Future Challenges for European Vehicles and Fuels

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1963–2013 50 concawe years delivering science for Europe

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Contents

- Regulatory Challenges & Technology Options
- Future Transport Energy & Fuels
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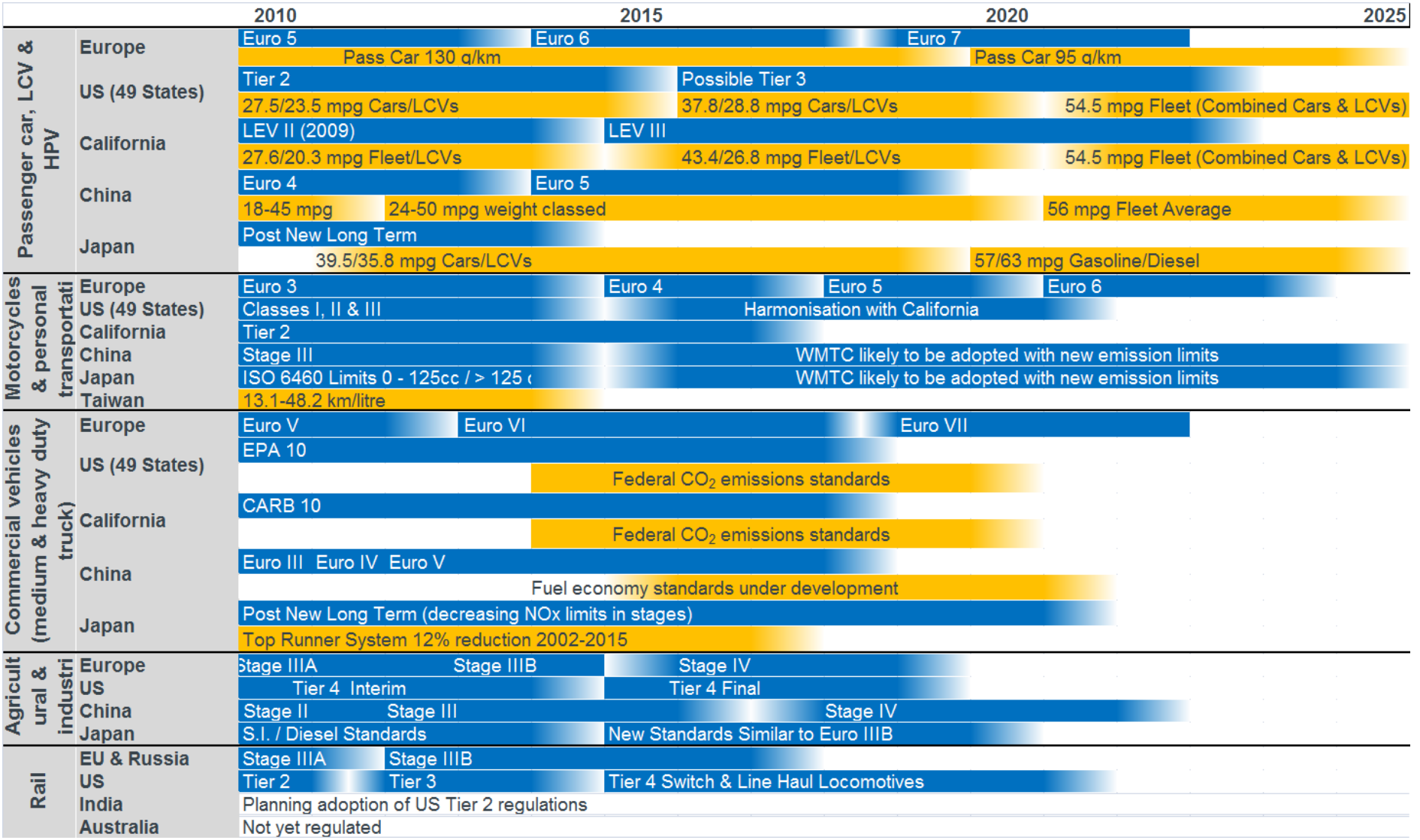
The growth of both regulation and targets for Clean Low Carbon Vehicles sets a major challenge in all sectors

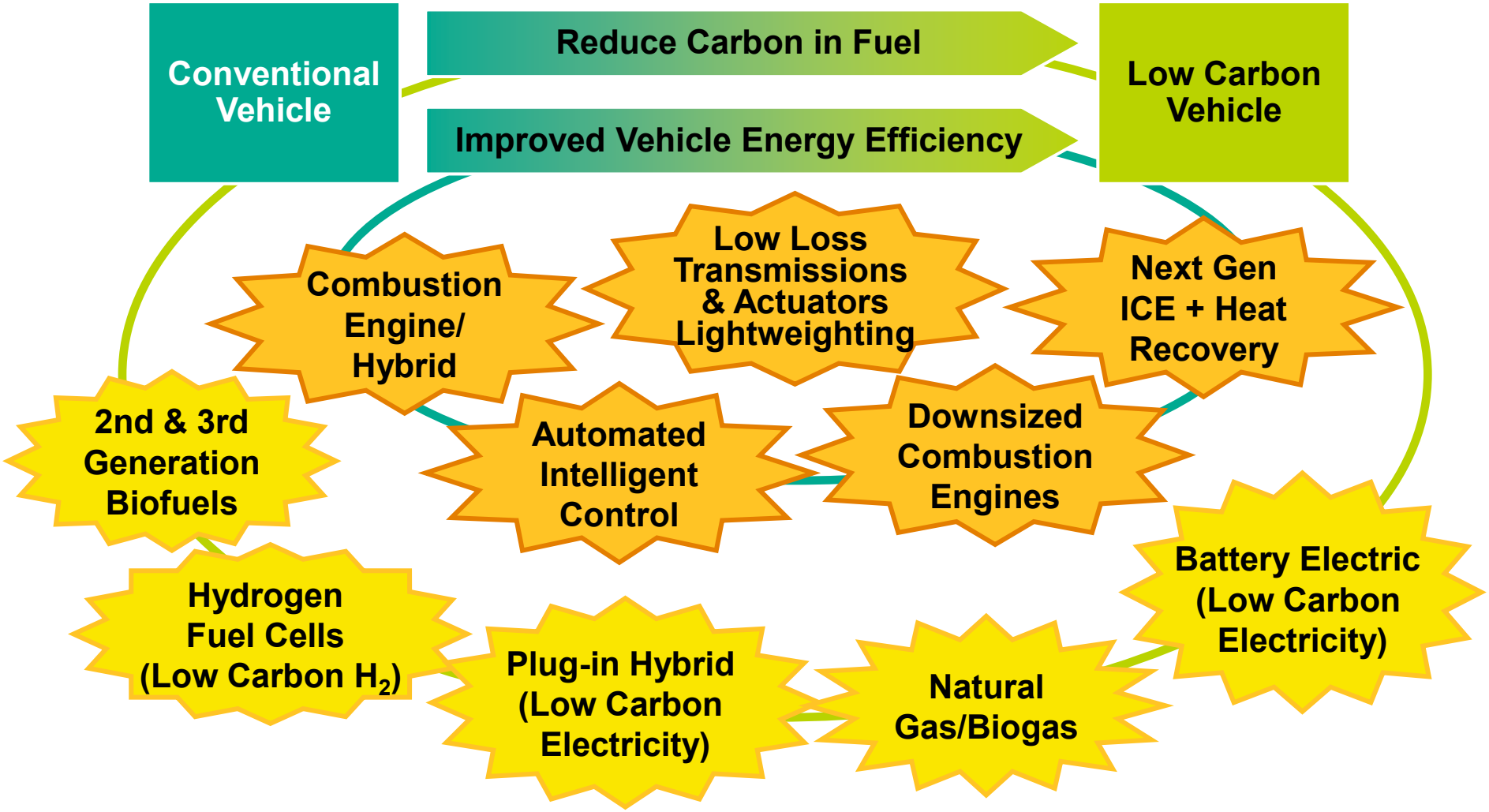


Air Quality Regulations

CO_2 or Fuel Economy Regulations

There are many technical options to reduce fuel consumption & CO_2 emissions – all have challenges – no clear winners

Low carbon vehicles achieved through improved efficiency and/or low carbon fuels:



Source: Ricardo analysis

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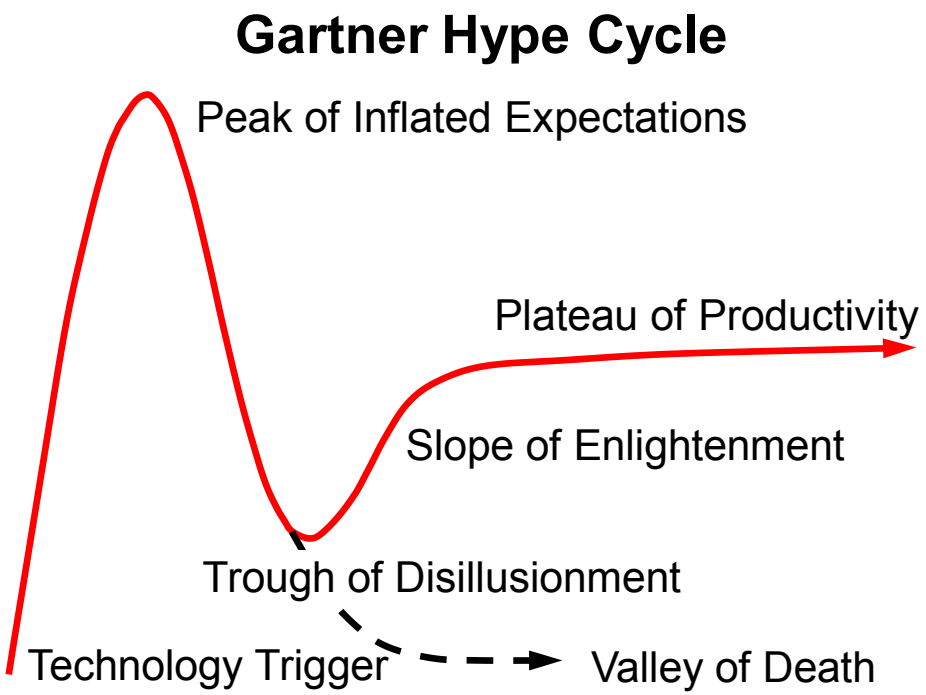
Be wary of jumping from one “favoured” technology to the next – there are no silver bullets, just hard work & persistence!

- Technology & “Fashion”

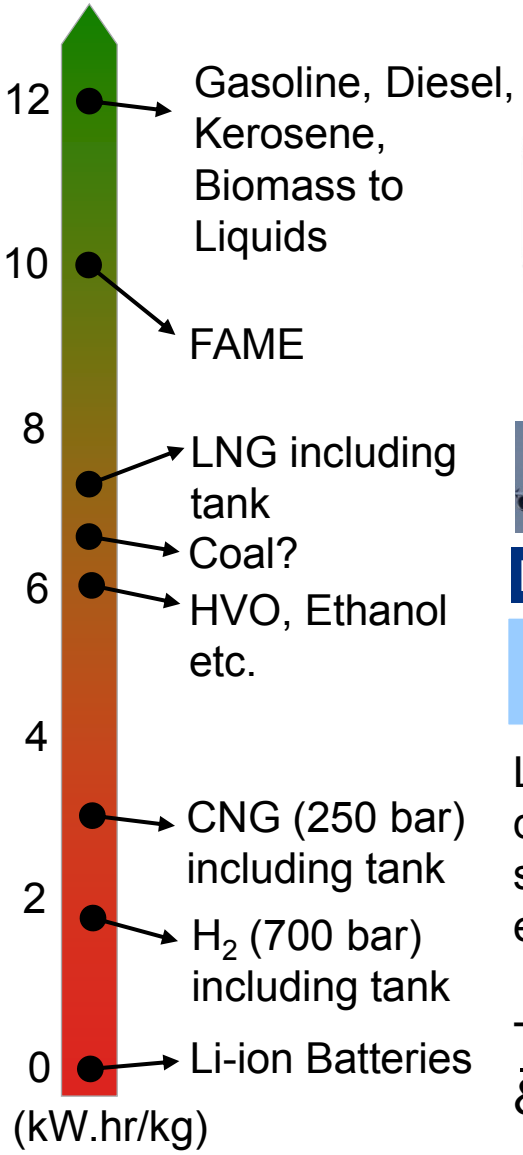
1980	Synthetic Fuels (Oil Crisis)
1985	“Adiabatic” Insulated Engines
1990	Methanol
1995	Electricity (CARB & EV1?)
2000	Hydrogen & Fuel Cells
2005	HCCI & “Alternative” Combustion
2007	Biofuels & Ethanol
2009	EV’s & Plug-in Hybrids
2013	What’s next?



- Policy makers often look for a “simple” solution that makes good headlines
- Auto Industry sometimes too eager to promote promising “Green” techs for PR

- Where are they now?
  - Biofuels
  - Plug-in Hybrids & EV’s
  - HCCI / Alternative Combustion

Long haul / heavy duty applications will require low carbon liquid fuels – light duty applications more suited to batteries



State of the Art Li-ion battery for 500 mile range 40 ton HGV would weigh 23 tons*

Long Distance/Heavy Duty — Short Distance/Light Duty

Low Carbon Liquid Fuels	Liquid Fuel / Battery Hybrid	Battery Electric
Long distance/ heavy duty vehicles need space/weight efficient energy storage	Use of both liquid fuel and grid re-charged battery offers more flexibility and utility	EV's suited to short distance/light duty applications to minimise cost
Technology/Cost & Availability →		← Technology/Cost Innovations

Source: Ricardo research & US DoE*

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Electrification is a major trend for the forseeable future but this comes in degrees and is a "continuim" from micro hybrid to EV

Electrification	CO_2 TtW reduction potential		Challenges	Outlook
Micro Hybrid (12V) – Stop/Go, Smart Charge	**- 6%**	*Best applications*: Urban delivery vans, Gasoline city cars	Larger Diesels harder, less benefit	Will be ubiquitous in regulated markets by 2015
Micro Hybrid (24-48V) – Stop/Go, Smart Charge/Assist	**- 10%**	*Best applications*: Urban delivery vans, Gasoline city cars	**Cost of battery** or energy store	Major growth area after stop/start smart charge
Mild Hybrid – Torque Assistance	**- 15%**	*Best applications*: Family cars with down sized turbo engines	**High cost** v ICE improvements	Possible mainstream solution 2015-20 in EU & US
Full Hybrid – Flexible power unit	**- 30%**	*Best applications*: Large/prem vehicles, delivery vans & trucks	**Very high cost** v ICE improvements	Image & niche products to 2015; growth thru 2020
Plug-in Hybrid – Flexible fuel source	**- 60%**	*Best applications*: Family cars with mixed journey usage	**Cost and life** of enlarged battery pack	Affluent early adopter niche 2015-20
Electric Vehicle – Farewell ICE? Or not…	**- 100%**	*Best applications*: Vehicles with limited, predictable daily use	**Battery cost / size** versus range; fast charge limits	Limited to city cars and vans until battery breakthrough

Source: Ricardo roadmaps and technology planning; Ricardo Carbon to Hydrogen Roadmap

Advanced combustion engines & electrification of the powertrain are key to the future of light duty vehicles

SHORT TERM: ~2015

- Boosting & downsizing
  - Turbocharging
  - Supercharging
- Low speed torque enhancements
- Friction reduction
- Advanced thermal systems
- Stop/Start & low cost Micro Hybrid technology
- Niche Hybrid, PHEV's & Electric Vehicles
- Weight reduction (5-10%)

MEDIUM TERM: ~2025

- Extreme downsizing with 2 & 3 cylinder engines
- Combined turbo/ supercharging systems
- Advance 48 volt micro hybrid systems dominate
- PHEV's in premium & performance products
- EV's for city vehicles
- Significant weight reduction
- High Efficiency Lean Stratified Gasoline
- Advanced low carbon fuel formulations

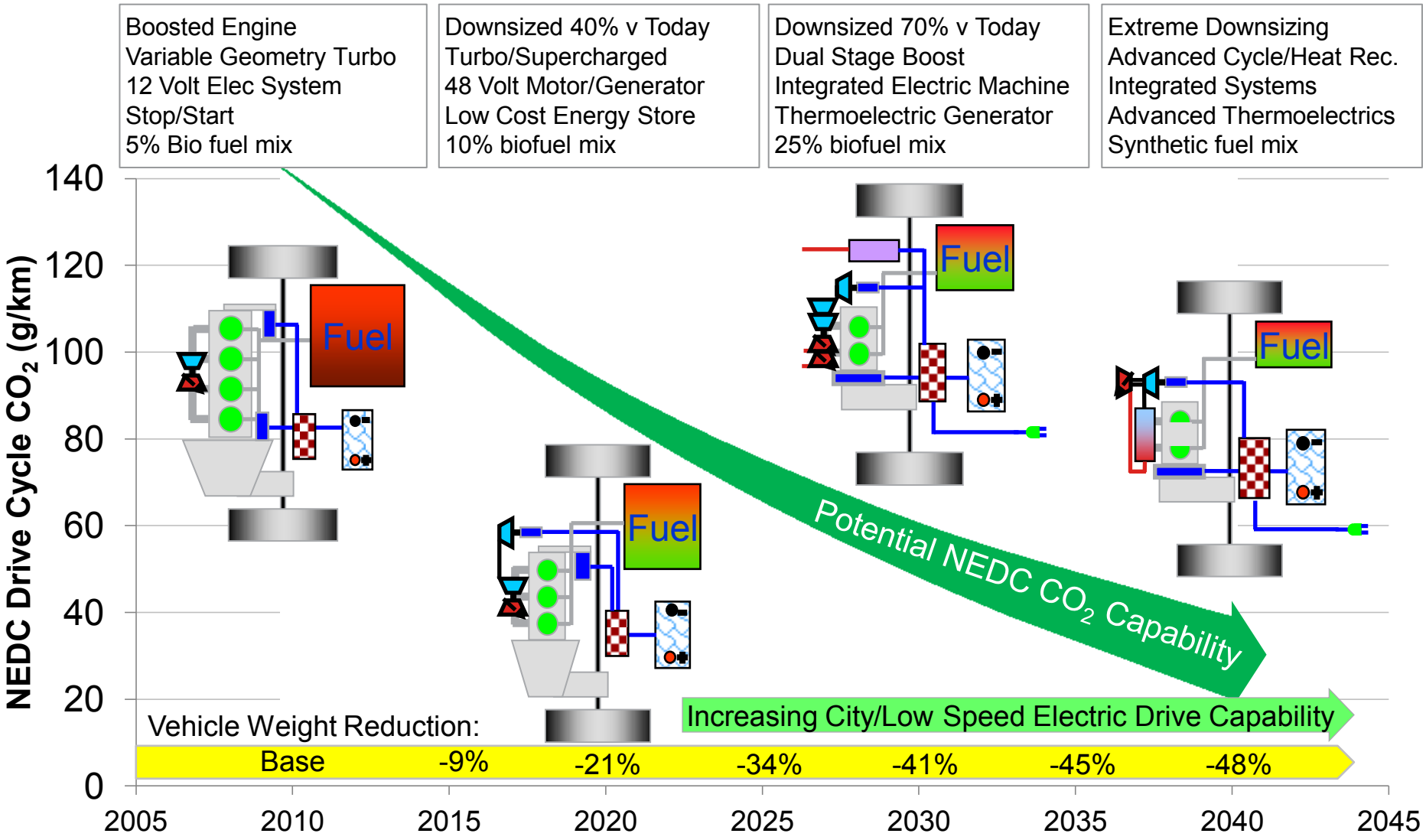
LONG TERM: ~2050

- Plug-in/Hybrid electric systems dominate
  - Very high specific power ICE's
- 50% lower weight
- Range of application specific low carbon fuels
- Exhaust & Coolant energy recovery
- Advanced thermodynamic Cycles
  - Split Cycle?
  - Heat Pumps?

Increasing Importance of Electrification

Source: Ricardo Technology Roadmaps, Ricardo Analysis

Many technology pathways for improved pass car powertrains – Example: downsizing/electrification/heat recovery combinations



IC Engine/System efficiency improvements & low carbon fuels could deliver ~ 30g/km CO_2 by 2040

IC based systems competitive with EV's on life cycle carbon basis

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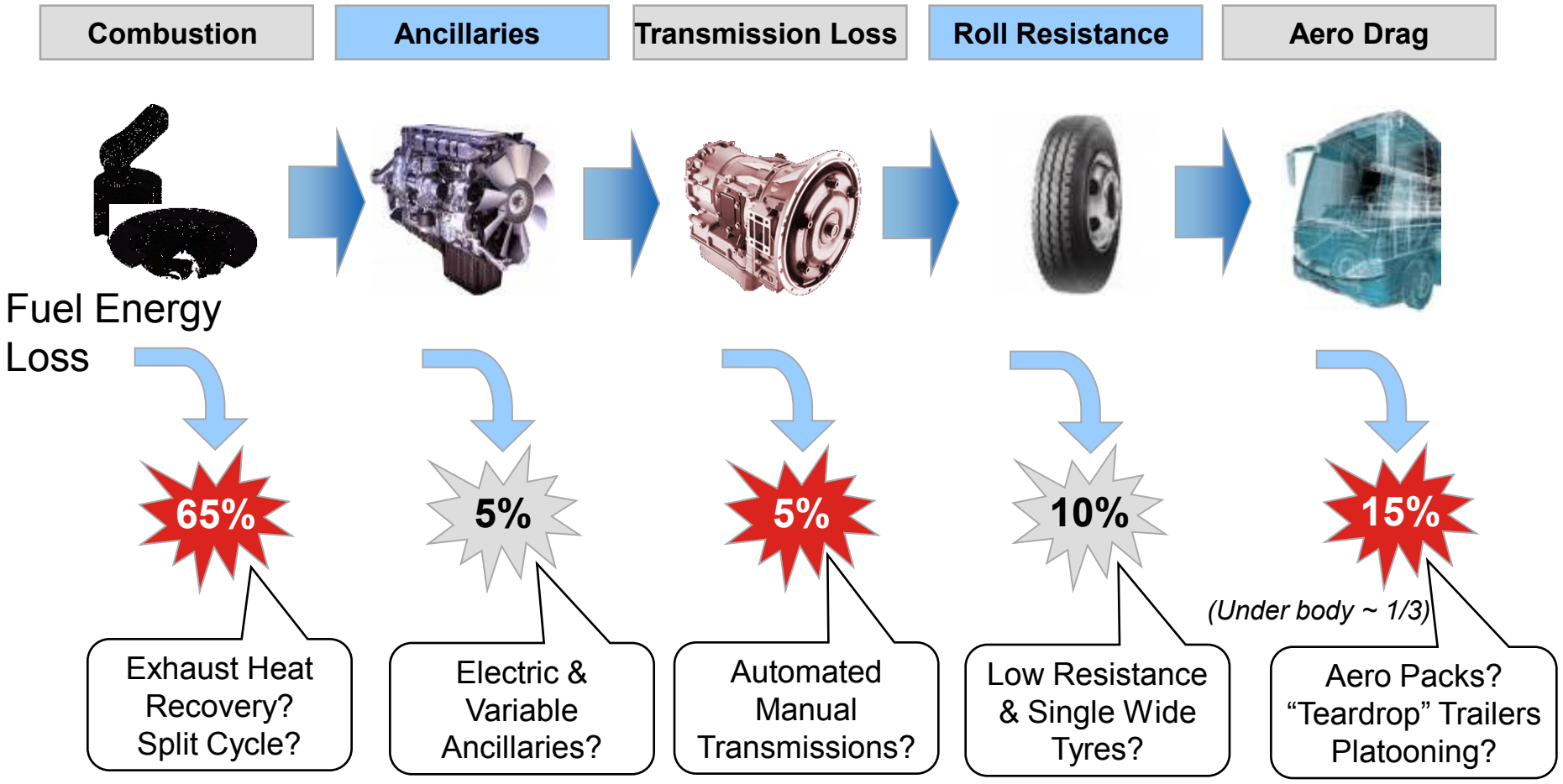
Heavy duty/high power applications offer opportunities for a range of efficiency enhancements

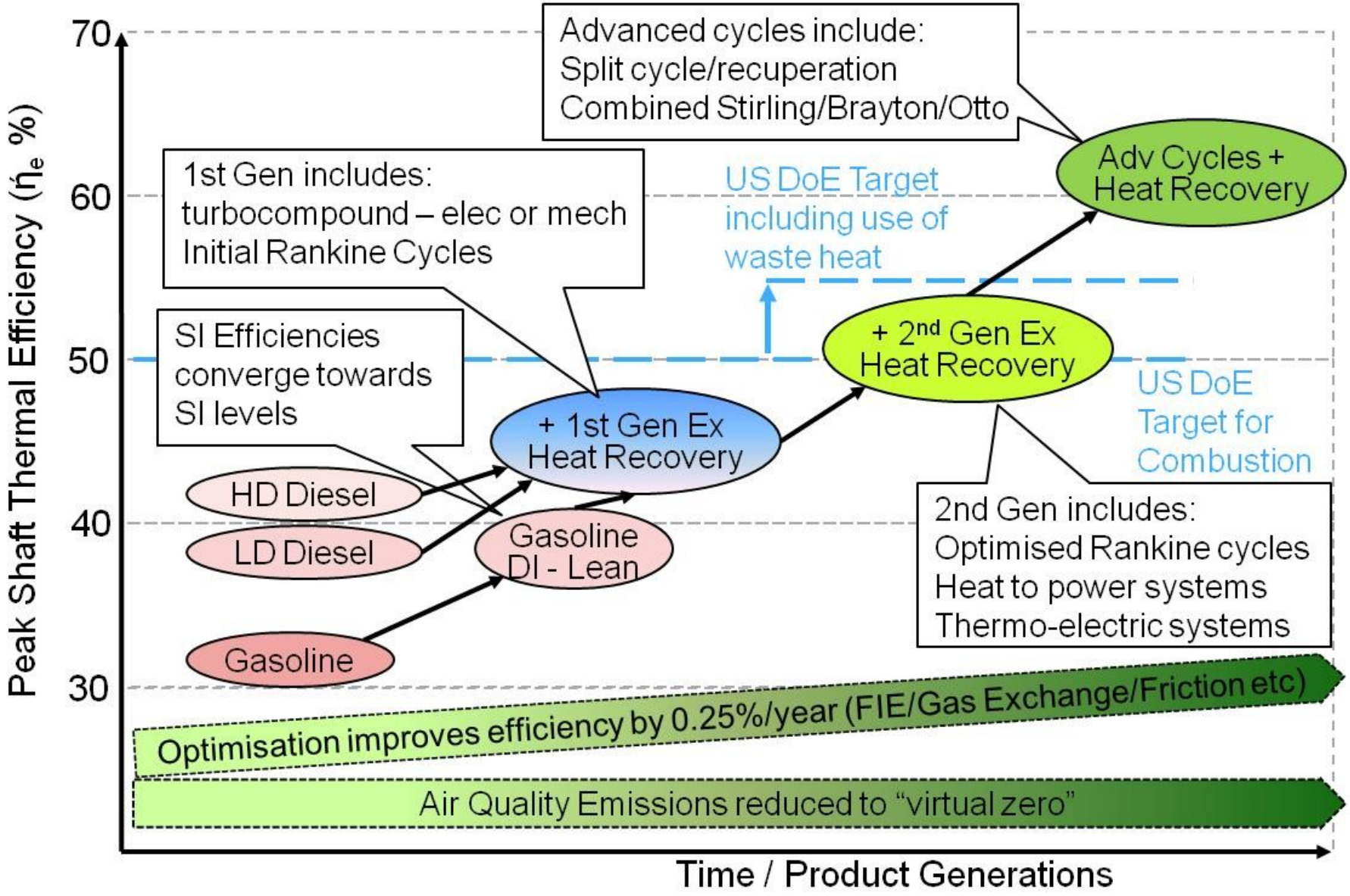
Analysis of Vehicle Energy Flows (Loaded Heavy Duty Truck Example)

- From the total amount of fuel used (at 100km/h), the energy flows are as follows:



Source: Ricardo analysis

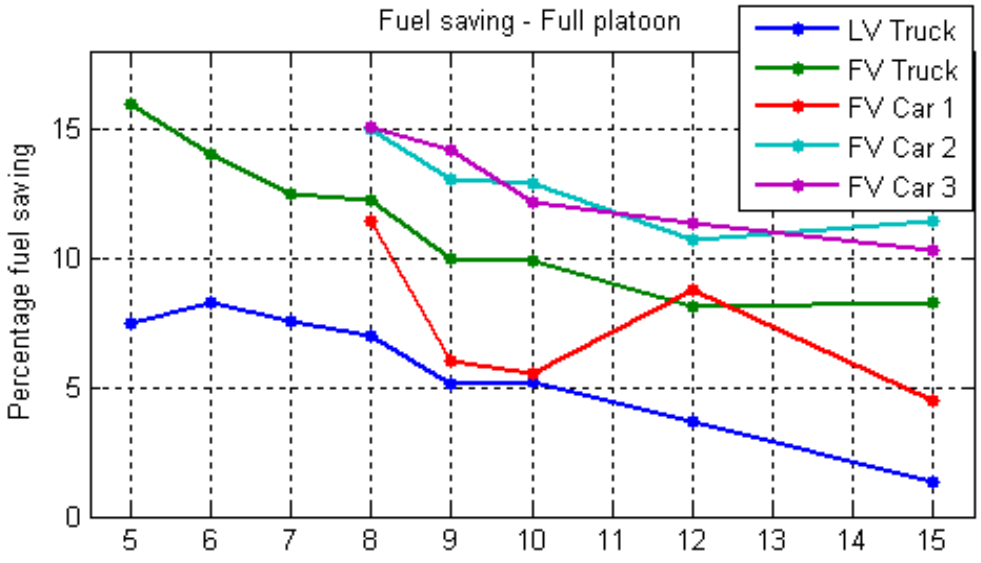
ICE Thermal Efficiency has considerable scope to improve & could reach over 60% in future products



Source: Ricardo Analysis

SARTRE - Cooperative control of automated platoon vehicles improves safety and fuel economy

- Five vehicle road train of mixed types
- Control system performance is enhanced using real-time V2V data
- Based on existing technologies with some software enhancements, combined with advanced control software
- Up to 90 km/h and 4m gaps
  - 90 km/h is truck speed limit
- Interactions with non-platoon traffic
- Tested on test tracks and public roads
- Demonstrator system - not a production implementation
- Fuel consumption results
  - 16% for following vehicles
  - 8% for lead vehicle



There are three interlinked phases of change required to current heavy duty powertrain technology and strategy

SHORT TERM: ~2015

- ICE optimisation for improved air quality
- SCR/EGR/DPF Integration
- Ancillary system control/electrification
- Friction reduction
- Waste heat recovery (e.g. mechanical & electrical turbocompound)
- Alternative fuel combustion technology (NG, LNG)

MEDIUM TERM: ~2025

- ICE optimisation for reduced CO_2
- High Efficiency Advanced Fuel Inj. & Combustion:
  - Low temperature low NOx combustion
- Low Carbon Fuels & Dedicated CNG/LNG & biomethane engines
- Minimised Aftertreatment
- Advanced waste heat recovery
- Advanced electrical ancillaries

LONG TERM: ~2050

- Dedicated low carbon liquid fuels for long distance transport
- Advanced thermodynamic Cycles
  - Split Cycle?
  - Heat Pumps?
- Exhaust & Coolant energy recovery
- Embedded thermo-electric materials

Increasing Importance Of Low Carbon Fuels

Source: Ricardo Technology Roadmaps, Ricardo Analysis

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Thank you for listening!