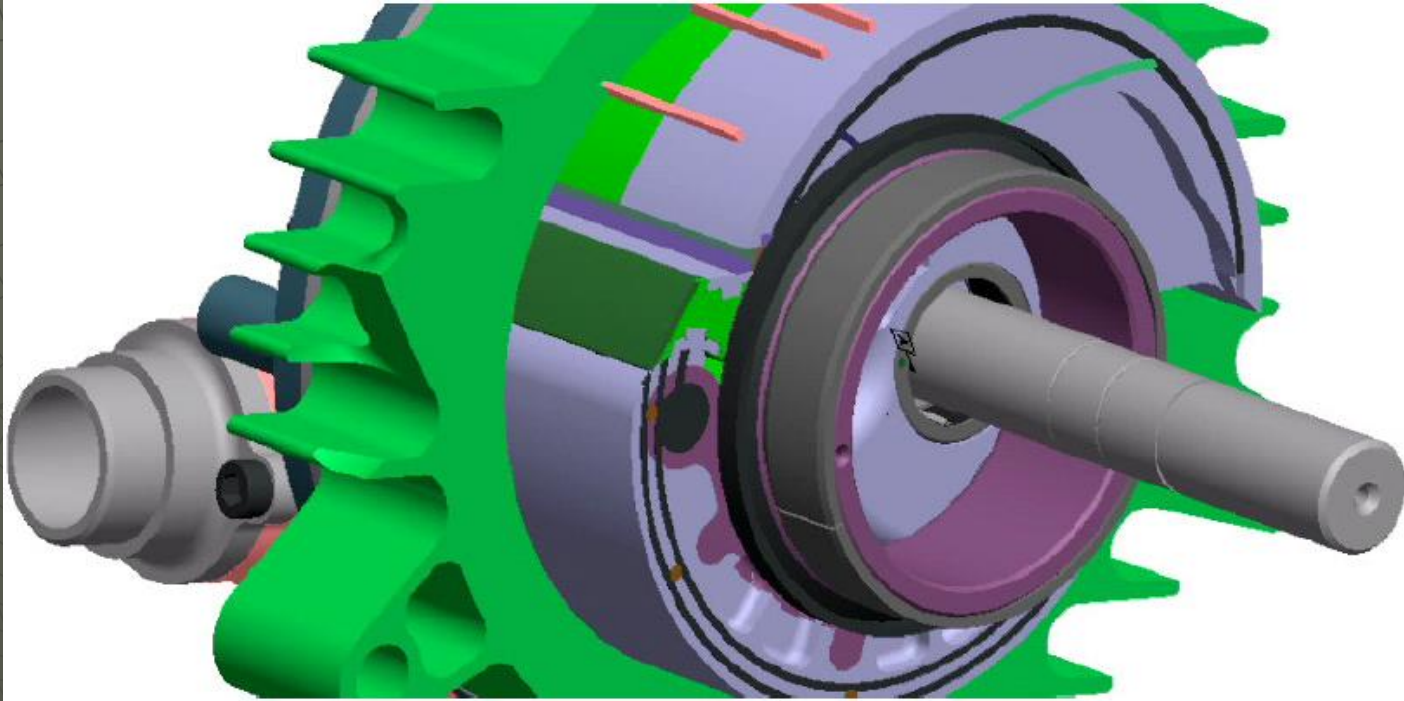
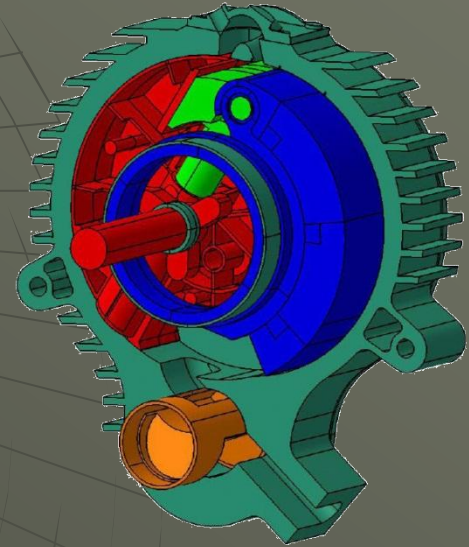


Libralato Engine



Objectives of Presentation

- ◆ How the Libralato engine works
- ◆ Why the Libralato engine is a game changer for HEVs, PHEVs and ER-EVs
- ◆ Route to Production
- ◆ Collaboration?



Libralato FP7 Green Cars Initiative

£2m project; TRL 4 – 5

Project Partners

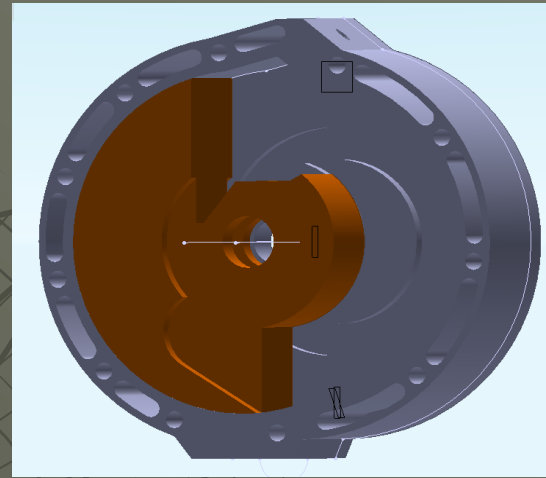
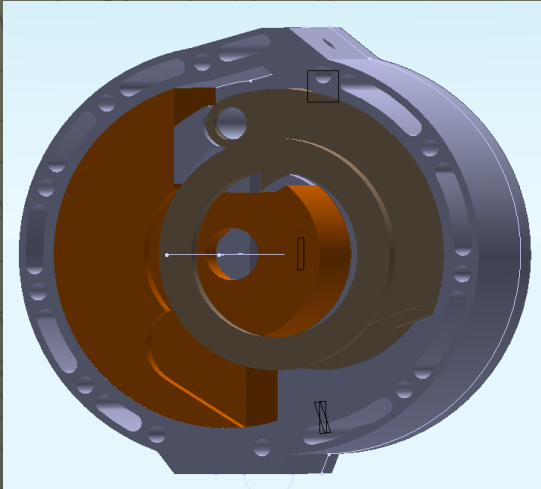
- ◆ Loughborough University (UK) – Coordinator
- ◆ Libralato Holdings Ltd (UK) – Technical direction
- ◆ The Engine Consultancy (UK) - Coordination & CFD
- ◆ Bucharest University (RO) – mechanical design
- ◆ ATARD (TR) – mechanical design
- ◆ Infineon Technologies (DE) – Electronic Controls
- ◆ Techmachine (IT) – prototype machining & build
- ◆ CRITT M2A (FR) – testing

Industrial Advisory Group

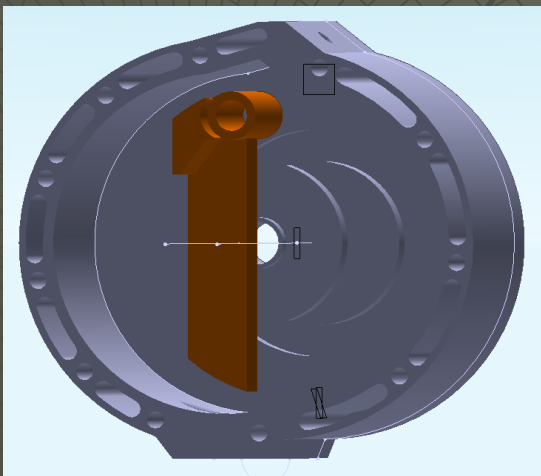
- ◆ SMTC (UK subsidiary of SAIC)
- ◆ Deutz (DE)
- ◆ JCB (UK)
- ◆ Mahindra & Mahindra (IN)
- ◆ BAE Systems (UK)



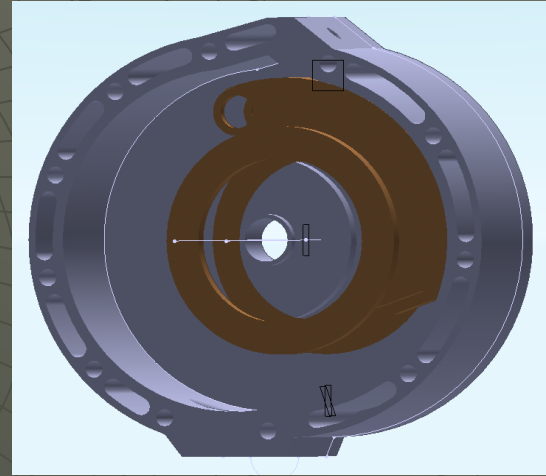
Libralato Engine



Power
rotor

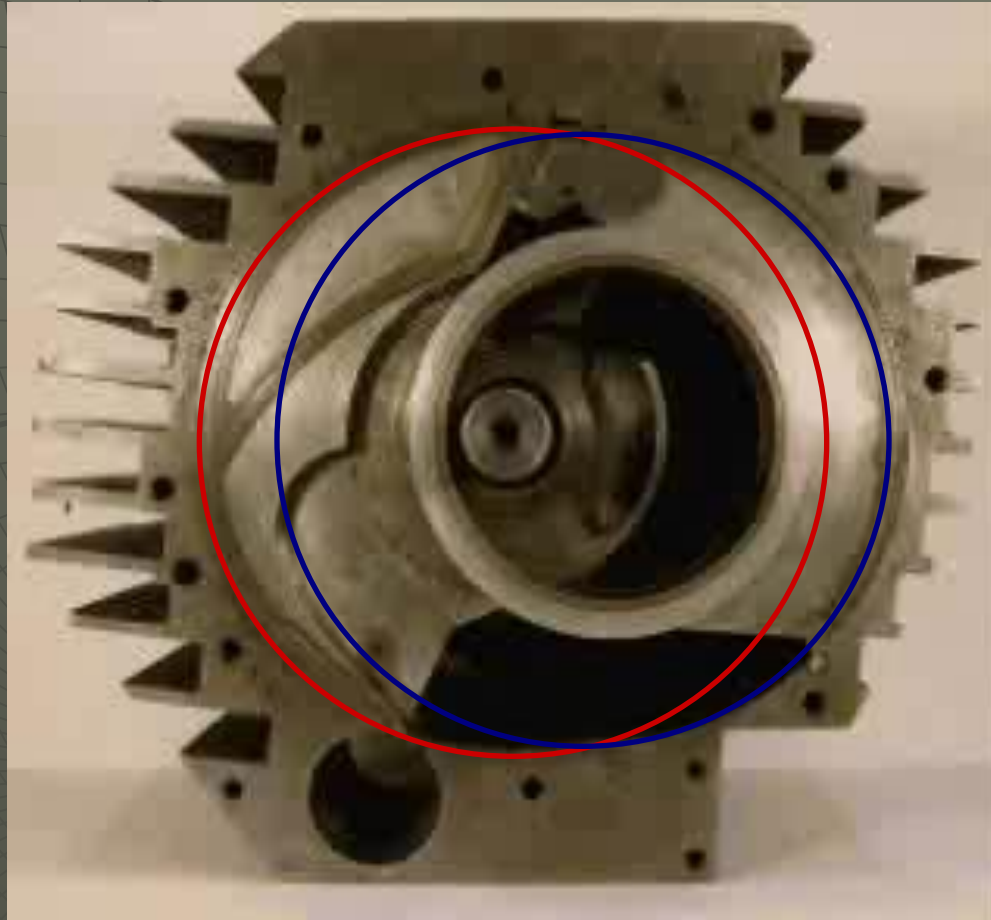


Sliding Bar



Following
rotor

World First Rotary Atkinson Cycle

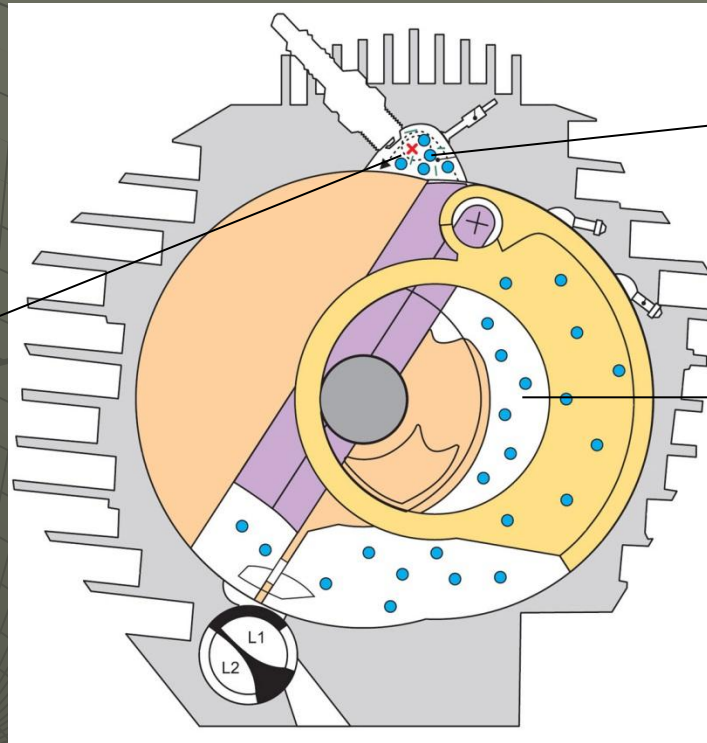


Patents no:
WO2004020791
WO2010031585

Independent assessment – predicted to be the most efficient compact gasoline engine in the world – **208 g/ kWh**.
Gasoline version ~ 39% efficiency v 30% efficient avg

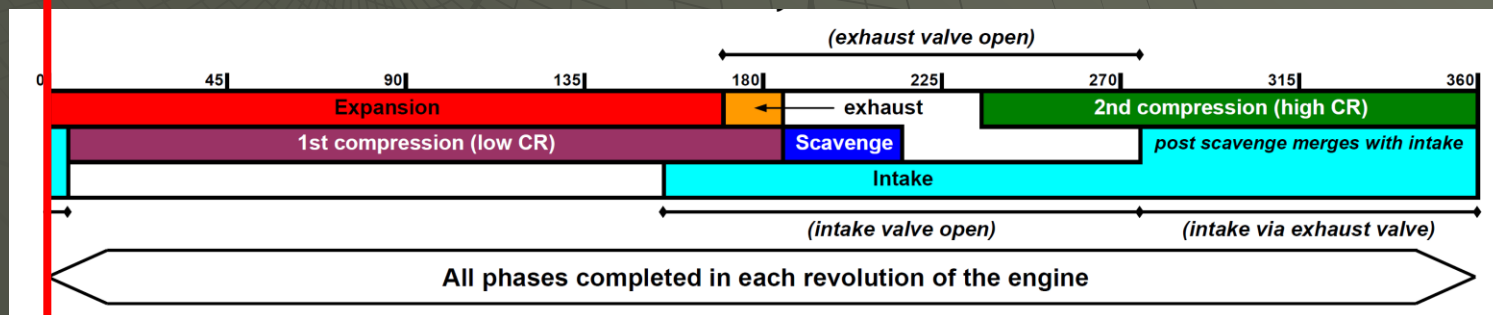
Libralato Cycle

Top dead centre
– spark ignites
fuel air mixture



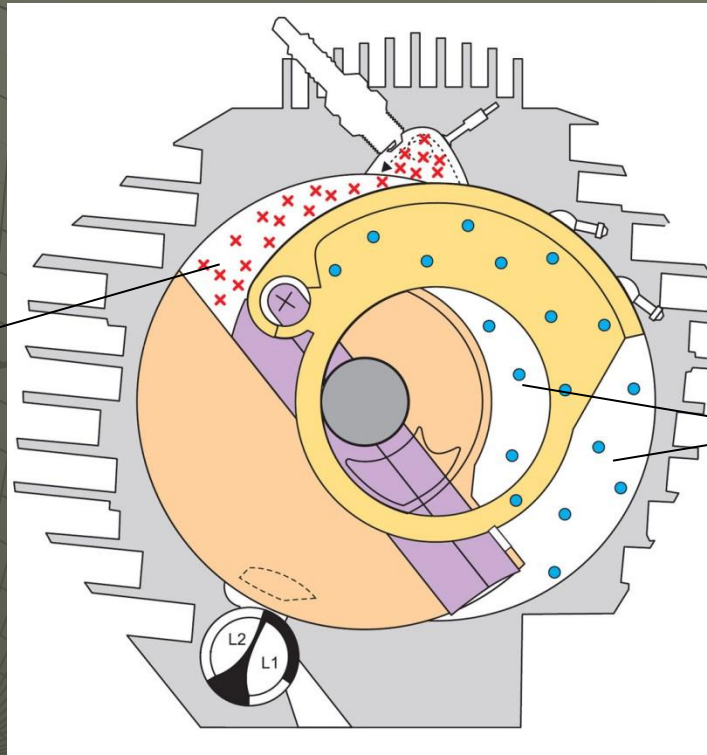
Direct injection
Lean burn

Maximum
intake
volume

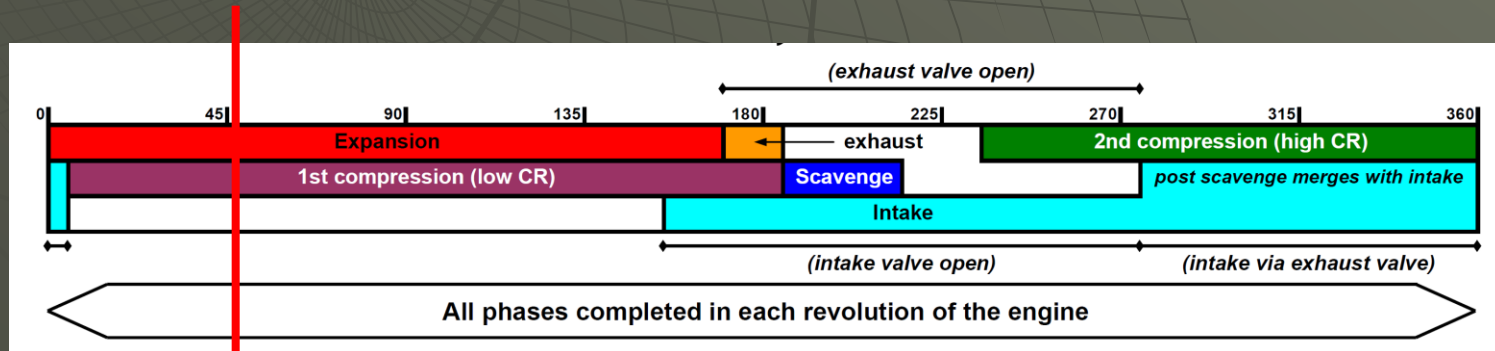


Libralato Cycle

Expansion –
High torque from
5° acting directly
on an expanding
working surface
area – force
transferred
directly to
output shaft



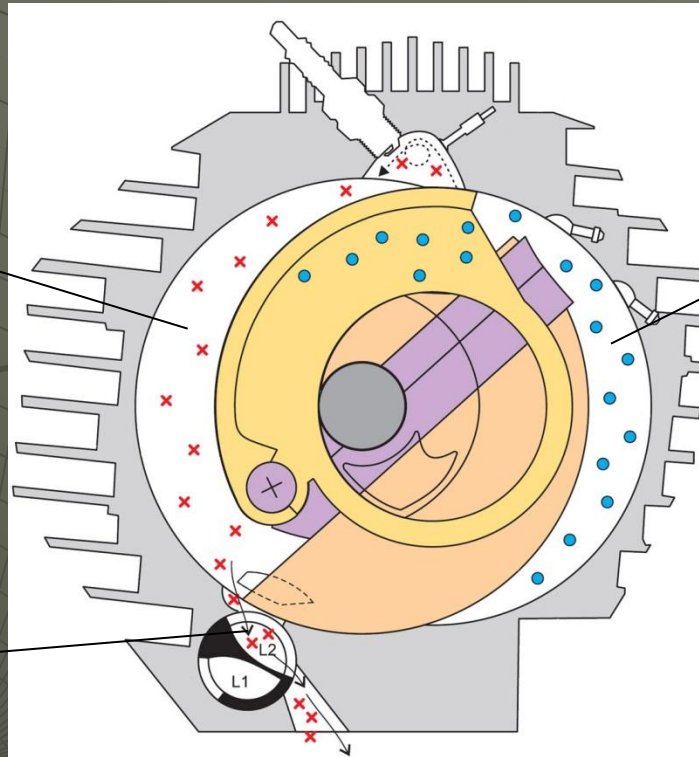
Compression – first stage
compression
starts



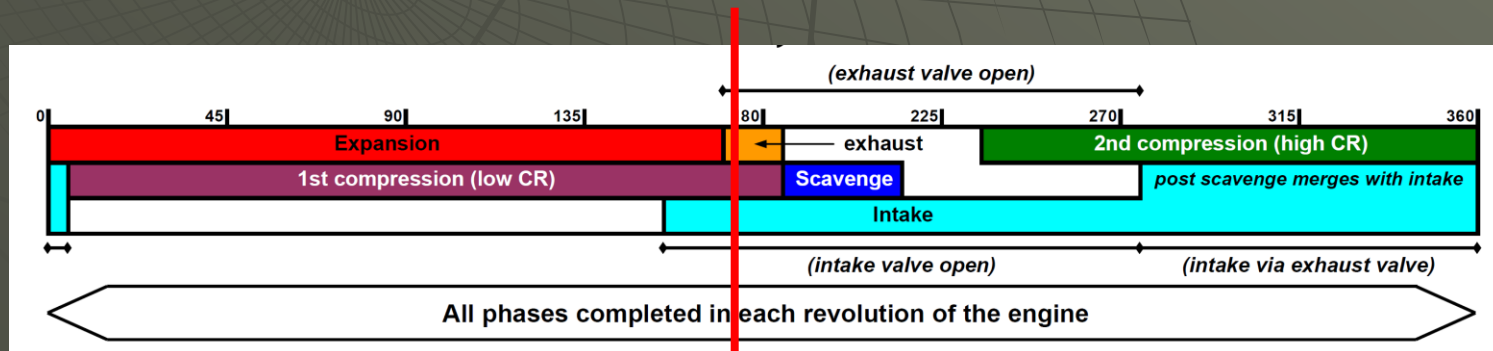
Libralato Cycle

Asymmetric geometry allows more complete combustion

Exhaust valve opens and exhaust gases exit under their own pressure

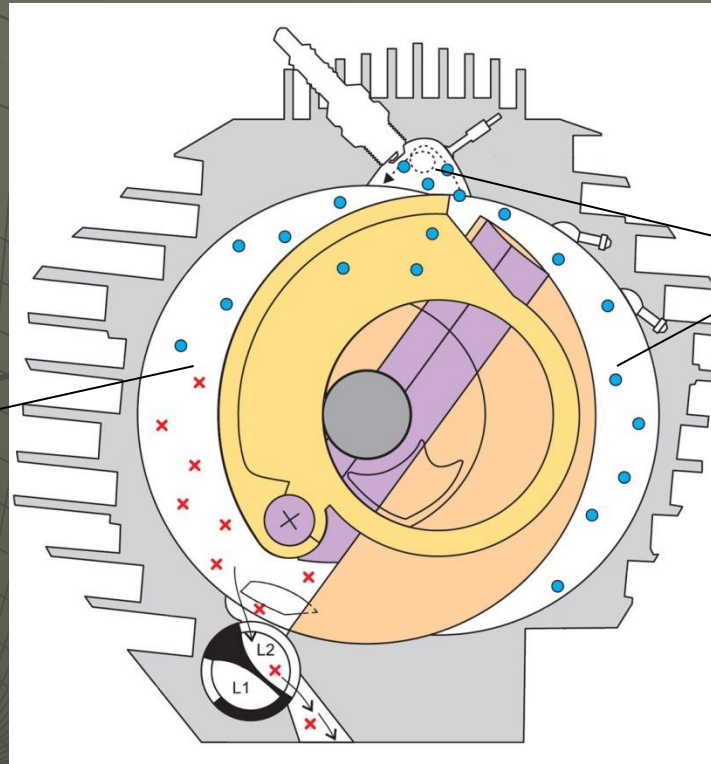


First stage compression almost complete

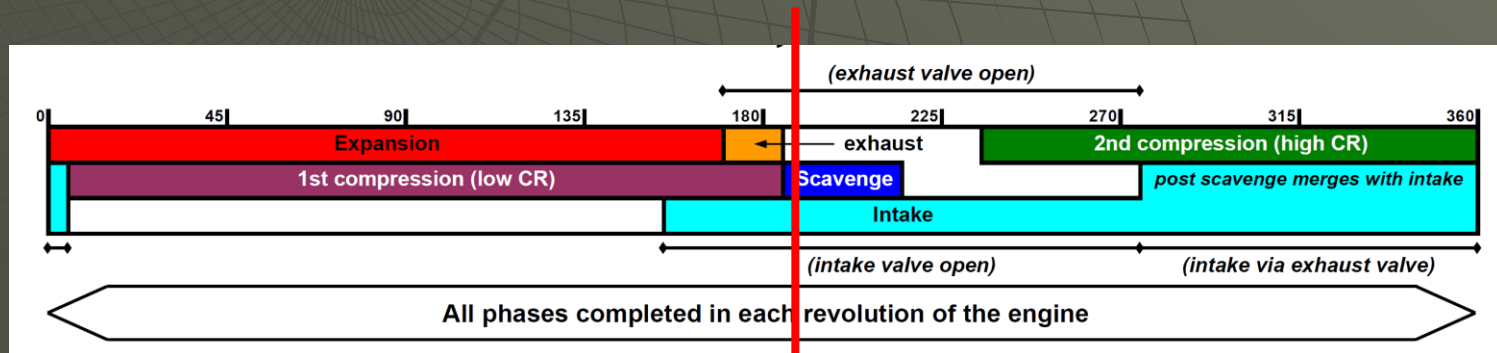


Libralato Cycle

Fresh air scavenges residual exhaust gases completely and cools expansion chamber



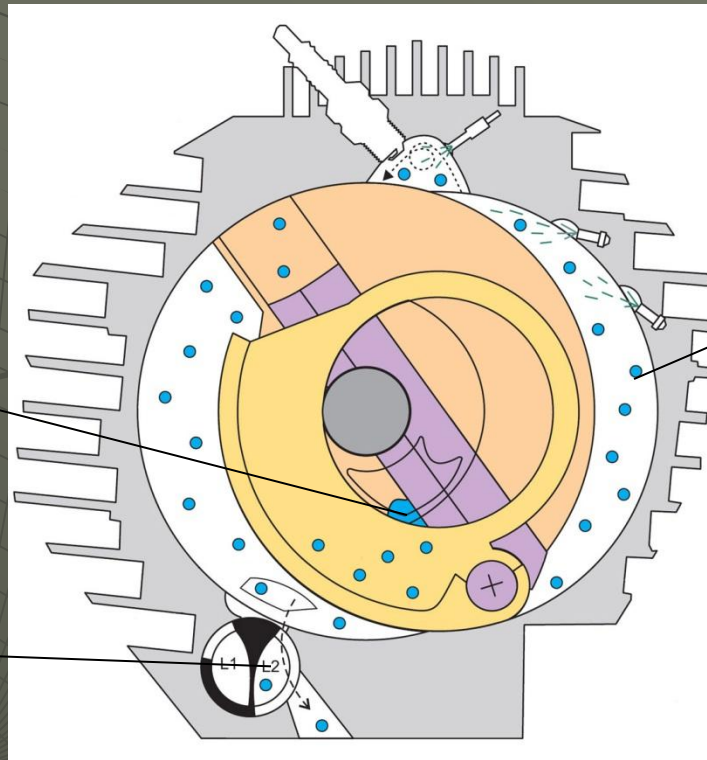
First stage compression complete – combustion chamber forms a bridge between the two sides of the engine



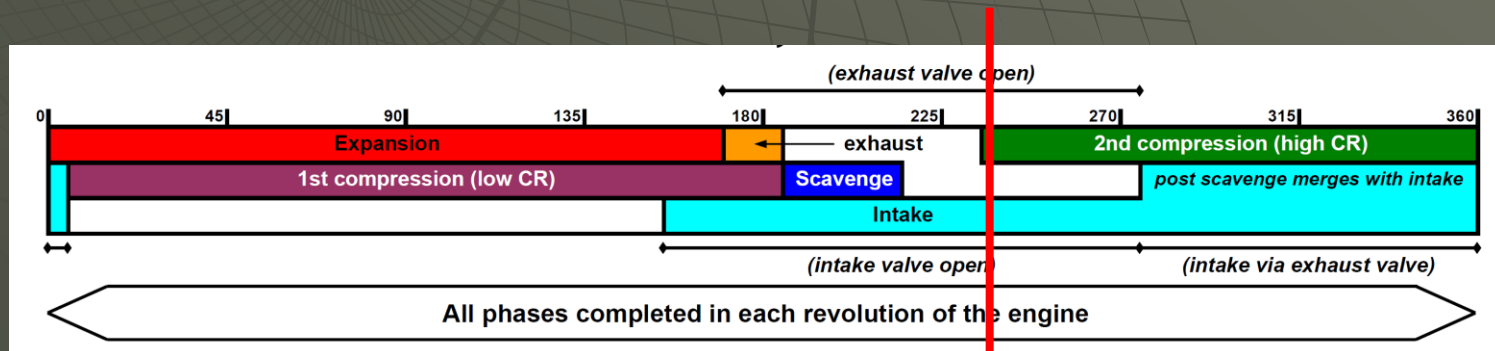
Libralato Cycle

Intake via
central port

Fresh air exiting
— no negative
pressure build up

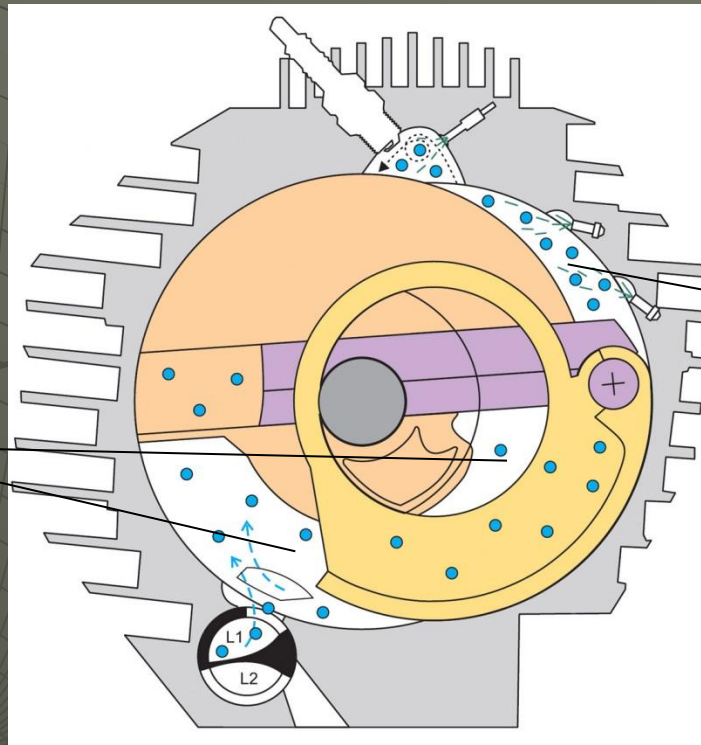


2nd stage
compression
starts

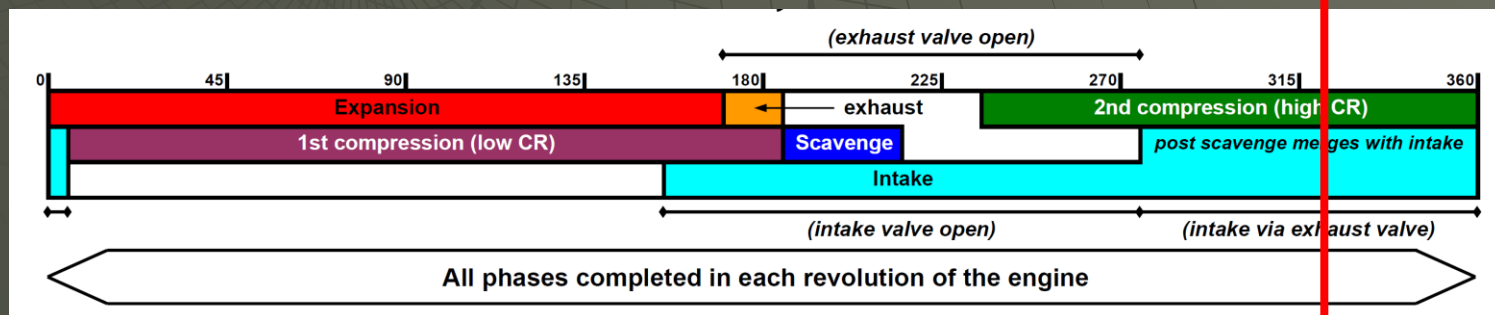


Libralato Cycle

Intake from central port joined by intake via exhaust port

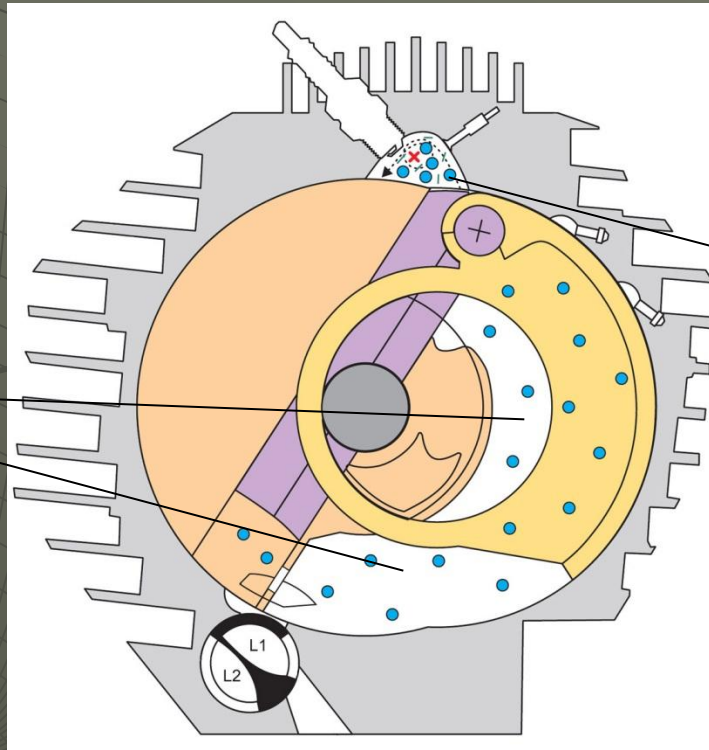


2nd stage compression continues

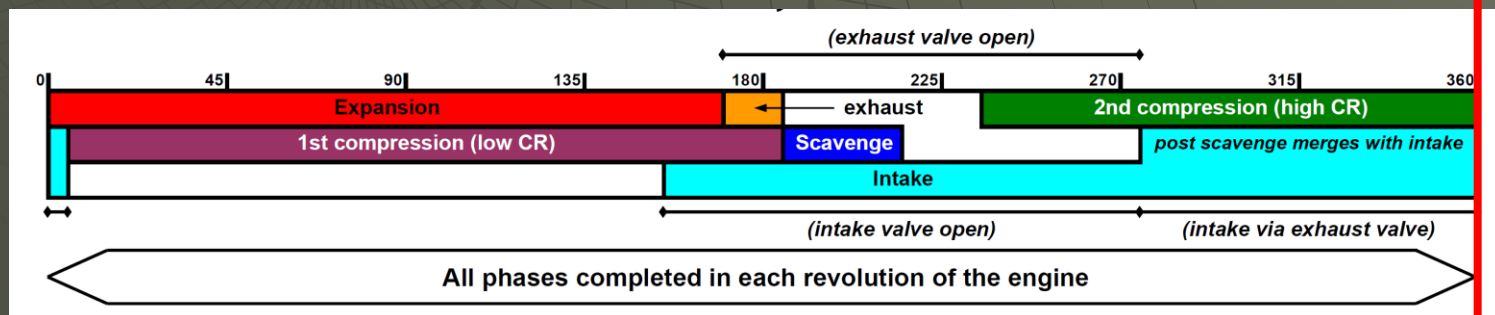


Libralato Cycle

Maximum
intake
volume



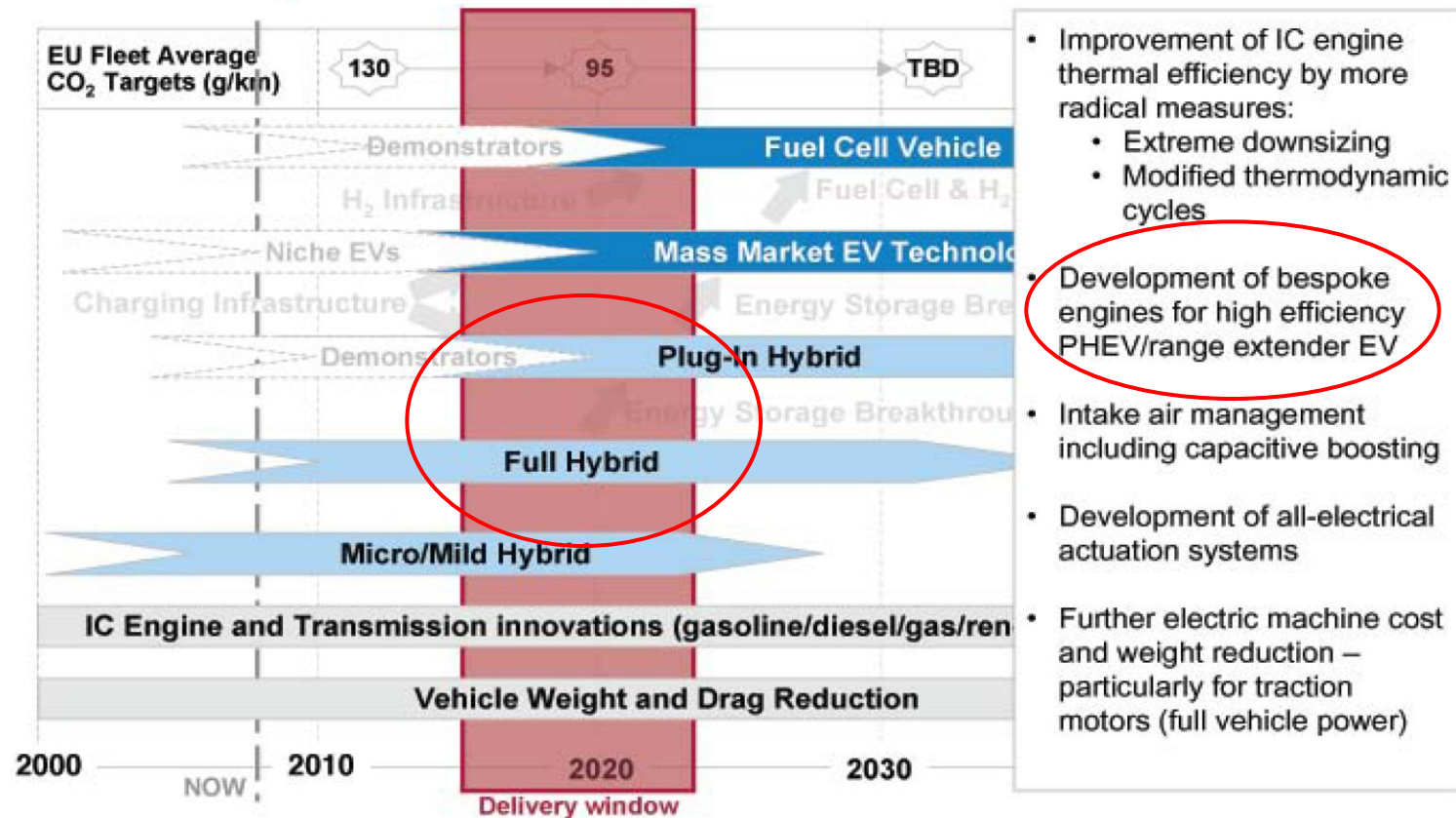
2nd stage
compression
complete –
back to
top dead centre



Powertrain Options 2015 - 2020

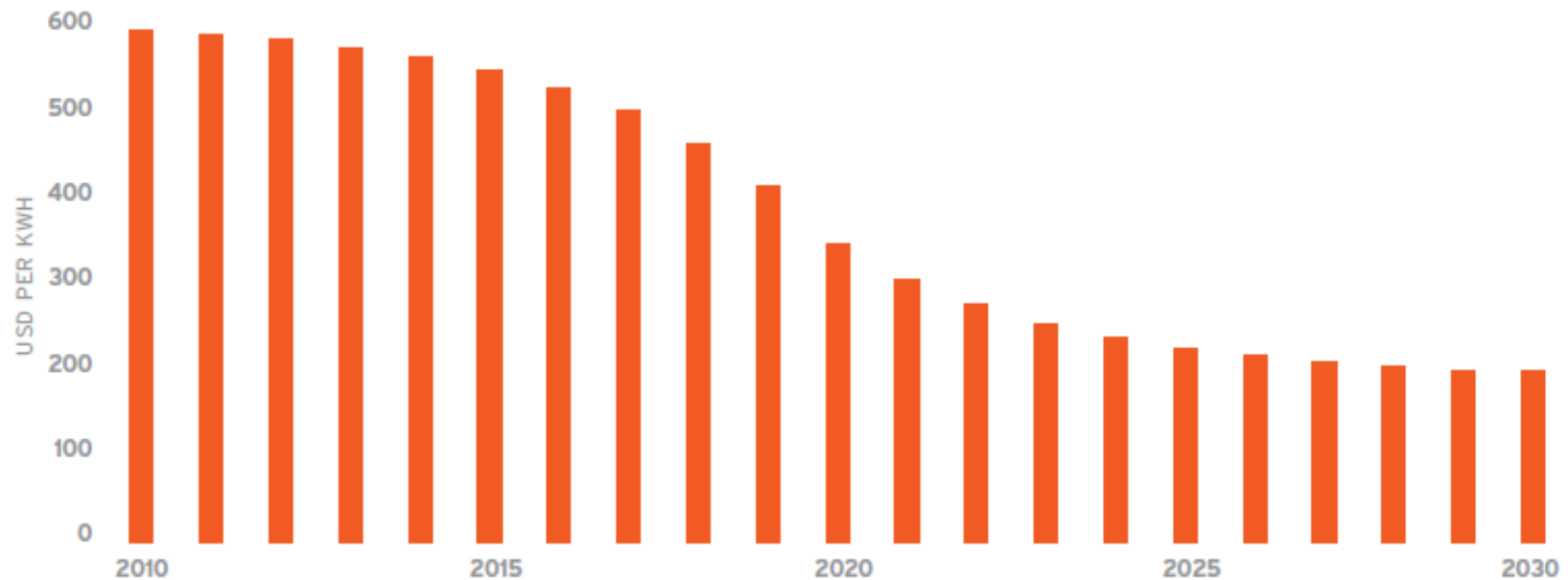
Propulsion technology

– research requirements to support medium term products



Source: UK NAIGT, May 2009

Pure EVs prohibitively expensive for at least a decade

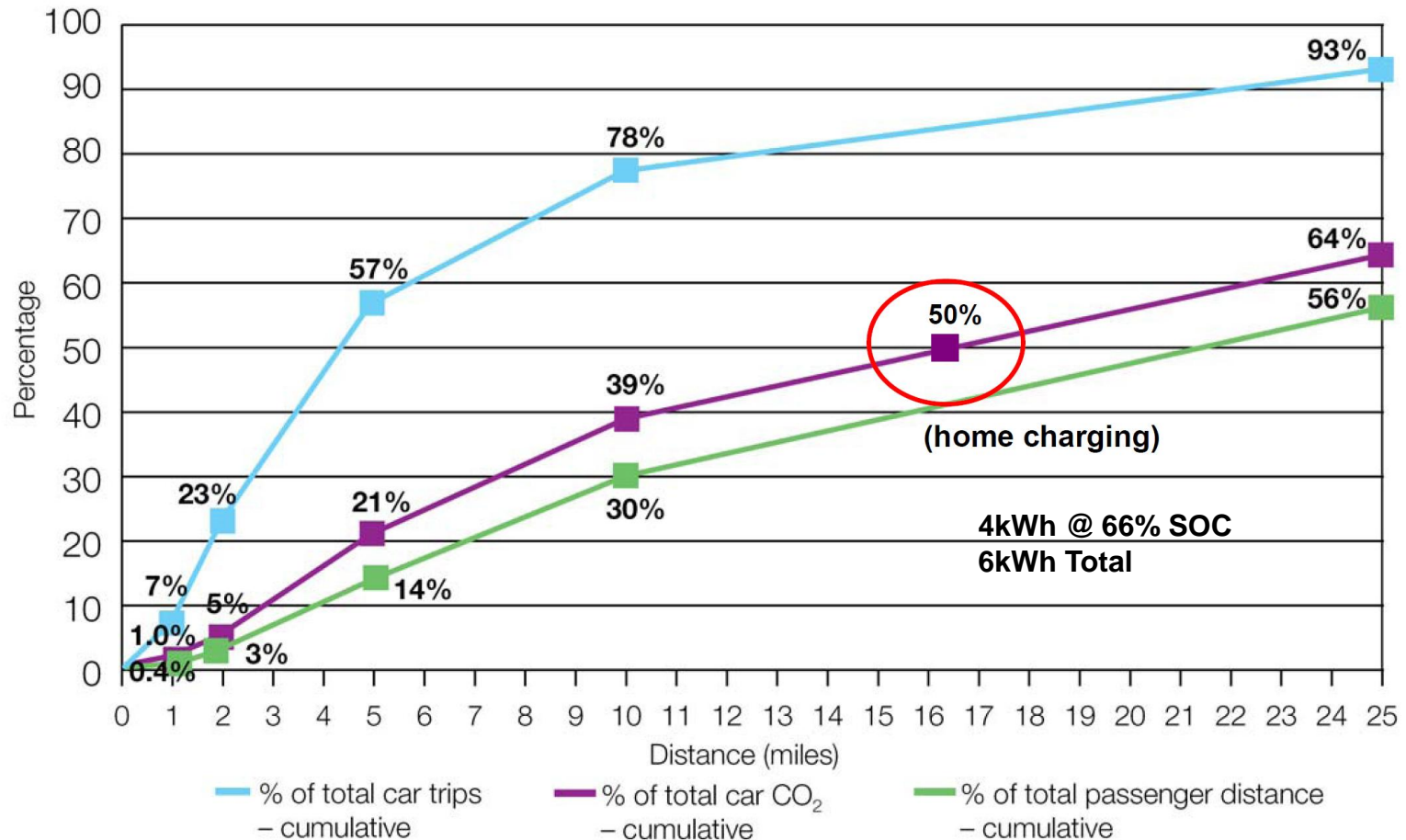


Source: PRTM Analysis

EV - 24 kWh (80 miles) 2015 = \$13,200 / £8,200

HEV/ PHEV - 6 kWh (15 miles) 2015 = \$ 3,300 / £2,000

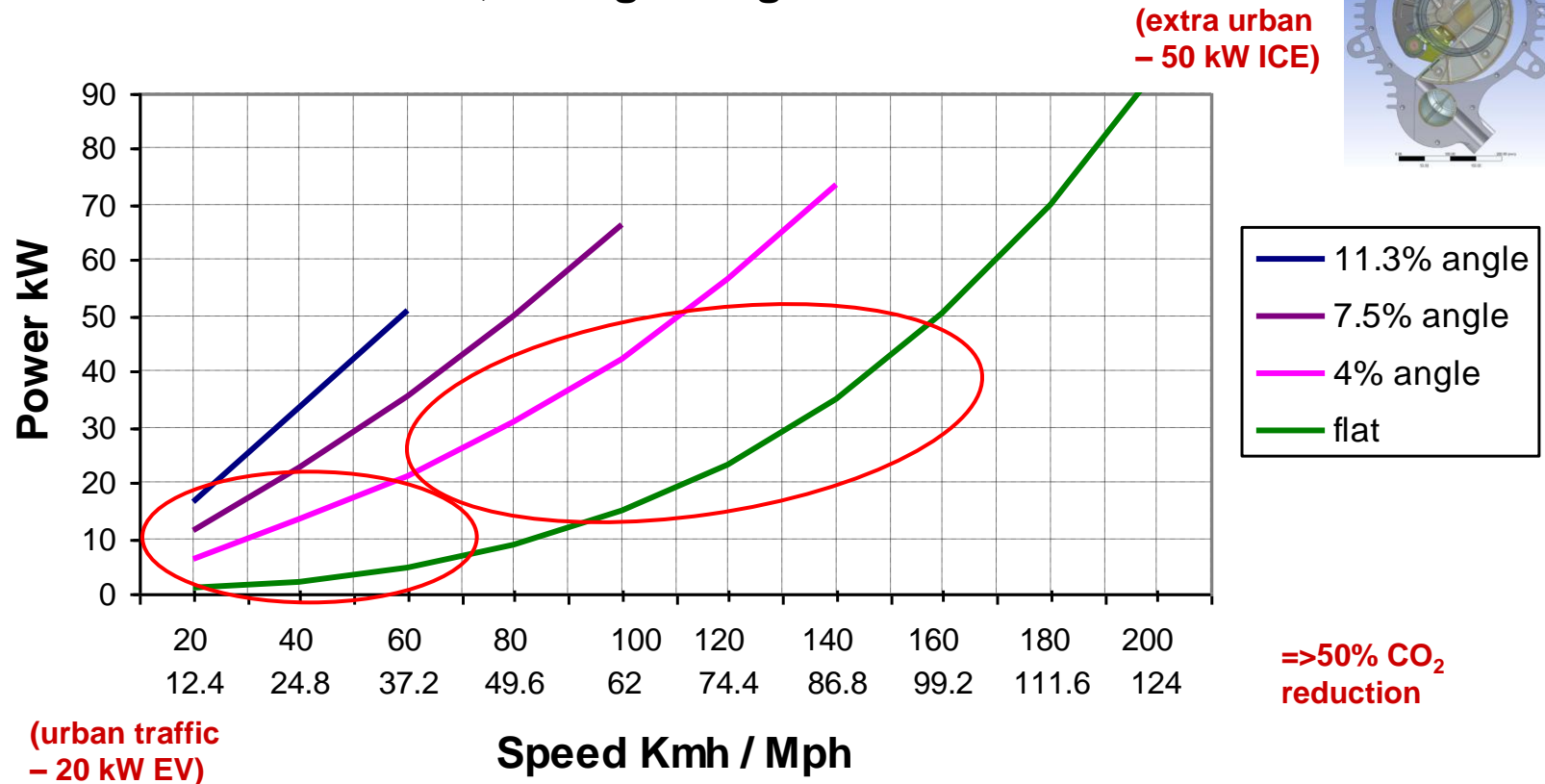
50% of CO₂ under 16 miles!



Cumulative trips, passenger distance and CO₂ emissions from household car journeys by trip length, GB, 2002/2006.
Source: DfT Analysis, 2009

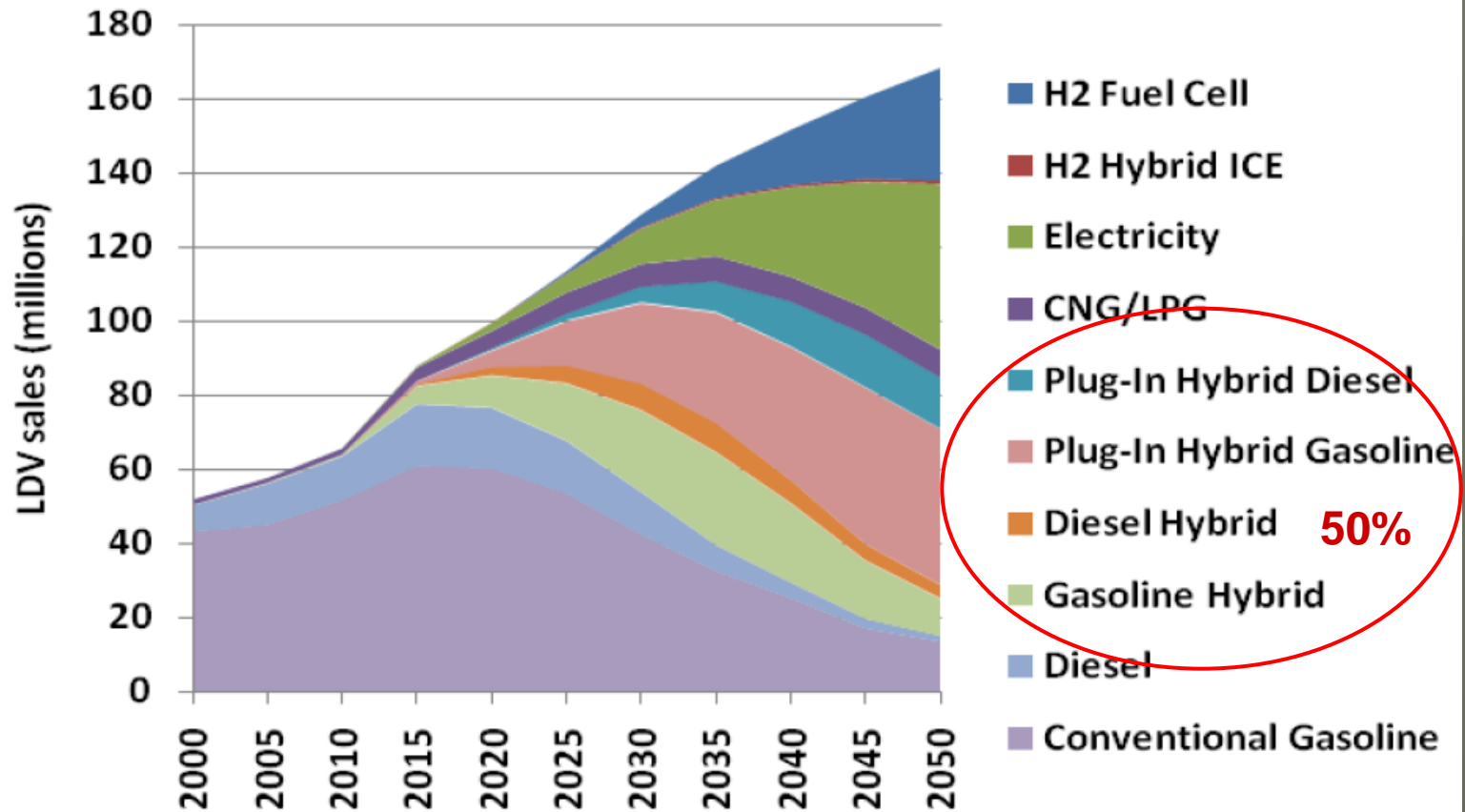
EV in the city / ICE on open road

1,374 Kg C Segment Vehicle



“Town & Country Hybrid”™

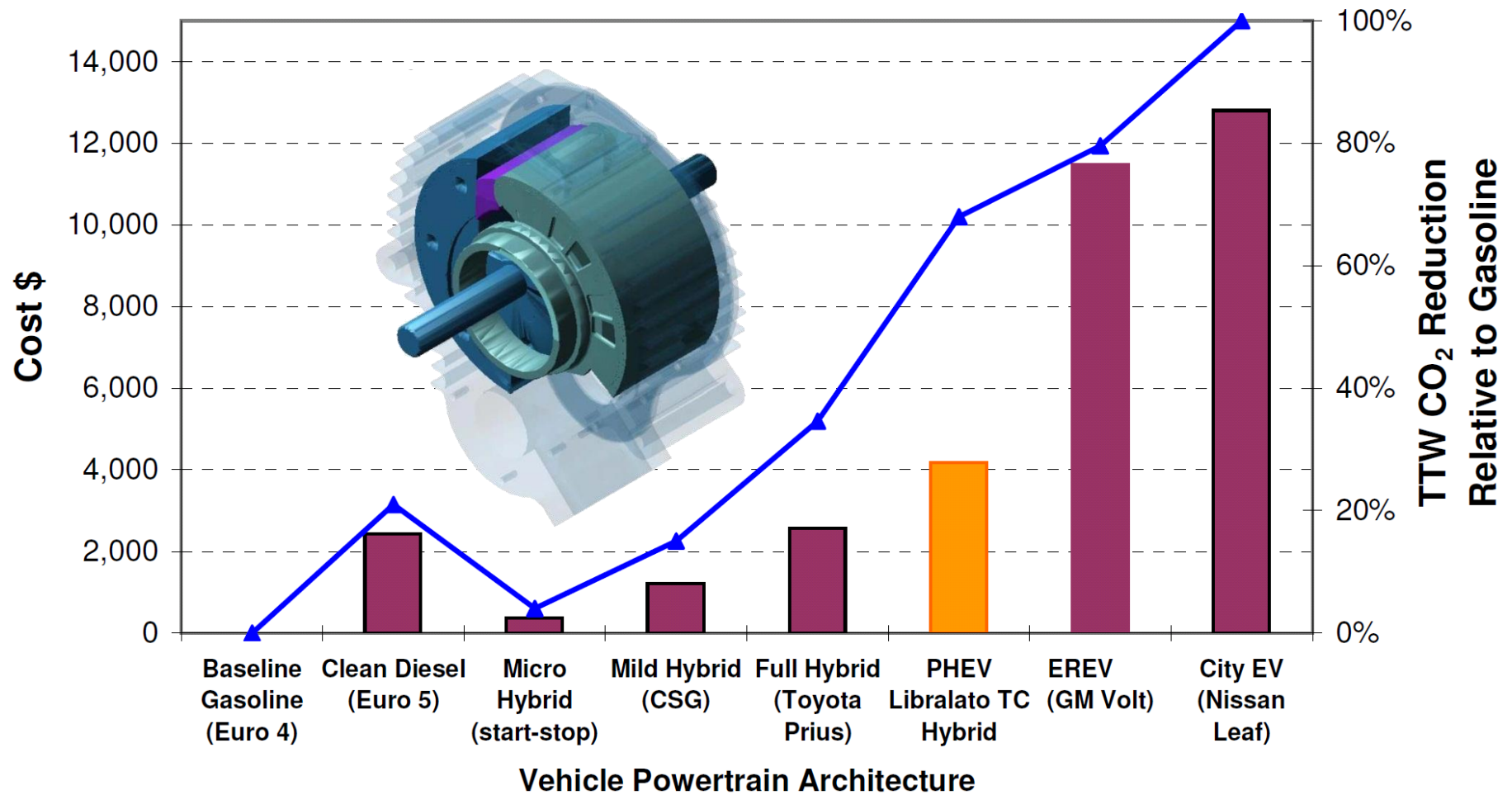
World forecast for low CO₂ vehicles



Source: IEA

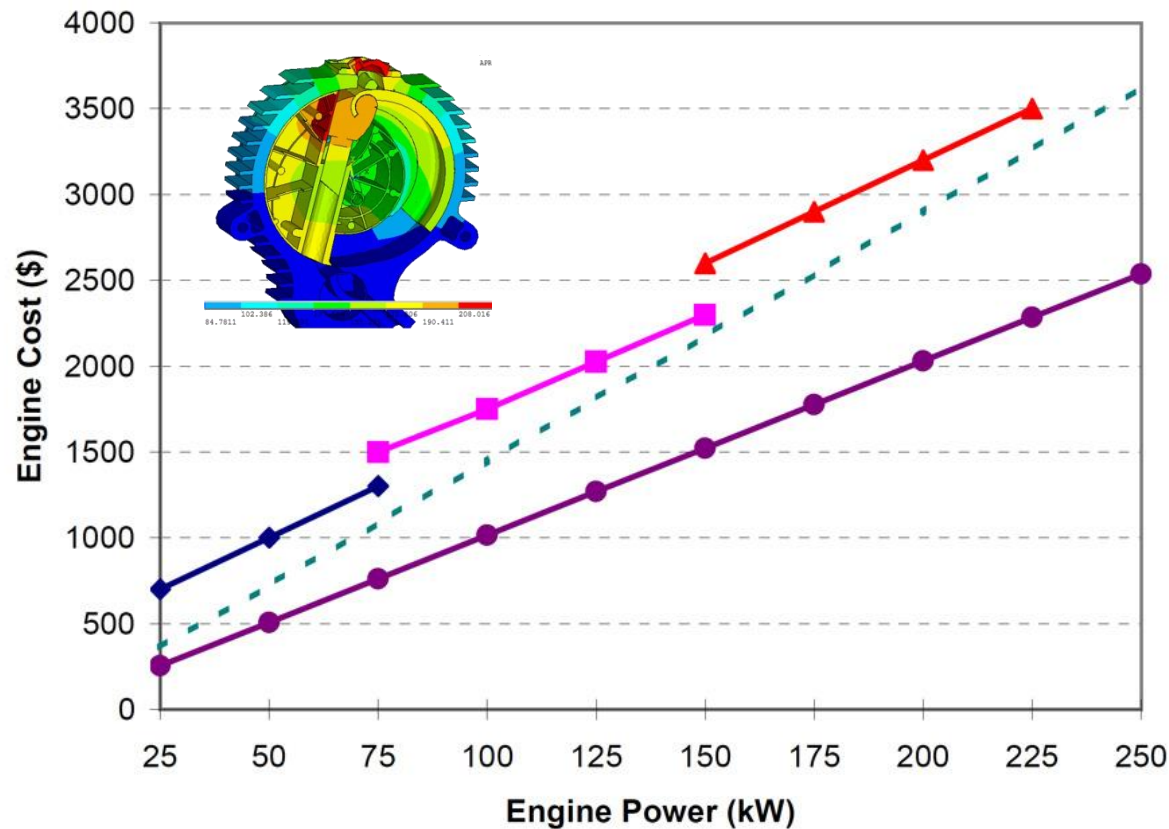
TTW CO₂ v Incremental Cost 2015

Incremental Cost 2015 Percentage CO₂ Reduction (TTW)



Production Costs

Engine Power v Cost



Dispenses with subsystems:

- Crank drive
- Counter balance
- Cylinder head
- Valvetrain
- Induction air charging



Production cost estimate:
\$10/kW; £6/kW

Route to Production

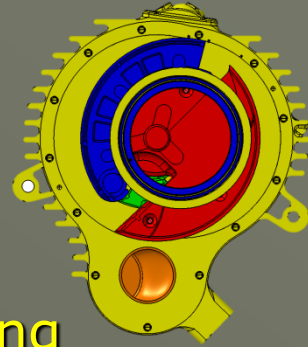
- ◆ Libralato FP7 prototype project (2012-14)
- ◆ Joint development & license agreements with Tier 1s / engine OEMs, including component supply chains (2012-2014)
- ◆ Develop production models (2013-2014)
- ◆ Trial production (2014-15)
- ◆ Engine assembly plant in Manchester UK (2015).
- ◆ OEM engine assembly plants (2015-18)
- ◆ Penetrate markets: HEVs & PHEVs; generator sets; APUs, light planes, boats, helicopters etc. (2015 - 2020)

Collaboration?

- ◆ Infineon Technologies – world no.1 developer of micro-controllers for HEVs / EVs
- ◆ Confidential discussions with IAG member re: non European license and component supply agreement
- ◆ Discussions with MacDonald Humfrey Automation re: assembly plant specifications
- ◆ UK is a world leader in engine development but is facing fierce international competition from firms such as AVL, FEV and EcoMotors.
- ◆ **We are not your competition. We can add unique value to your low CO₂ powertrain developments.**
- ◆ **We are seeking partners to accelerate the development of production models.**

Libralato engine value proposition:

- ◆ Diesel efficiency using petrol
- ◆ Compliant with Euro 6 emissions standards
- ◆ 50kW = 40kg; 50% mass reduction
- ◆ >30% cost reduction +50% downsized = £600 saving
- ◆ Engine + 6 kWh battery fit within standard cavities



Game changer for HEVs/ PHEVs/ ER-EVs:-

- ◆ EV driving in towns & cities
- ◆ Diesel efficiency on the open road
- ◆ Combined avg 107 mpg / 44g CO₂ /km
- ◆ Cost competitive **without subsidy**

Contact: dan.aris@libralato.co.uk