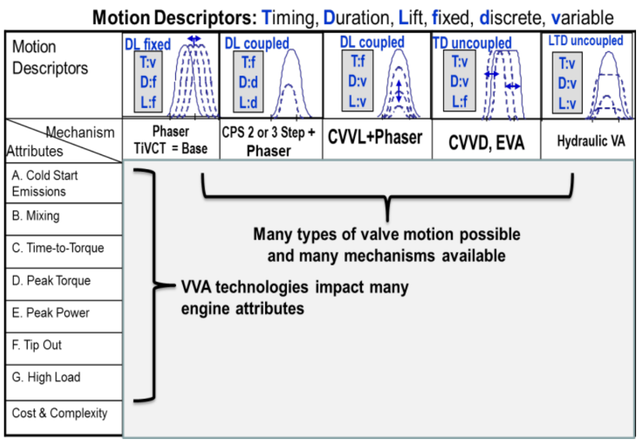
Fuel Injection

Piezoelectric Direct Injection	
Multi-Hole Solenoid Direct Injection at Increased Fuel Pressure	
PFI + Solenoid DI	

Boosting Systems

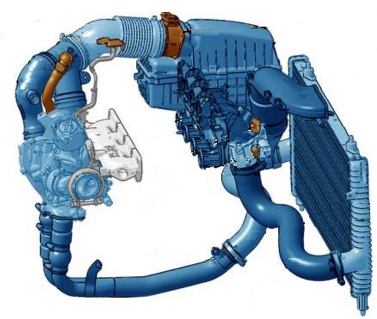
- Improved power density (down sizing)
- Improved transient response (fun to drive)
- Boost Requirements to drive wide range Cooled EGR





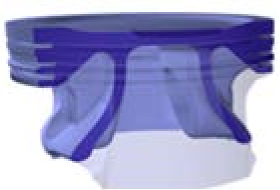
Variable Valvetrain

- Improved breathing efficiency
- Improved transient response
- Variable timing, lift and duration



Cooled EGR

- Improved combustion efficiency
- Decreased Pumping Work
- Knock Mitigation



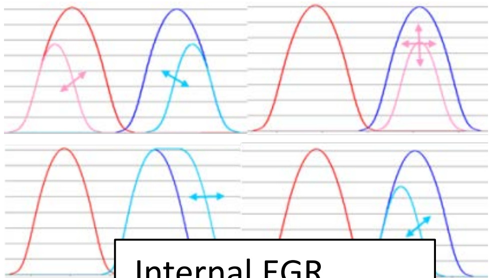
Power Cylinder Systems

- Reduction of power cylinder mass and inertia
- Advanced piston skirt coatings
- Low tension ring packs

Advanced technologies will extend the viability of internal combustion engines, addressing the various physical effects (thermal efficiency, pumping, friction, etc.).

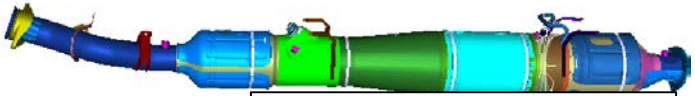
Advanced Diesel Engine Technologies

Variable Valve Actuation



Internal EGR
Charge Motion
Atkinson / Miller

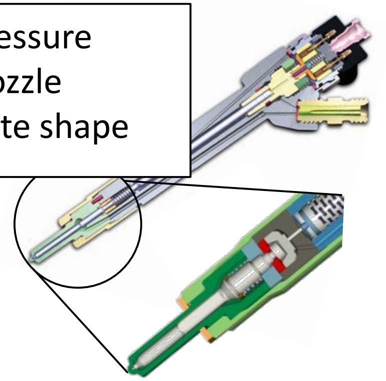
Aftertreatment



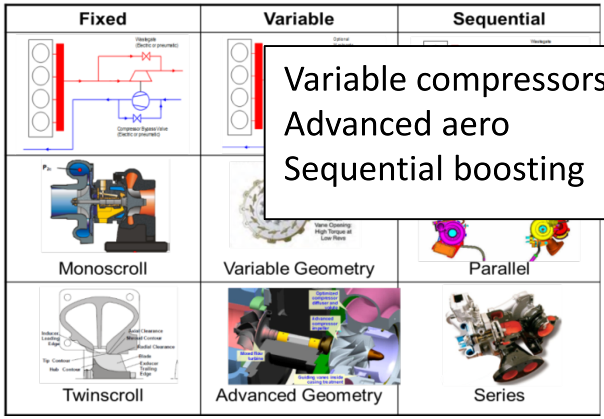
SCR Filters
Passive NOx storage
HC storage catalysts
Ammonia injection

Fuel System

Pressure
Nozzle
Rate shape



Turbocharging



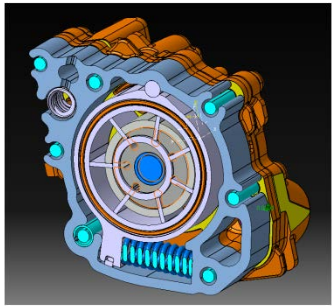
Variable compressors
Advanced aero
Sequential boosting

Engine Controls

Air path control
A/T control
Comb feedback
Virtual sensing
OBD

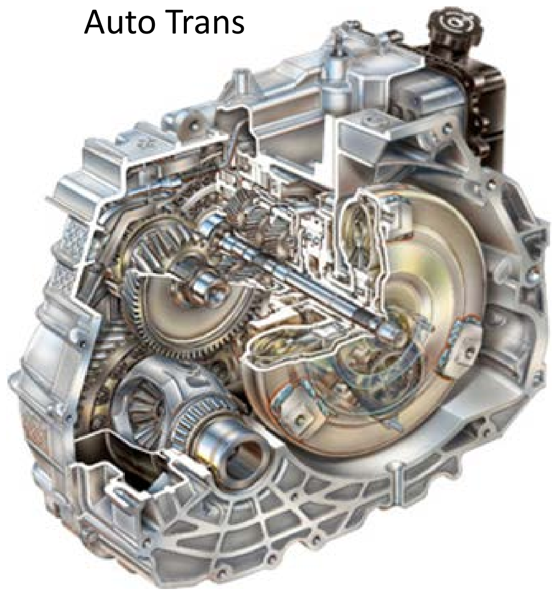
Similarly in Diesel engines, key enablers to CO_2 and emissions reductions include technology advances in fuel systems, boosting, variable valve actuation, aftertreatment and controls.

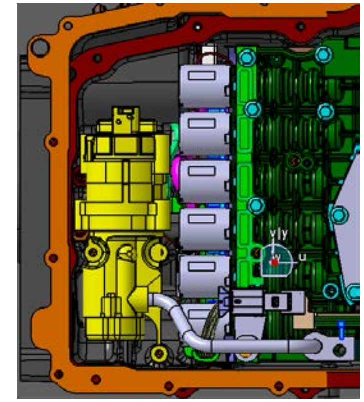
Transmission & Driveline Efficiency



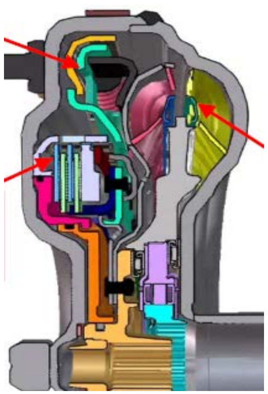
Variable Displacement
Vane Pump

8+-Speed Planetary
Auto Trans



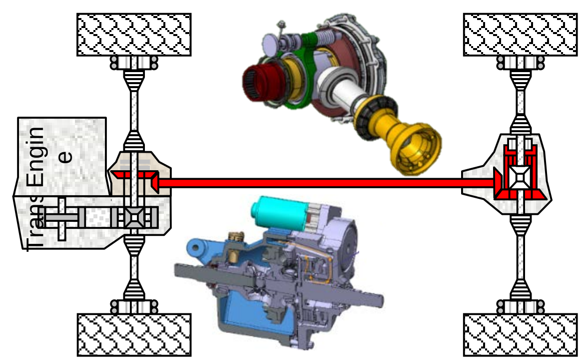


Integrated Stop-Start
E-pump



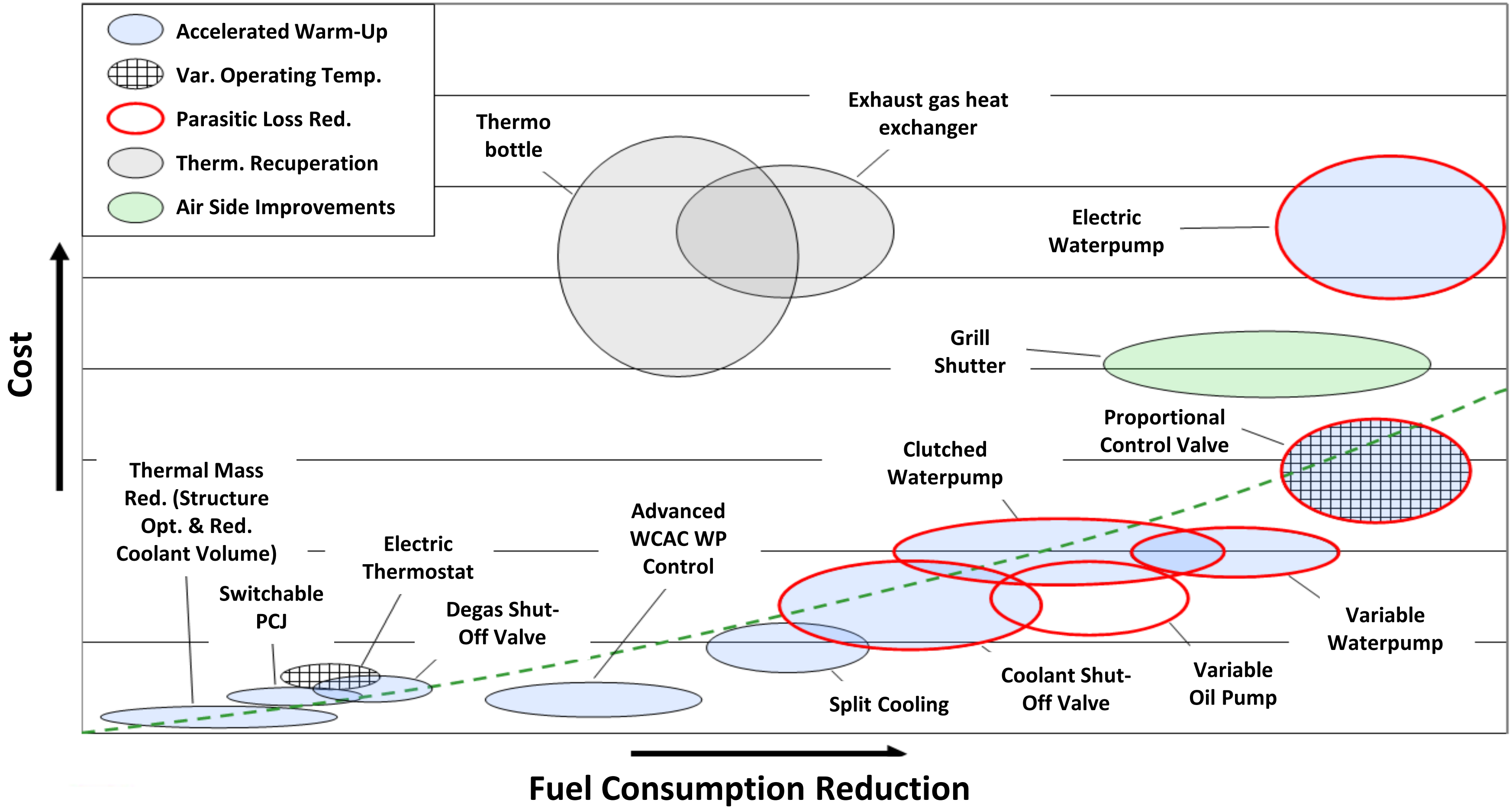
Next Gen
Torque Converter

Automated AWD Disconnect



Transmission efficiency improvements also include clutches, gears, bearings, shafts…along with technologies targeting reduced driveline losses.

Thermal Management Opportunities

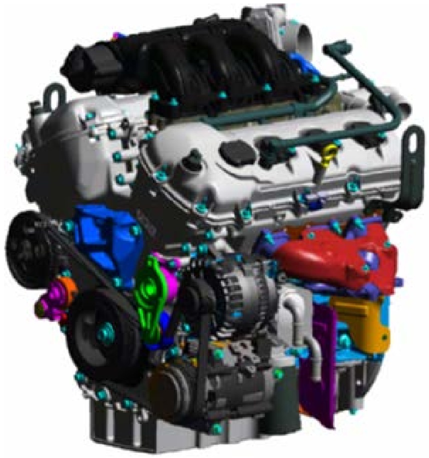


Thermal Management, Warmup, and Energy Recovery technologies will play a more significant role in helping achieve aggressive future targets, without compromising customer needs.

Opportunities with Lubricants

Near Term

- Gasoline Engine Oil (GF-6)
  - Fuel economy, LSPI Resistance & Hardware Durability
- Diesel Engine Oil (CK-4)
  - Improved fuel economy through lower viscosity without degrading durability

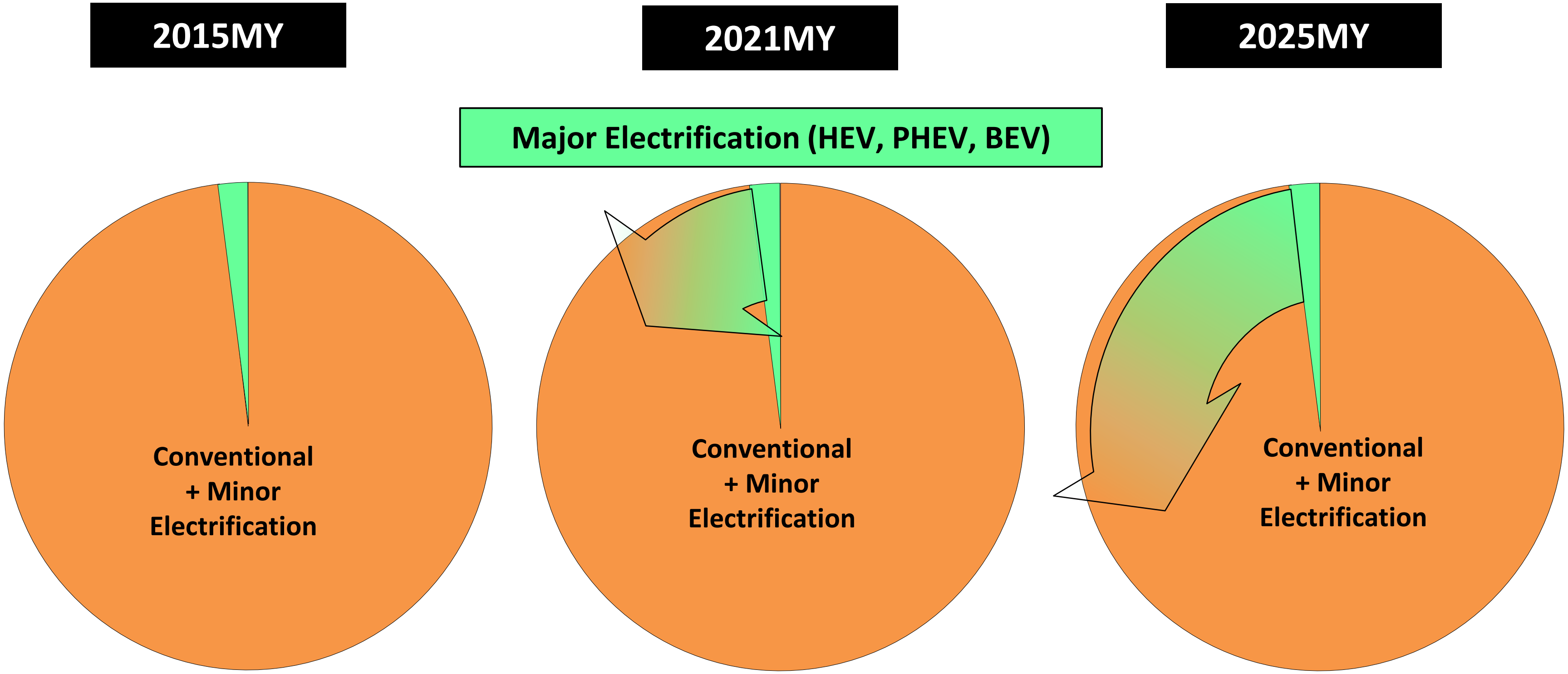


Medium and Longer Term

- Gasoline Engine Oil
  - Lower Viscosity novel base oil / additive chemistry (i.e. polyalkylene glycol, others)
- Diesel Engine Oil
  - Improved turbocharger performance (coking)
- Transmission & Driveline Lubricants
  - Lower viscosity lubricant for improved fuel economy through new formulations

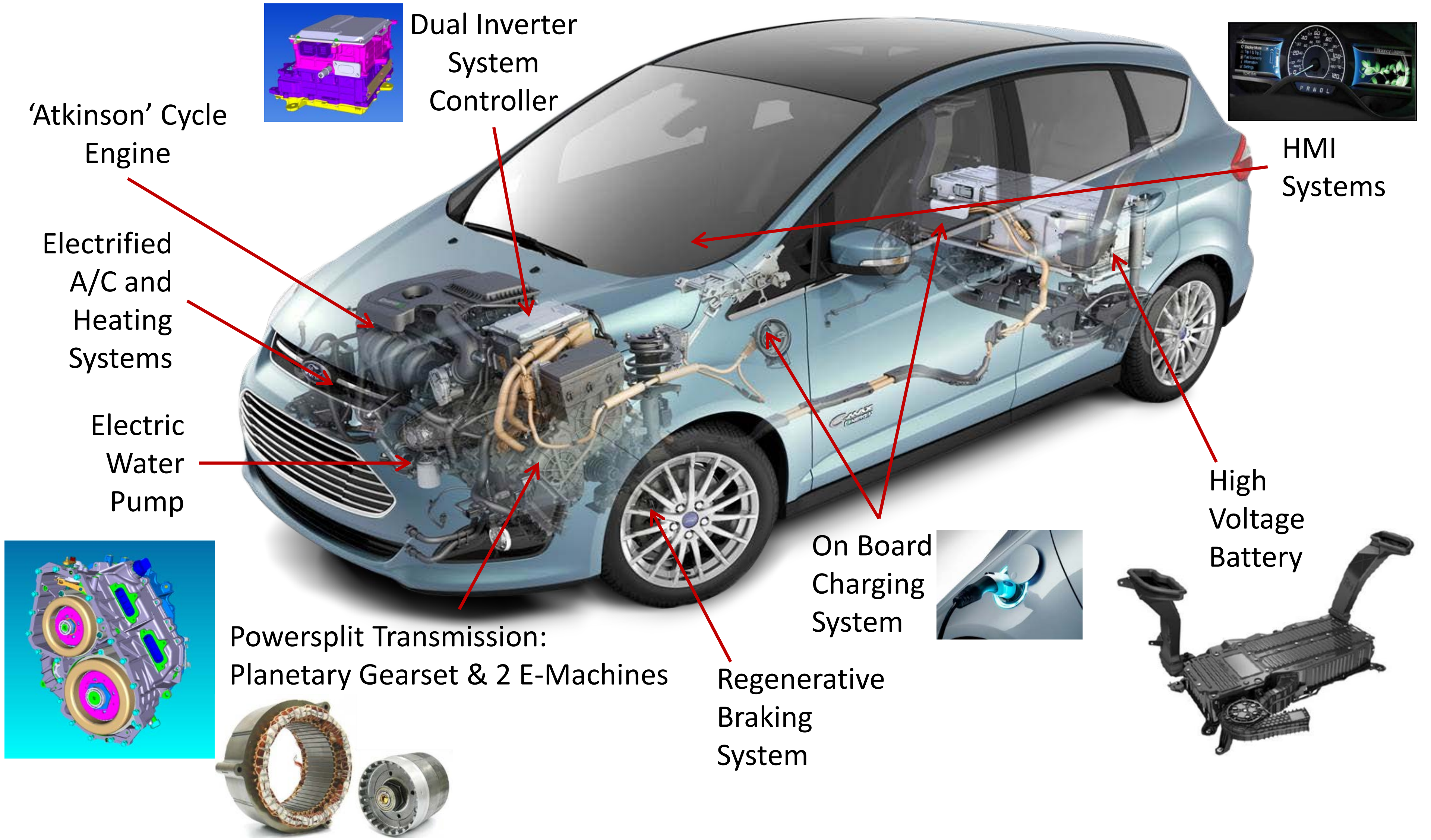
Continued development of powertrain lubricants offer further fuel economy improvements but other attributes, such as durability, cannot be compromised.

Electrification Projections



Conventional technology capability limits and stringent regulatory requirements will drive higher levels of electrification in order to achieve compliance over time.

Electrification Technologies



Focus is on further optimization of critical systems & technologies for improved performance, increased efficiency and reduced cost.

Electrification – Powertrain

Fusion HEV

C-Max PHEV

Focus BEV

Electrification technology development applies across a broad range of applications.

Fuel Cell Vehicles

MAIN TECHNICAL CHALLENGES

Durability
Cost reduction / commercialization

CO-OPERATIONS

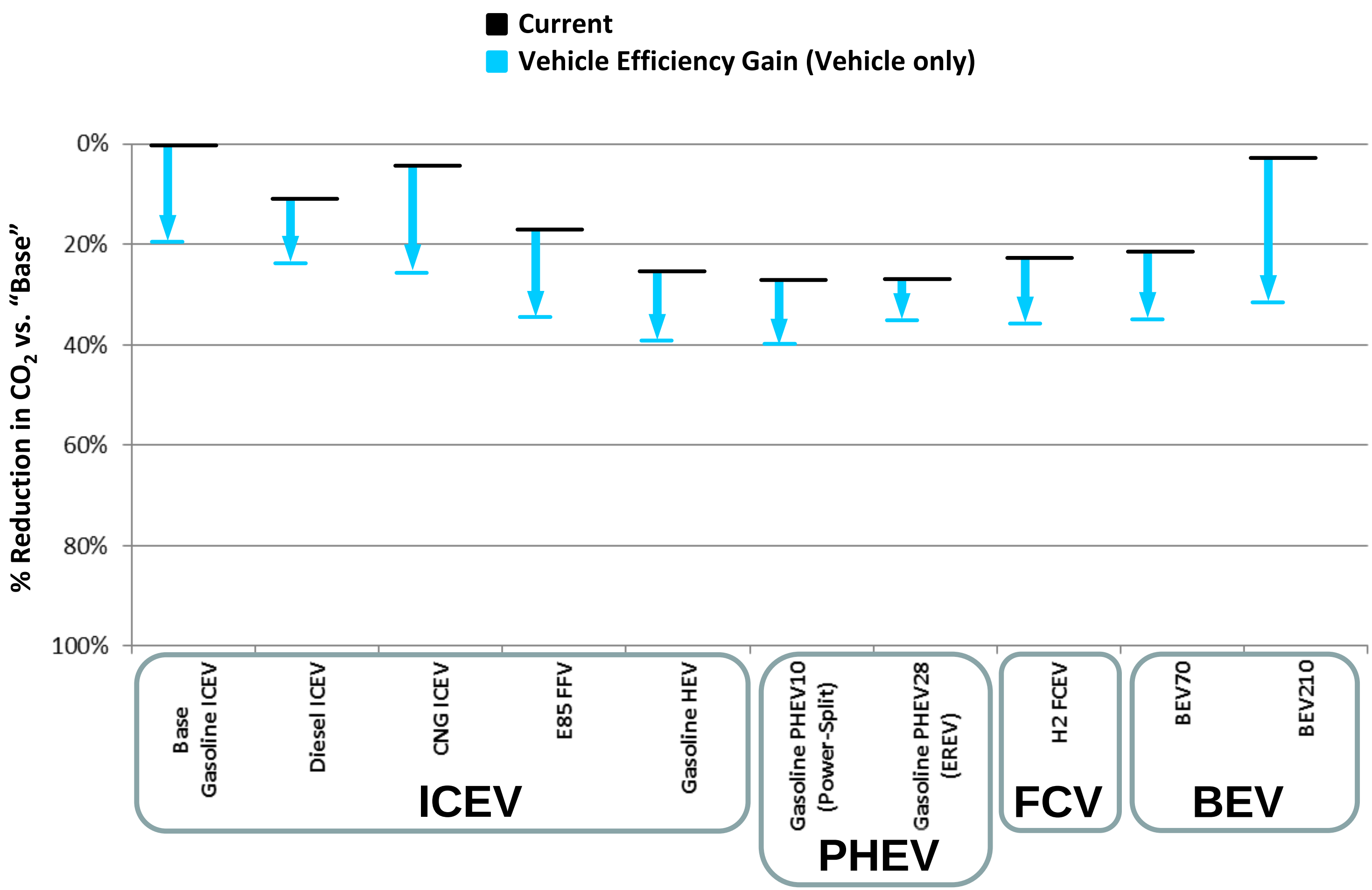
Automotive Fuel Cell Co-operation (AFCC)
Strategic Agreement with Daimler

INFRASTRUCTURE AND FUEL CELL VEHICLES

Development of Fuel Cell vehicles and the supporting hydrogen infrastructure must occur in parallel

Joint OEM development of next generation H2 fuel cell powertrain continues, with a target to transfer fuel cell technology from research to production.

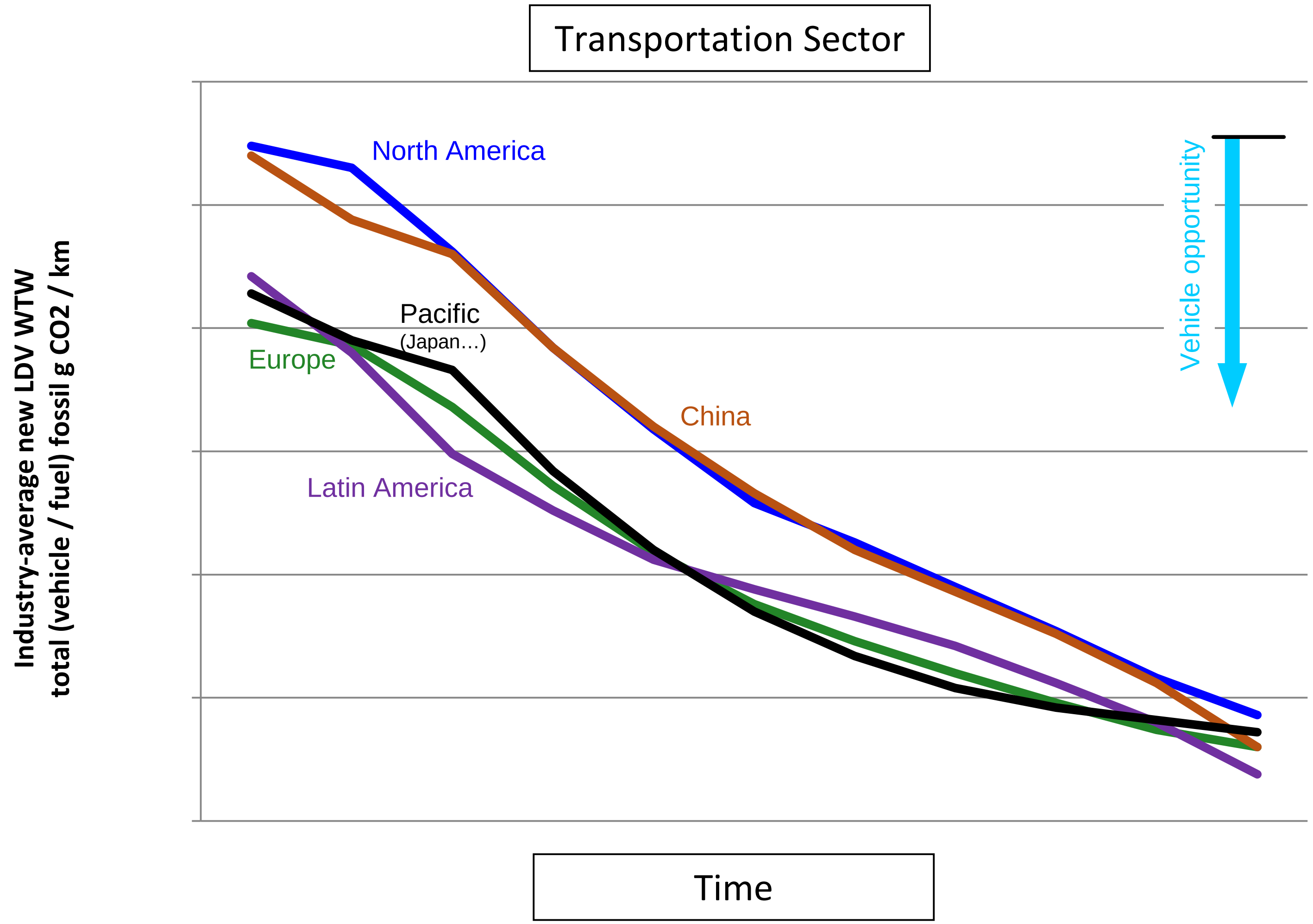
Vehicle Technologies / Current Fuels



Adapted from: DOE Hydrogen and Fuel Cells Program Record 14006, http://www.hydrogen.energy.gov/pdfs/14006_cradle_to_grave_analysis.pdf

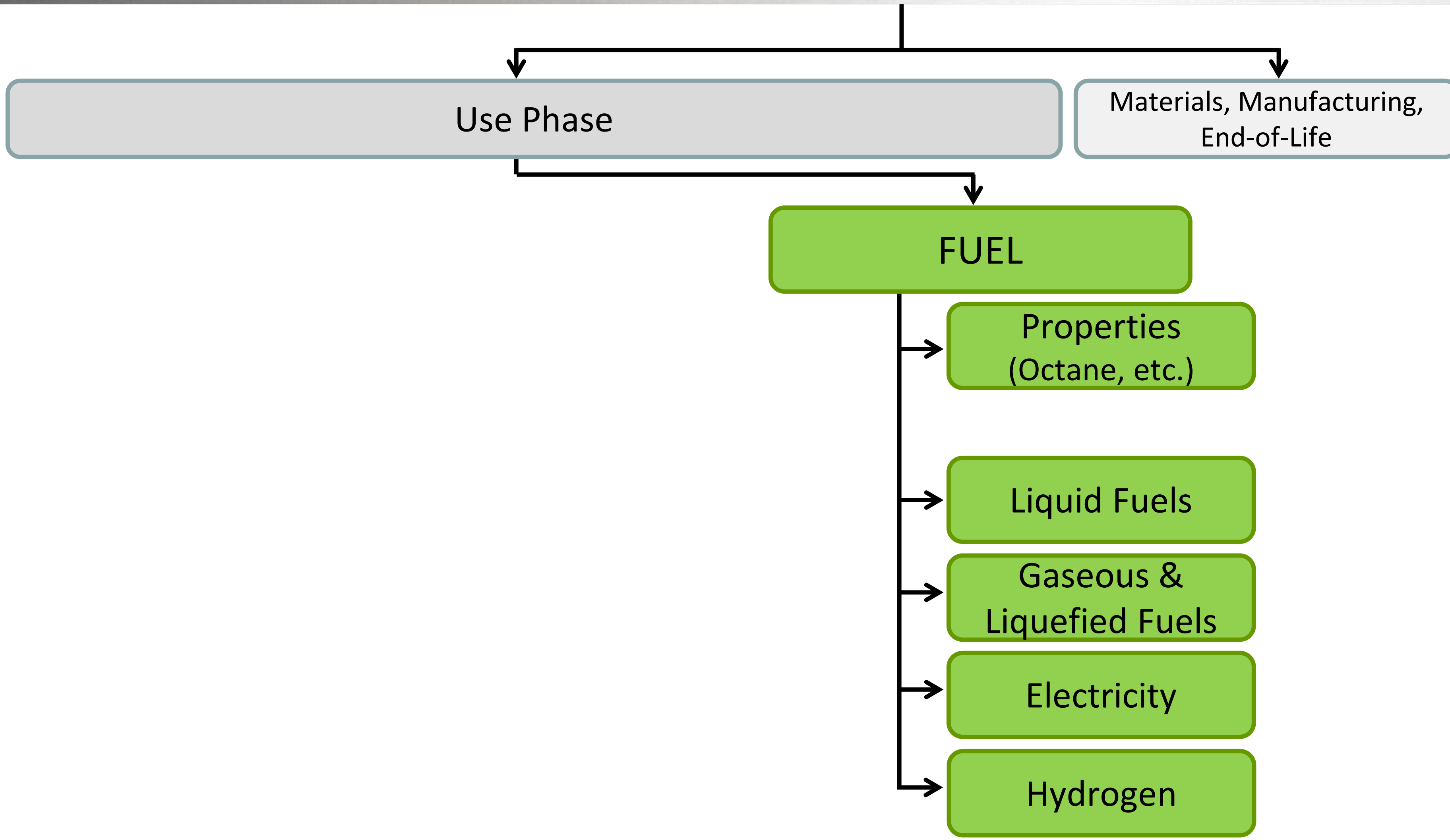
From a Well-to-Wheels standpoint, maximum CO_2 reduction based on vehicle-only technology improvements will be limited, irrespective of the pathway chosen.

Sustainability – CO_2 Glidepath – Well-to-Wheels



Even with the significant gains in vehicle operating efficiency, vehicle-only CO_2 reduction will fall short of future long-term needs.

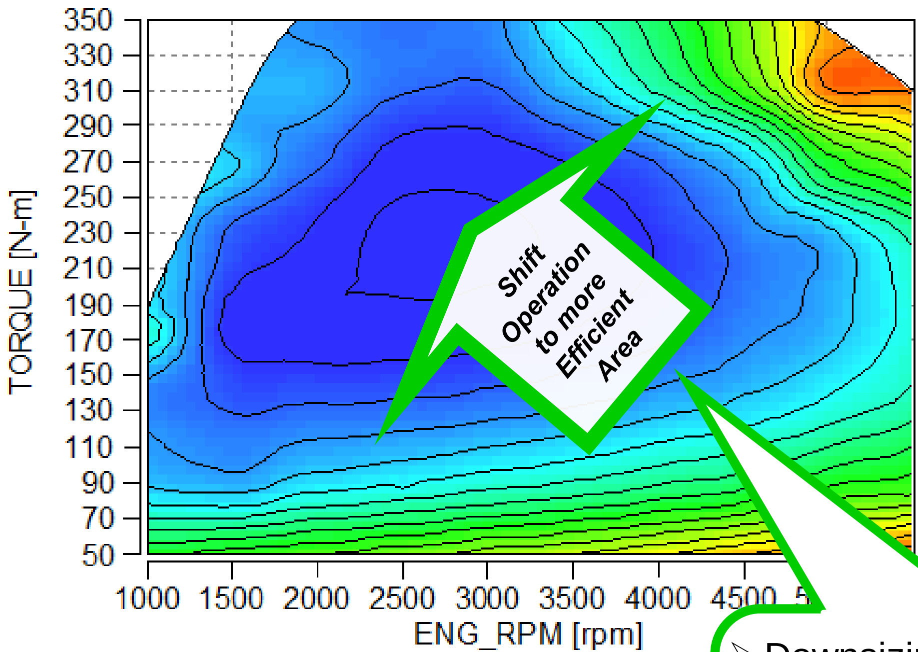
Sustainable Transportation – Areas of Focus



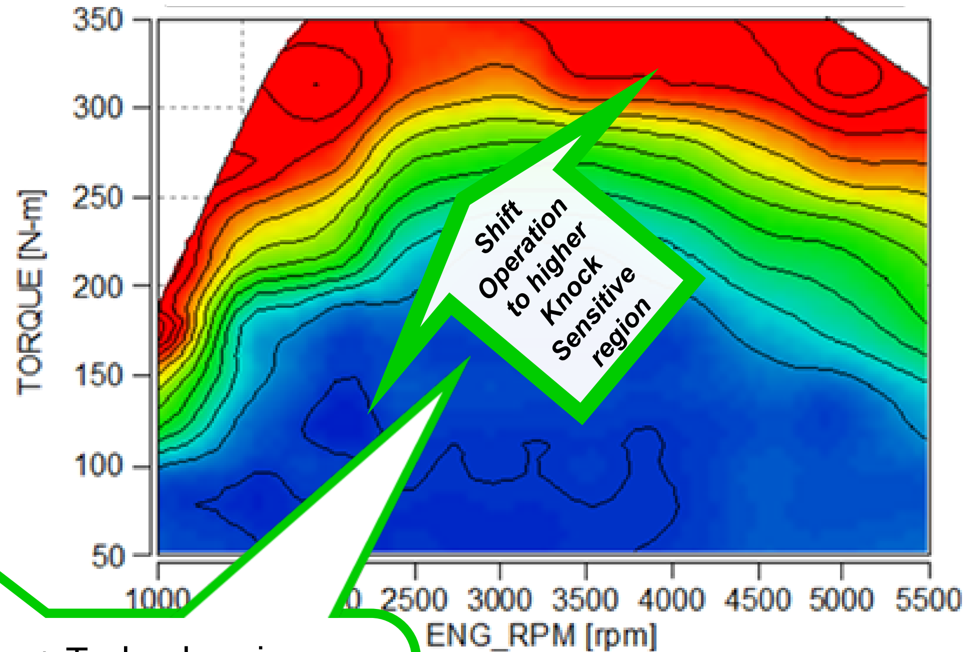
Sustainable LDV transportation requires actions on multiple fronts: Vehicle | Usage | Fuel

Higher Load / Lower Speed Operation - Knock Implications

Brake Thermal Efficiency



Knock Sensitivity (CA50)

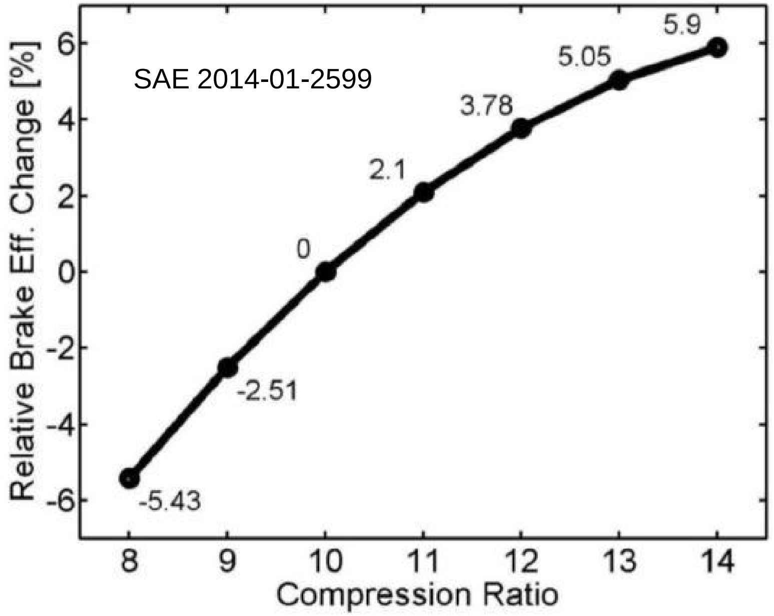


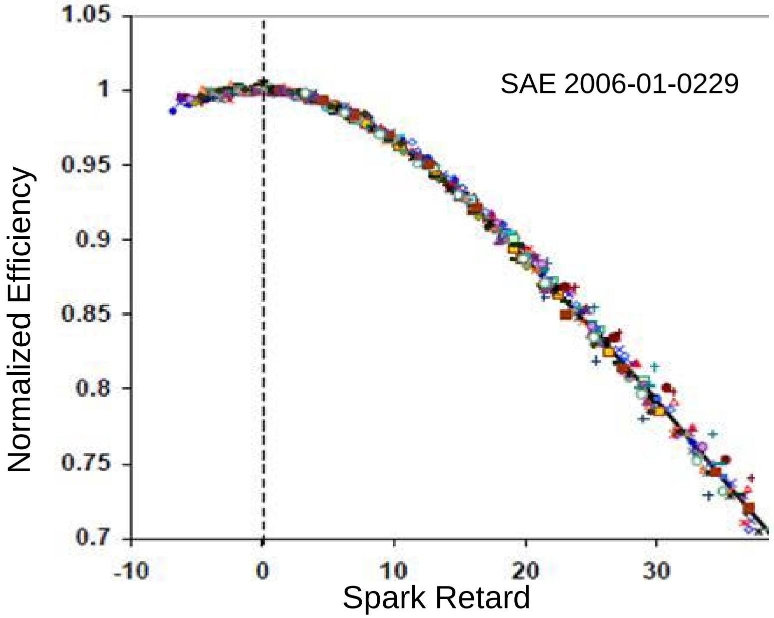
- Downsizing + Turbocharging
- Downspeeding (Longer Gearing)
- Cyl. Deactivation
- 7+ speed trans
- HEV powertrains

As advanced technologies shift operation to higher load / lower speed to improve efficiency…
…knock risk increases. Improved fuel properties can help address these constraints.

Higher Octane - Efficiency Improvement - Compression Ratio and Spark Timing

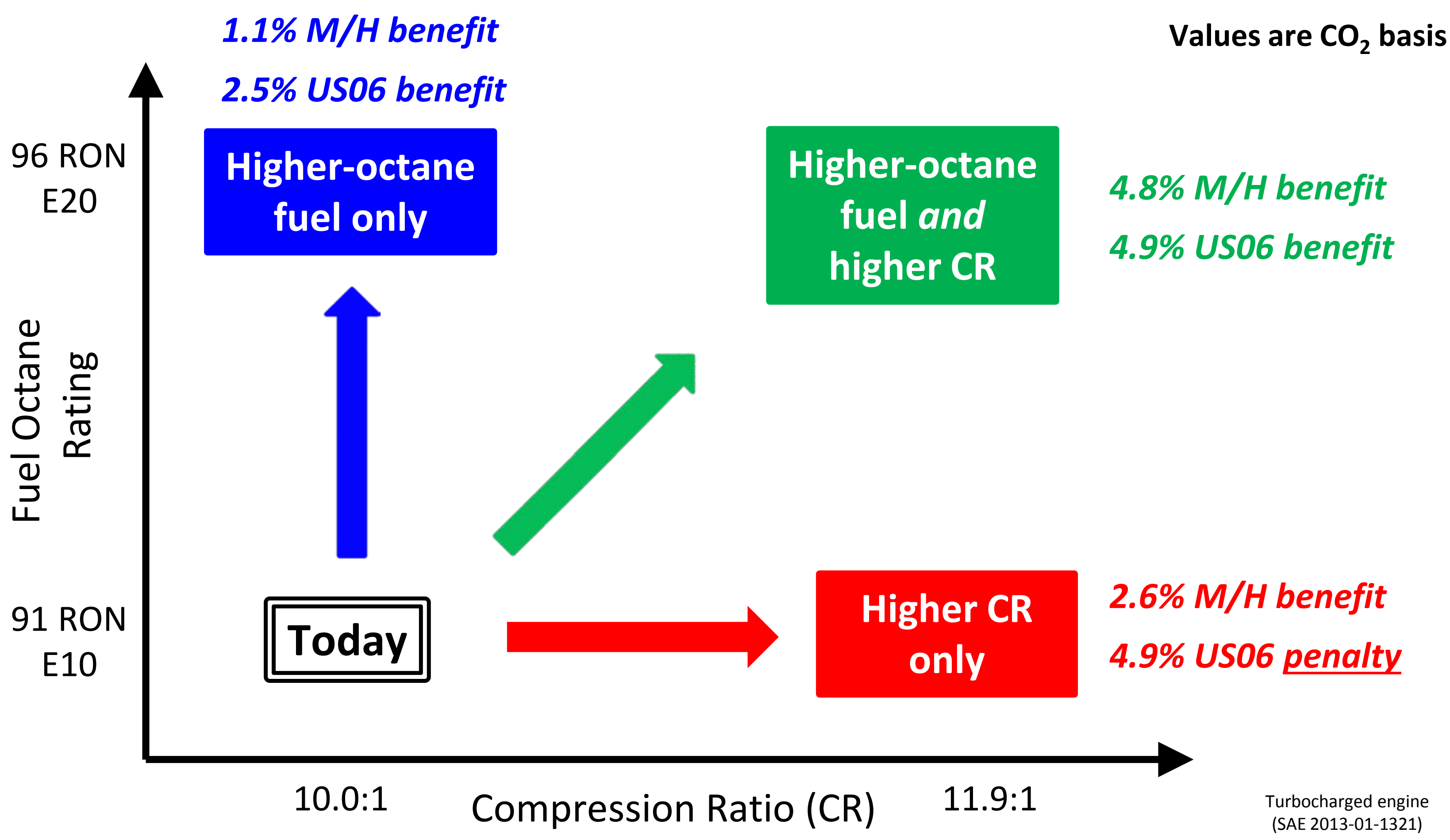
- Higher compression ratio (CR) can improve fuel efficiency with higher octane rated fuel.
- At a fixed compression ratio, higher octane rated fuel enables more optimum spark timing.





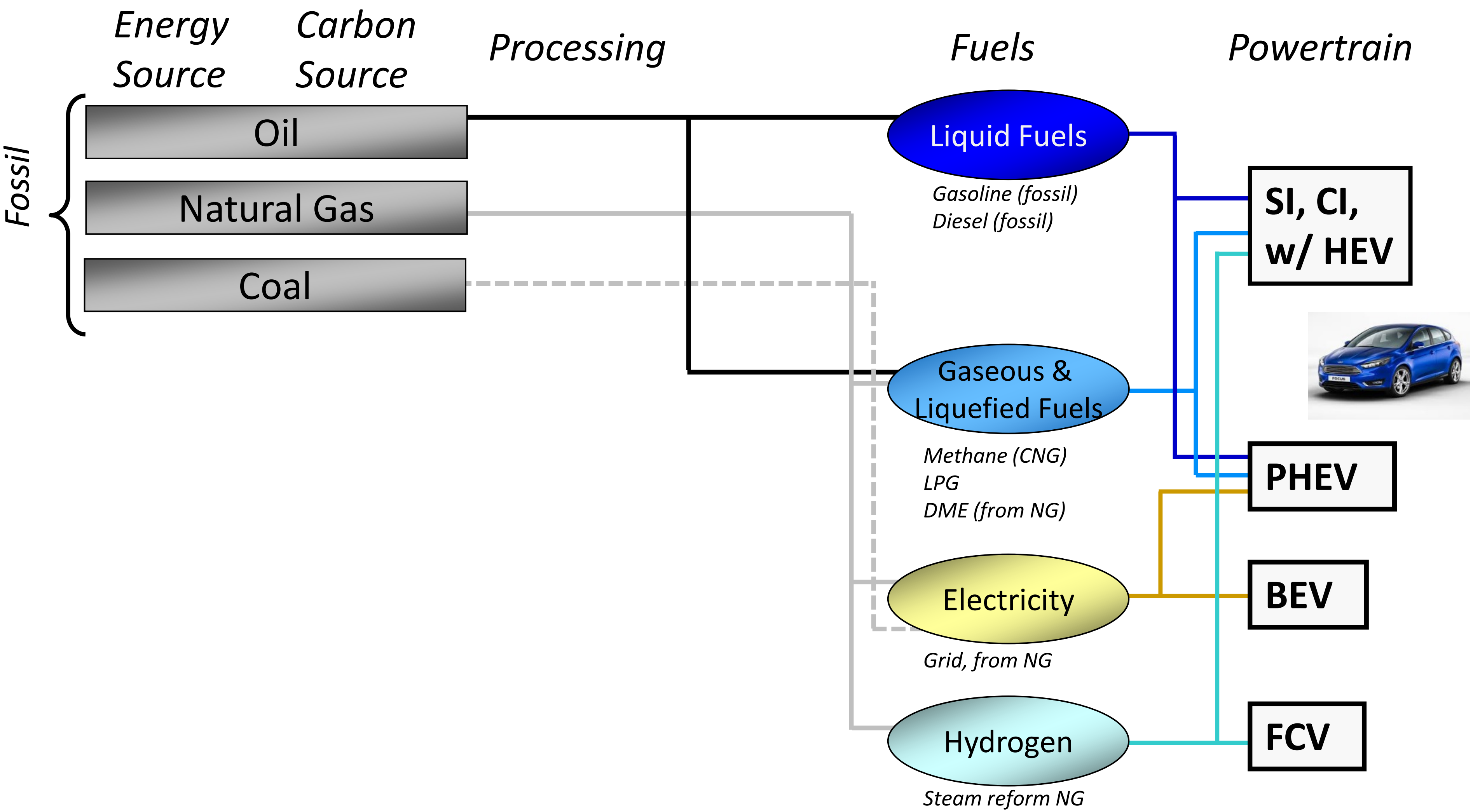
Higher octane rated fuel reduces knock, enabling both higher compression ratio and more optimum spark timing.

Efficiency Changes with Octane Rating and CR



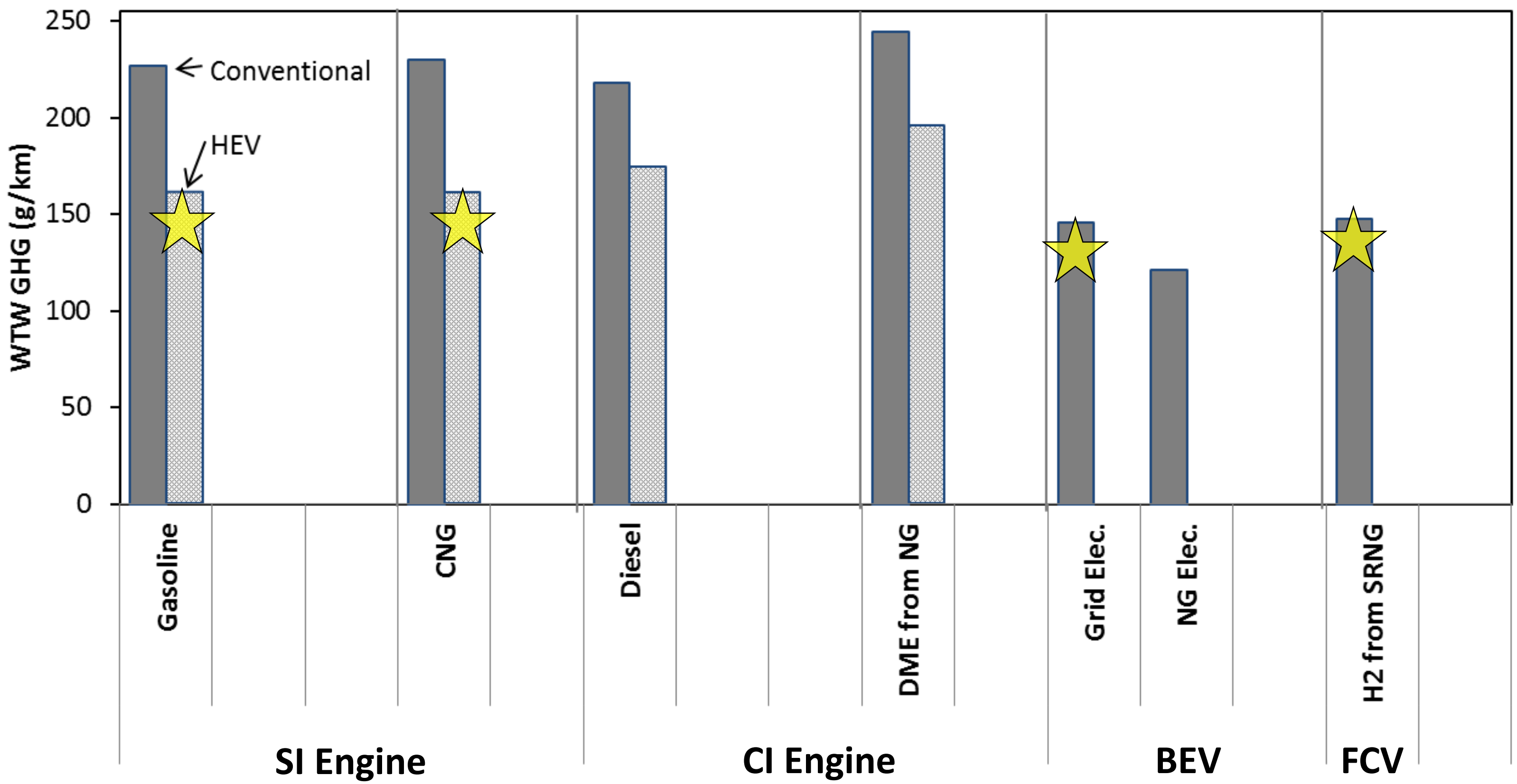
Though higher-octane fuel and higher compression ratio individually improve M-H cycle efficiency… the best results are achieved by a design-optimized combination of the two.

Fossil Fuel Pathways



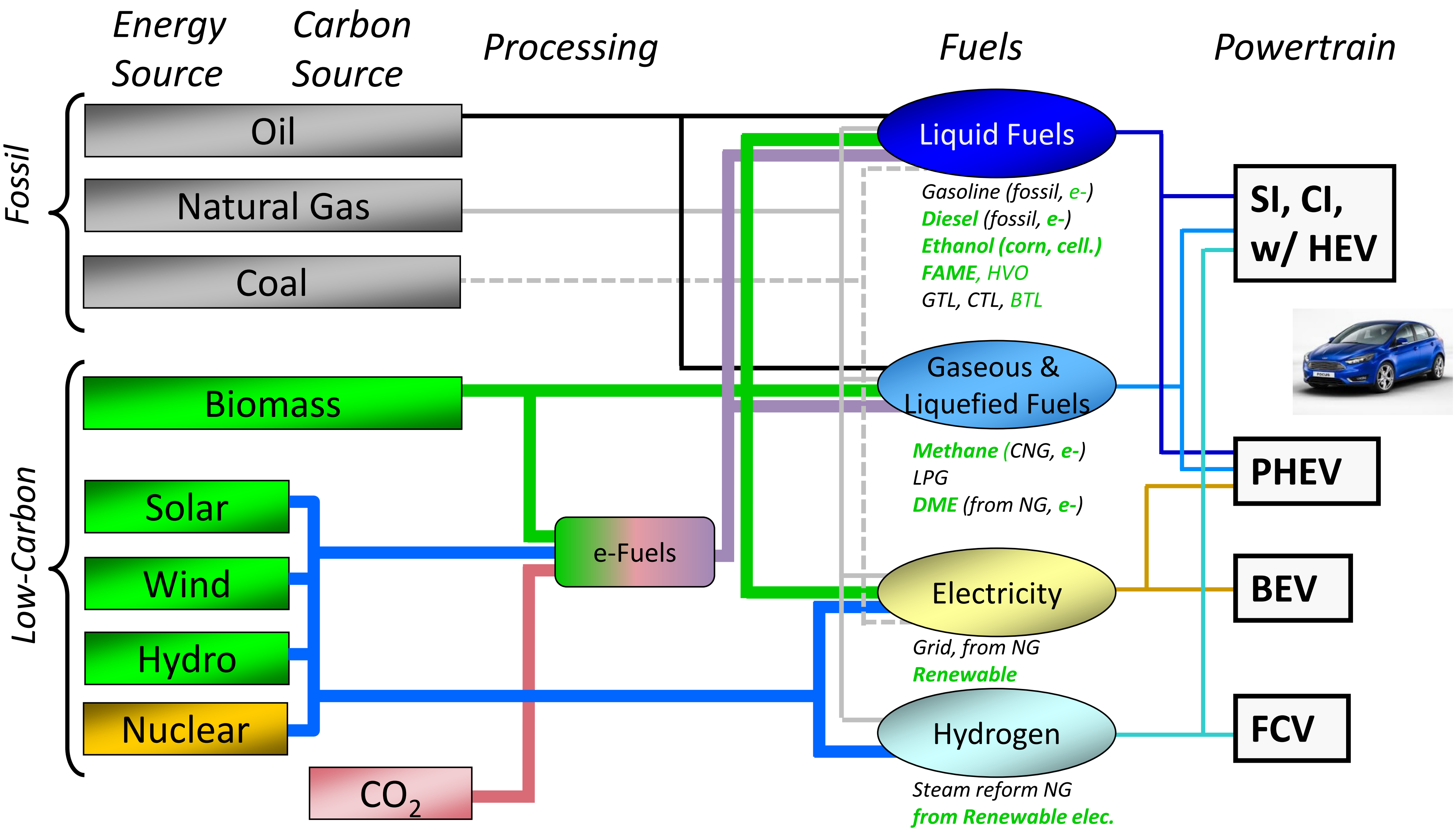
Fossil fuel pathways supply energy for most of today's alternative powertrain vehicles.

Well-to-Wheels Impact of Conventional Fuels



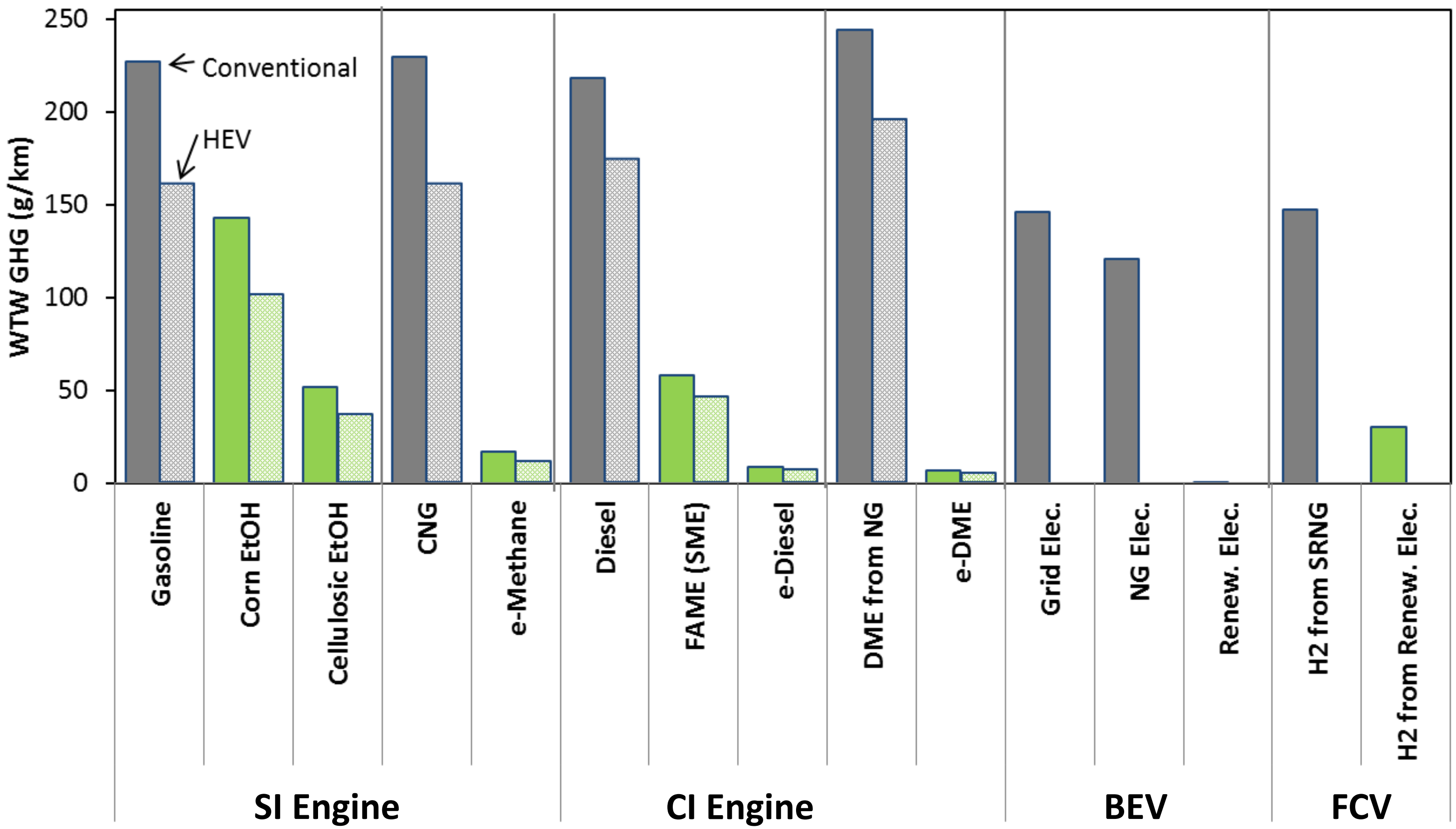
On a well-to-wheels basis, today's fuels in HEVs approximate the CO_2 emissions reductions provided by BEVs and FCVs.

Low Carbon Fuel Pathways



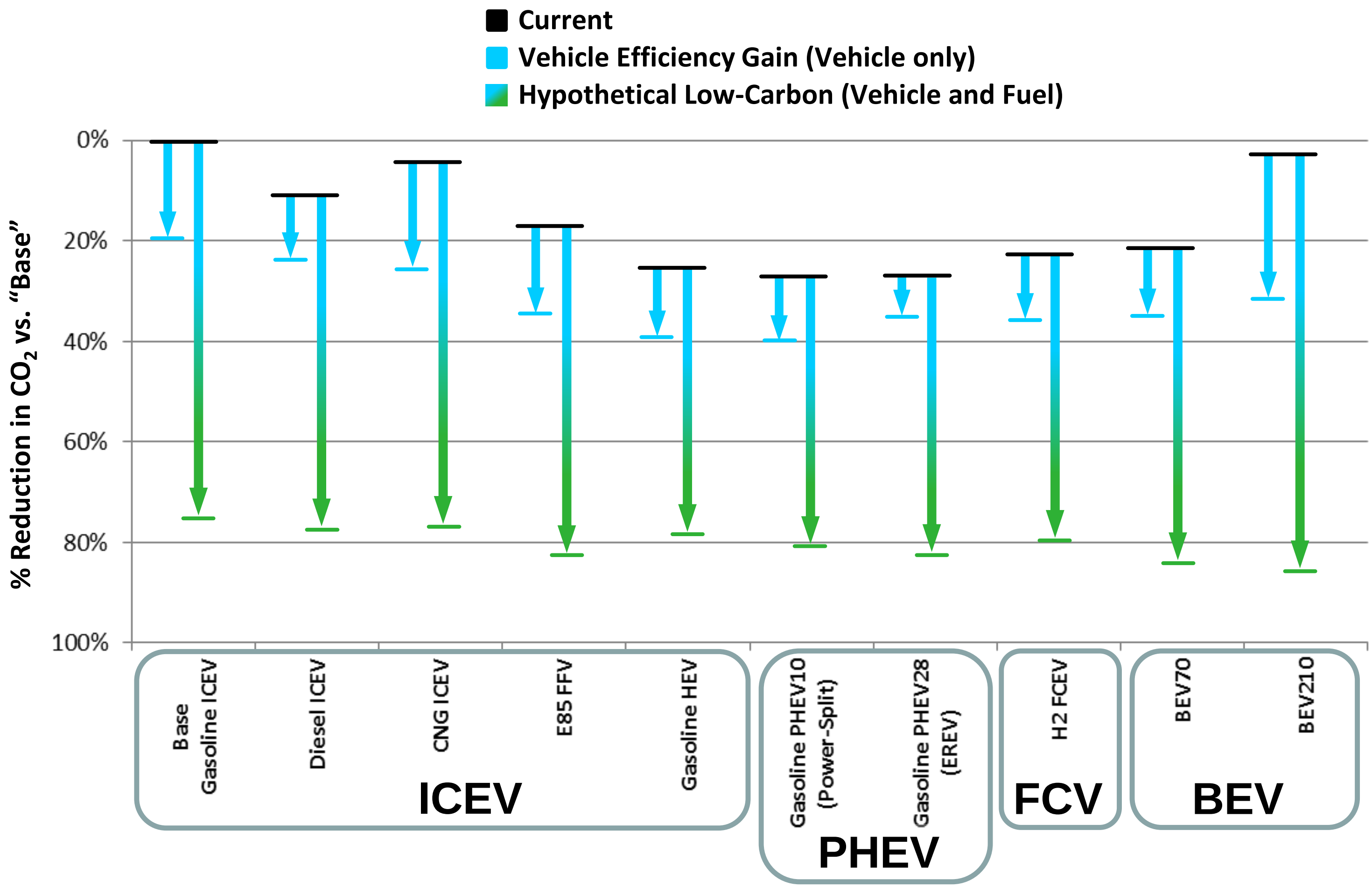
A wide variety of alternative fuel pathways have been identified that could provide greatly reduced Well-to-Tank CO_2 emissions.

Well-to-Wheel Impact of Low Carbon Fuels



For any powertrain approach, low-carbon fuels are ultimately required to achieve the extensive Well-to-Wheel CO_2 emissions reductions in the future.

Vehicle Technologies / Future Low-Carbon Fuels



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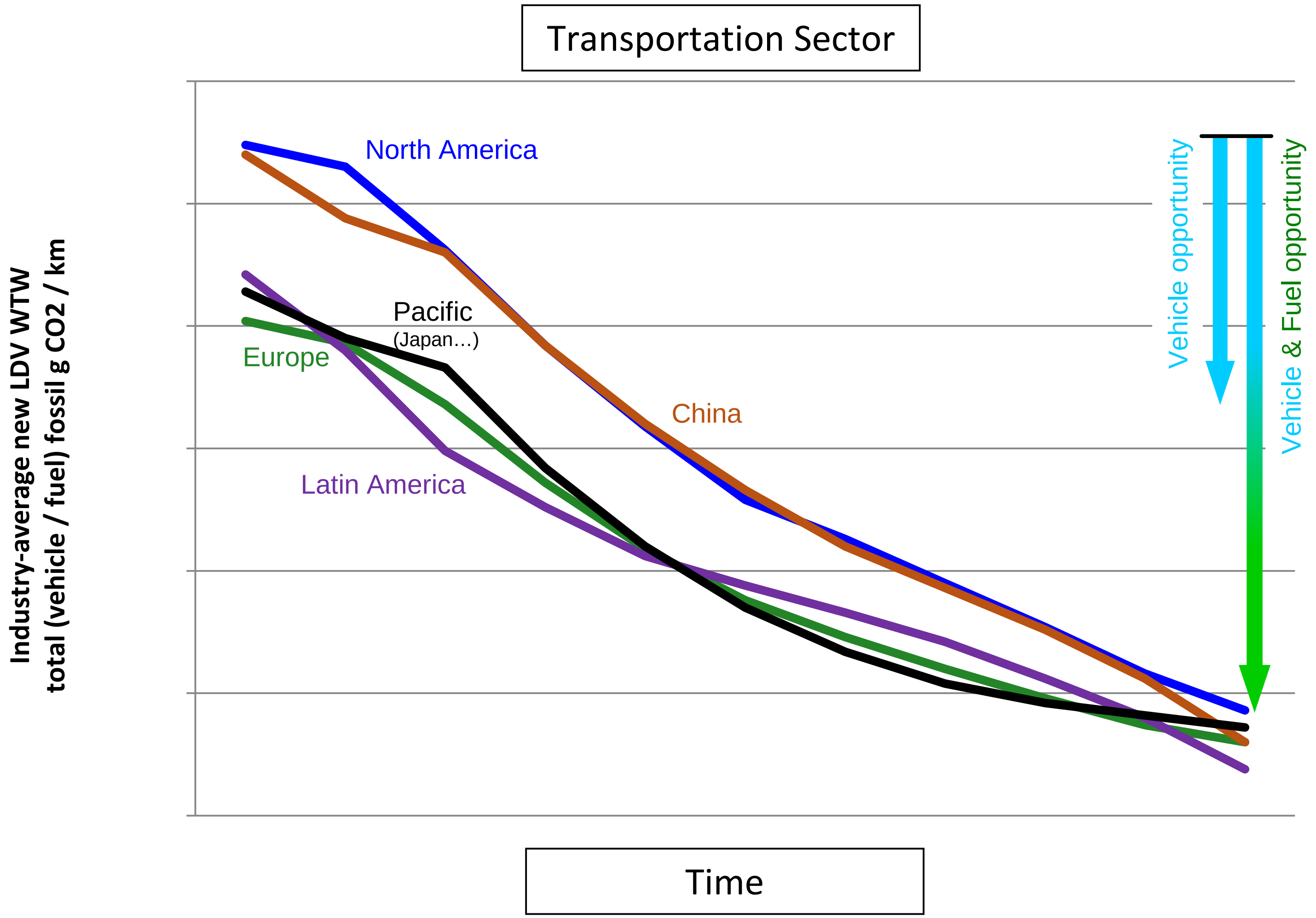
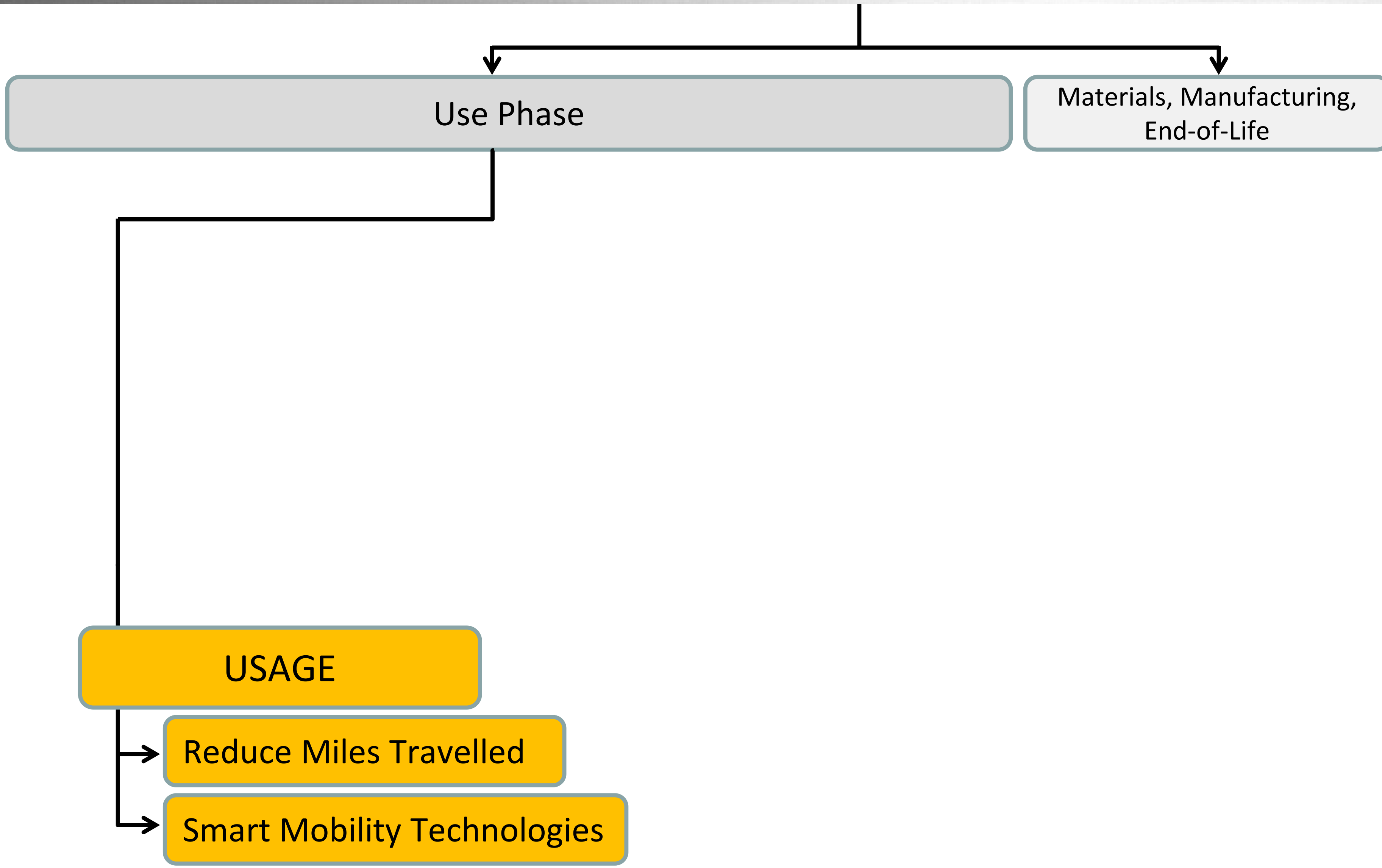
From a Well-to-Wheels standpoint, the combination of vehicle technologies and low-carbon fuel dramatically extends the CO_2 reduction potential.

Sustainability – CO_2 Glidepath – Well-to-Wheels



Along with vehicle CO_2 reductions, achieving long-term CO_2 glide path targets will <u>require</u> renewable / low-carbon fuels.

Sustainable Transportation – Areas of Focus



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Changing Global Societal Trends

Urbanization

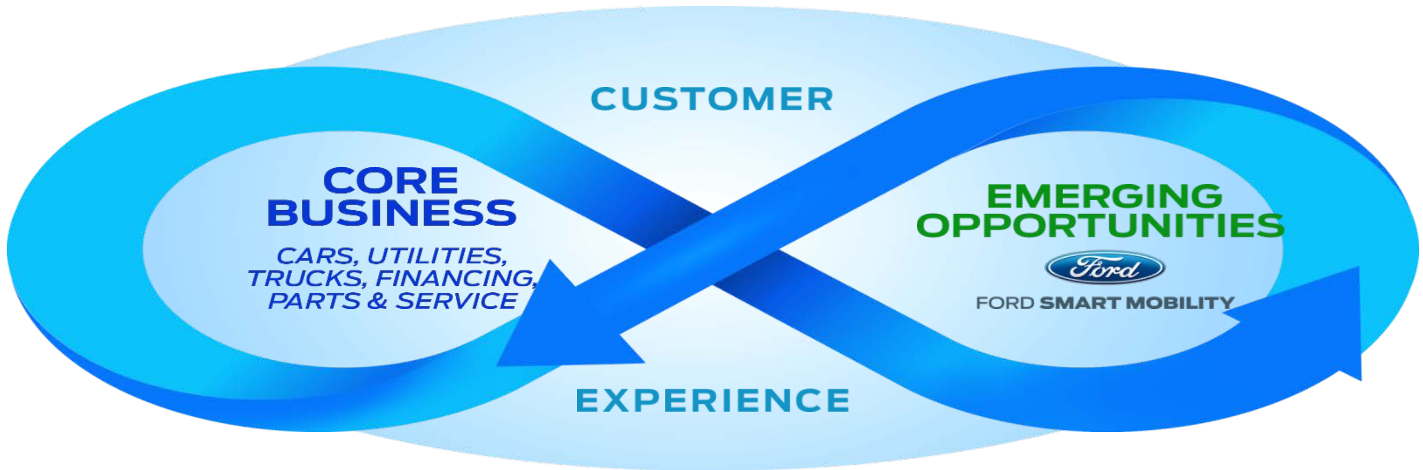
Growing Middle Class

Air Quality & Climate Change

Changing Consumer Attitudes

Beyond regulatory mandates, changing Societal Trends will shape the future of our industry, and will transform the way we view innovation and mobility.

Ford Smart Mobility Strategy



FORD SMART MOBILITY

Vision

Changing how the world moves...again.

Mission: Leverage actionable insights across connectivity, autonomy, and full-service mobility solutions to provide innovative experiences loved by customers, enabling a better world.

Connectivity Blueprint

CONNECTIVITY

Near-Term

Build on SYNC, MyLincoln Mobile and MyFord Mobile

SYNC
Powered by Microsoft
SYNC® AppLink™

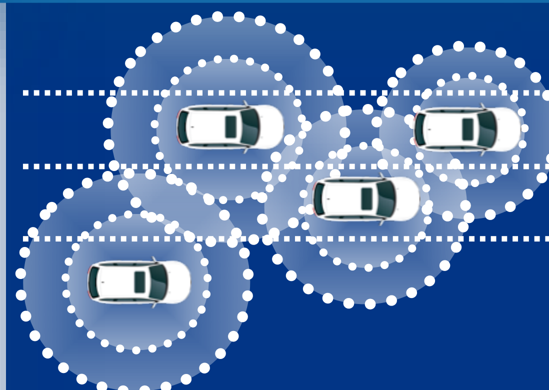
Mid-Term

Connect Vehicles And Expand Capabilities

- Embedded Modem
- Connected Vehicles
- Global Infrastructure

Long-Term

Fully Integrated Connectivity



Experiences Get Better Over Time

Business Model Development And Implementation

Gaining a better understanding of how customers use their vehicles will enable development of products, services and experiences that excite and delight, as well as enhance sustainability.

Innovation in Mobility

MOBILITY

Facilitate Flexible Ownership & Usership

CAR SHARING

FRACTIONAL OWNERSHIP

PAY-AS-YOU-GO SOLUTIONS

Provide Multi-Modal Urban Solutions

Smart Mobility key strategic areas: flexible use & ownership of vehicles, and multi-modal transportation.

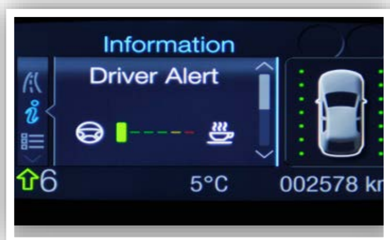
Autonomous – DAT to Full Control

Driver Assist Technologies (DAT)

Active Park Assist

Rear Cross-traffic Alert

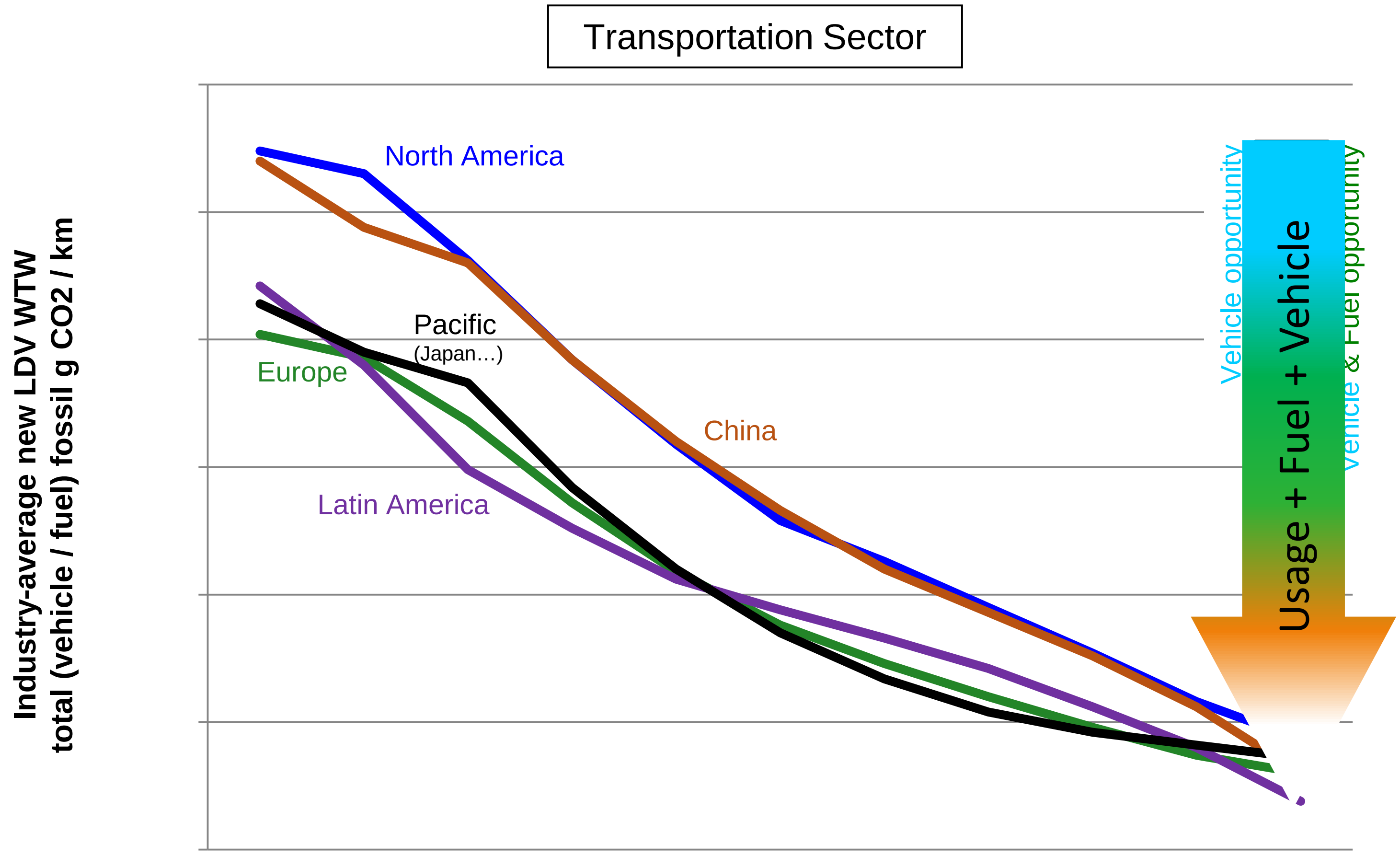
Lane Departure Warning with Lane Keeping Aid



Blind Spot Monitoring

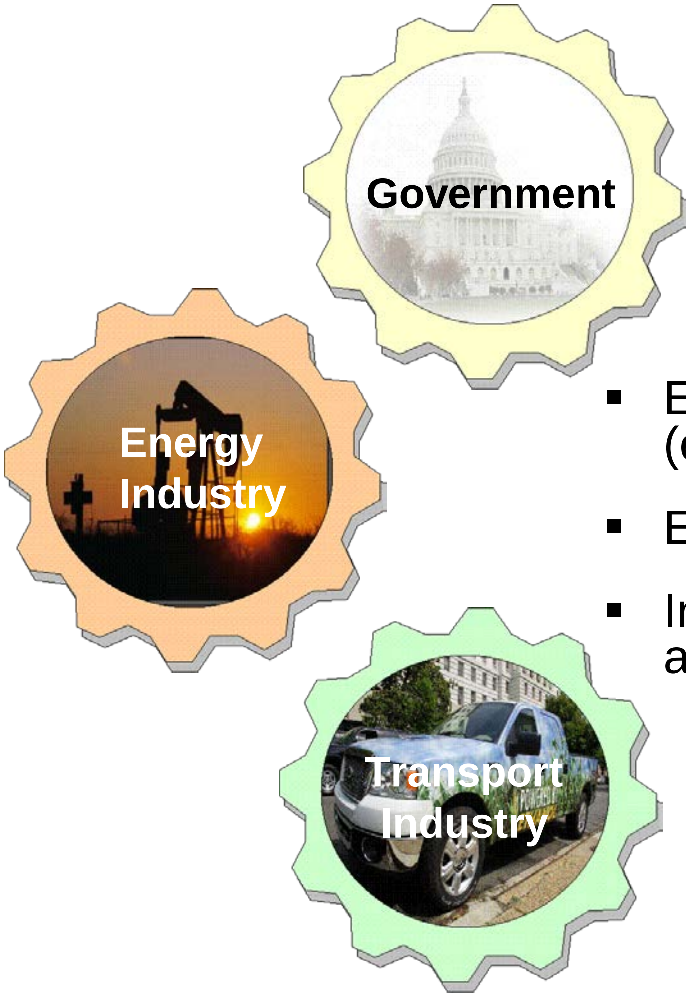
The transition from Driver Assist Technologies toward Autonomous driving is progressing rapidly.

Sustainability – CO_2 Glidepath – Well-to-Wheels



Beyond the Consumer Experiences, understanding how this additional degree of freedom known as "Usage" can impact long-term sustainability is a key question for industry.

Shared Responsibility – Collaborative Approach



- Environmental Sustainability (e.g. Well-to-Wheels CO_2)
- Economic Sustainability
- Investment in supporting Energy and Transportation Infrastructure

A collaborative approach to address these goals is required.

Summary & Conclusions

- Fuel economy and CO_2 regulations continue to drive rapid vehicle technology development.
- Customer savings from improved fuel economy alone will not offset growing technology costs.
- Long-term sustainable LDV transportation requires a Well-to-Wheels perspective and actions on multiple fronts, including: Vehicle, Fuel and Usage.
- There is extensive work on the full spectrum of vehicle technologies that can substantially improve fuel economy and CO_2 in the future.
- Higher octane rated fuel combined with today's advanced engine technology has even further efficiency potential by improving knock limit.
- From a Well-to-Wheels standpoint, multiple alternative pathways exist which can support achieving significant CO_2 reduction.
- Vehicle efficiency improvements will continue to play an important role, but achieving long-term CO_2 glide path targets will require low-carbon fuels.
- Understanding how customers will use vehicles in the future can enable development of products that address societal trends and enhance long-term sustainability.
- A collaborative approach among all major stakeholders is required to address overall sustainability goals, both environmental and economic.