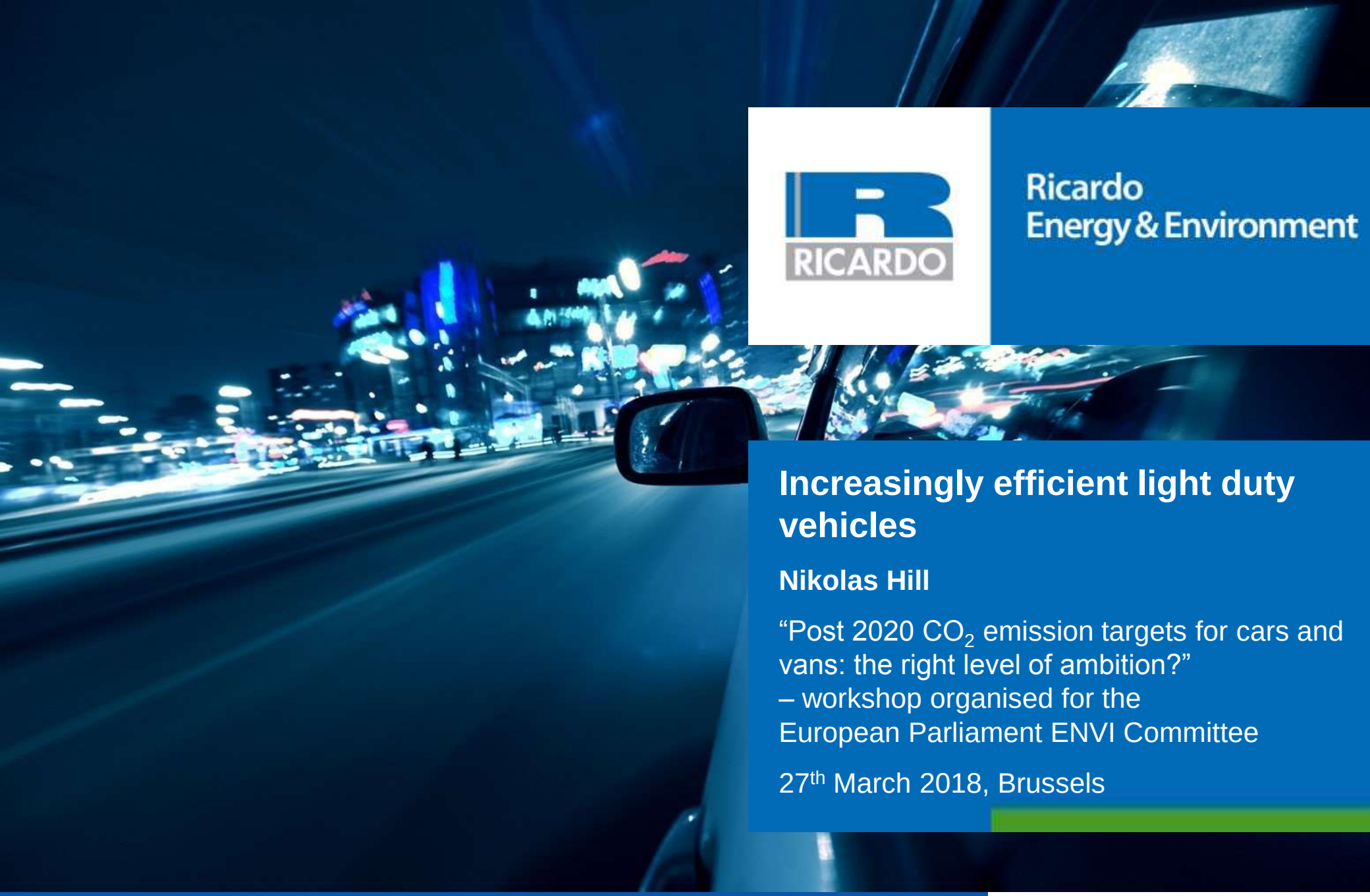


Ricardo
Energy & Environment

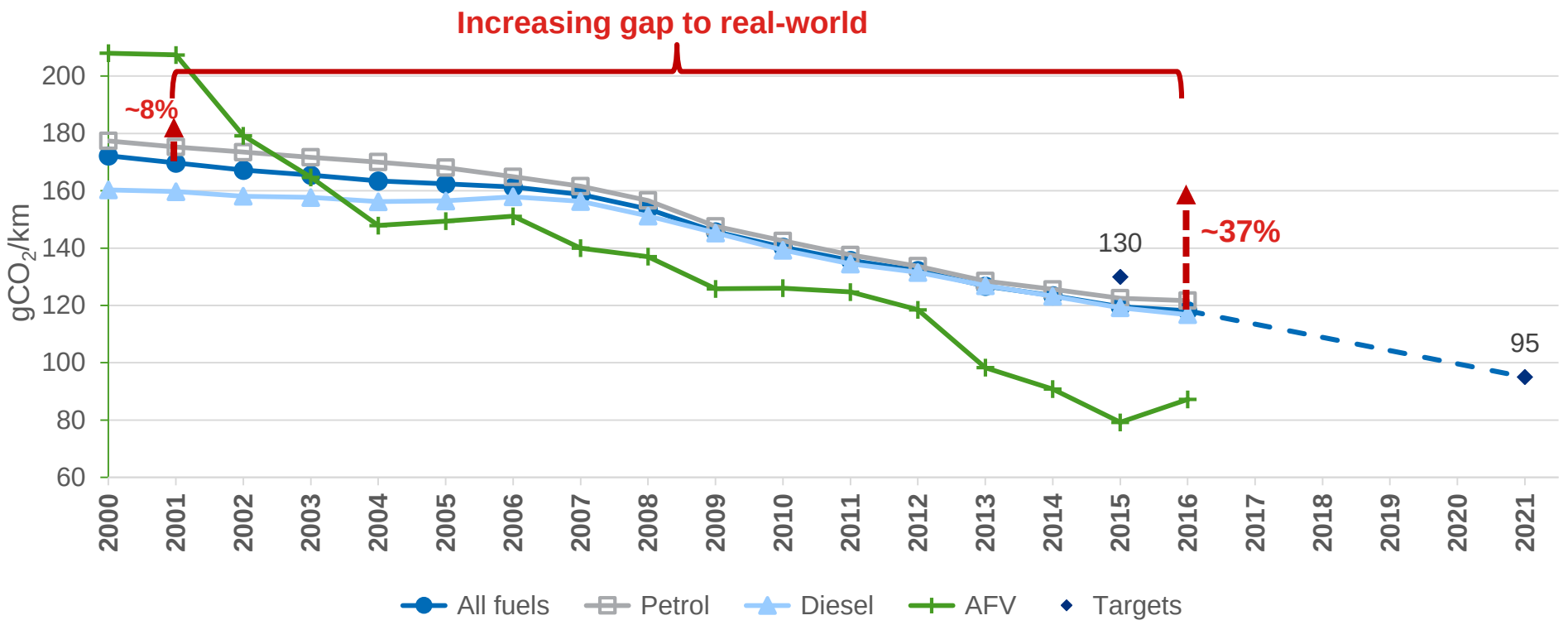
Increasingly efficient light duty vehicles

Nikolas Hill

"Post 2020 CO_2 emission targets for cars and vans: the right level of ambition?"
– workshop organised for the
European Parliament ENVI Committee

27th March 2018, Brussels

Analysis of historical trends shows improvement in official gCO_2/km increased post regulation, but not all is attributable to technology



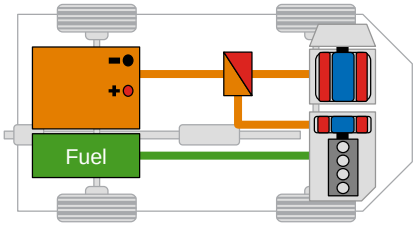
- Until the CO_2 emissions of new passenger cars and vans were regulated, improvements in average fuel efficiency/CO_2 emissions were relatively modest
- An increasing proportion of the improvements have not been reflected in real-world benefits:
  - Analysis of the CO_2 reduction benefits directly attributable to deployed technology up to 2013 has also shown this accounts for only part of the improvement in official gCO_2/km figures

Review of available technical options to improve LDV CO_2 emissions and efficiency showed there are many available for on-/off-cycle

Engine & Transmission

- **25 Engine**
- **8 Transmission**

Hybridisation and EVs



- **6 Hybridisation options**
- **6 xEV powertrains**

Driving resistance

10 technical options:

- Rolling resistance
- Drag reduction
- Mass reduction

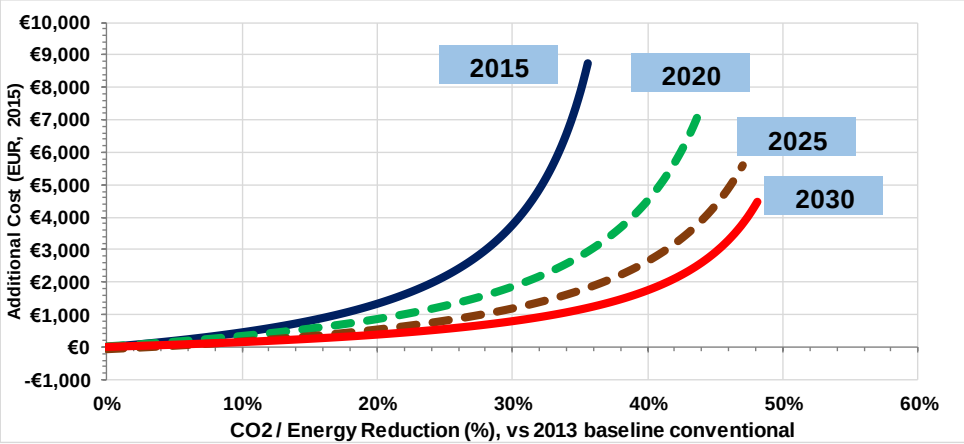
Other and off-cycle

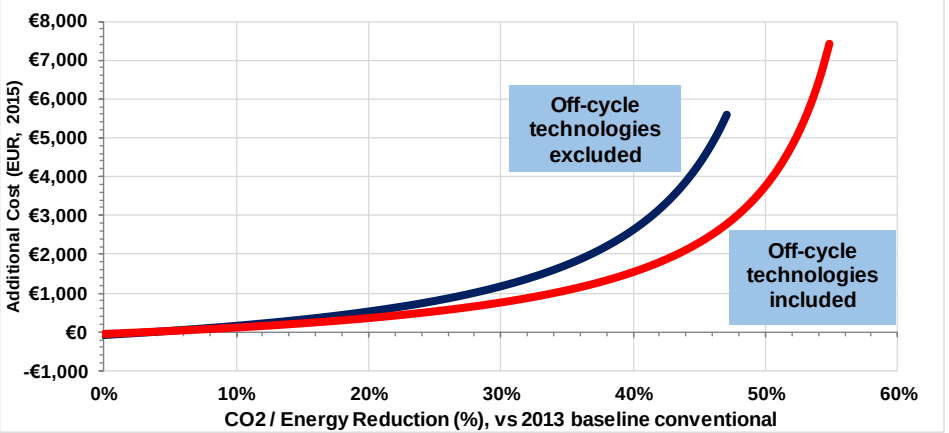
- **8 other on-cycle**
- **21 off-cycle technologies**

- There are many technical options available for reducing CO_2 and/or improving efficiency of cars and vans
- Some options are already available with varying deployment in the marketplace
- Most options show benefits in regulatory testing (i.e. NEDC, WLTP)
- Some options show only real-world benefits, but are not captured in regulatory tests
  - Only some of these are covered by the current eco-innovation provisions

Comparison of derived WLTP cost curves shows significant remaining improvement potential and cost reduction by 2030

WLTP cost curves for gasoline (including hybrid) cars (vs 2013 baseline)





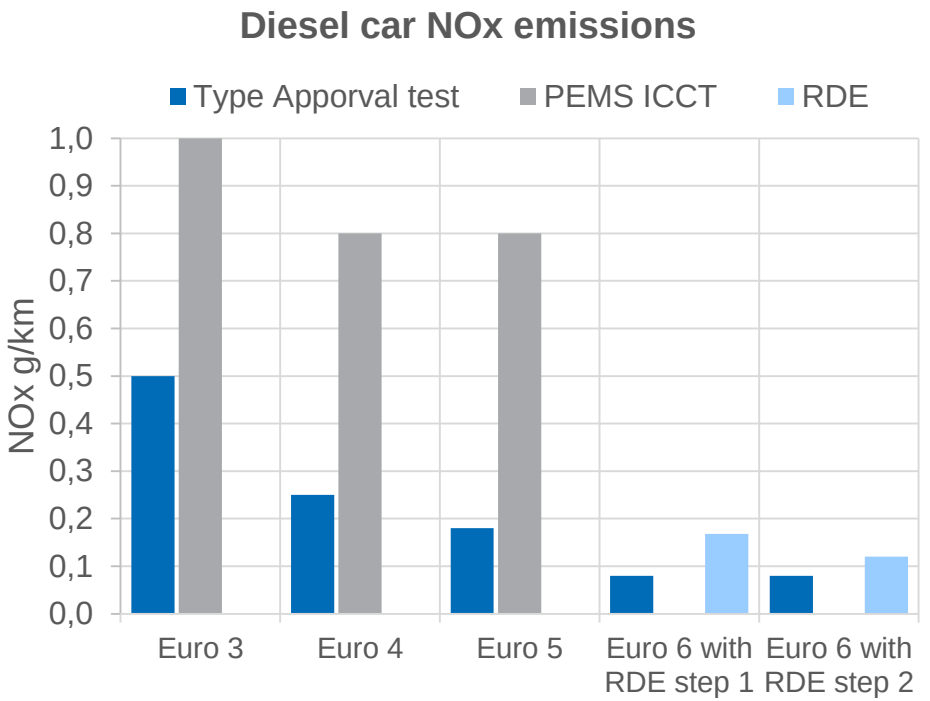
Year	Max CO_2 reduction potential (%)	Max additional cost (€, 2015)
2015	35.6%	€8,741
2020	44.0%	€7,435
2025	47.1%	€5,593
2030	48.1%	€4,474

Off-cycle technologies	Max CO_2 reduction potential (%)	Max additional cost (€, 2015)
Excluded	47.1%	€5,593
Included	54.8%	€7,420

- The development of cost-curves and projections for cost reduction demonstrate significant available technical improvement potential (including accounting for historic technology uptake)
- **Note:** Under WLTP the total cost is higher and % improvement potential is lower than for NEDC
- Inclusion of 'off-cycle' technologies has the potential to significantly reduce the average costs real-world improvements

The share of diesel sales in key European markets has fallen for the first time in 2017 with implications for reduction potential and cost

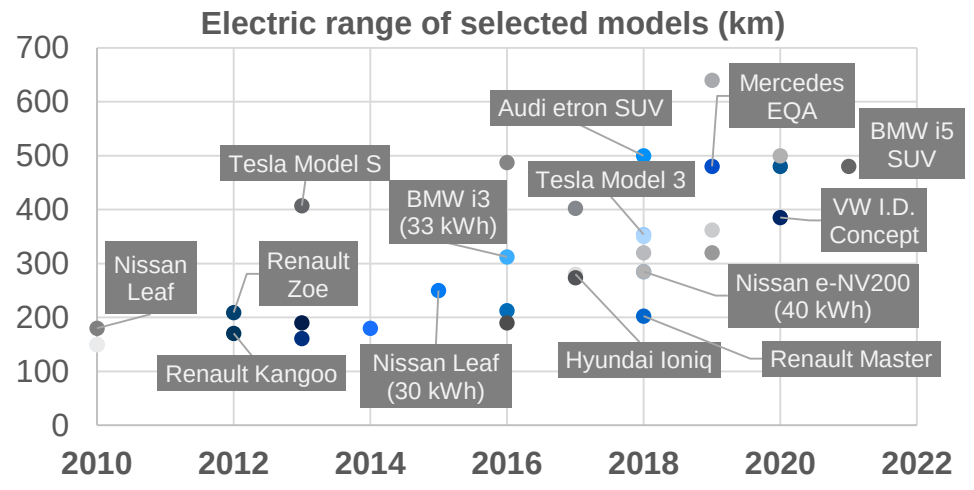
- **Euro 6 with RDE will significantly address current issues with real-world NOx (/NO_2)**
  - Cost of compliance likely to increase diesel ICEV costs versus petrol
  - Euro 6 vehicles unlikely to be excluded in most LEZs / CAZs under development
- **However, already seeing impacts of dieselgate (mainly shift to petrol, hybrid)**:
  - Loss of confidence from public in diesel – German registrations down 18% in October ’17, and UK diesel car registrations down 30%
  - OEMs removing car diesel engine options
  - Still uncertainty on implications for urban air quality control (e.g. LEZ, etc.) being planned
  - Potential risk for diesel residual values?
  - **Net reduction in CO_2 reduction potential**
- **Hybridisation is a less beneficial match for diesel versus petrol**
  - Recent analysis by Ricardo for existing diesel-hybrid models showed worse NOx emissions vs conventional diesel vehicles
- **In van market impacts likely lower, competition mainly with EVs**



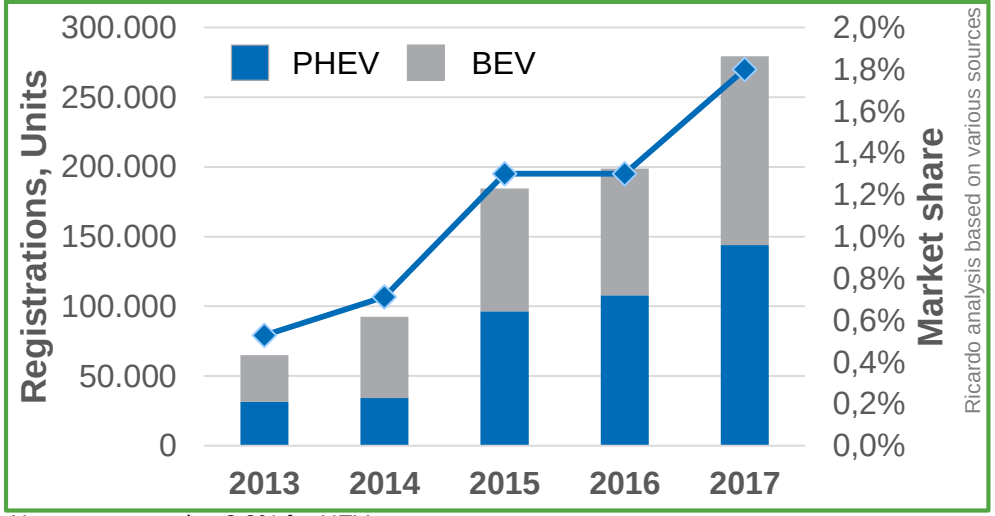
Source: SMMT (2017)

Electric vehicle and charging technology is improving: battery costs are coming down, electric range is increasing and TCO reducing

Technology improvements

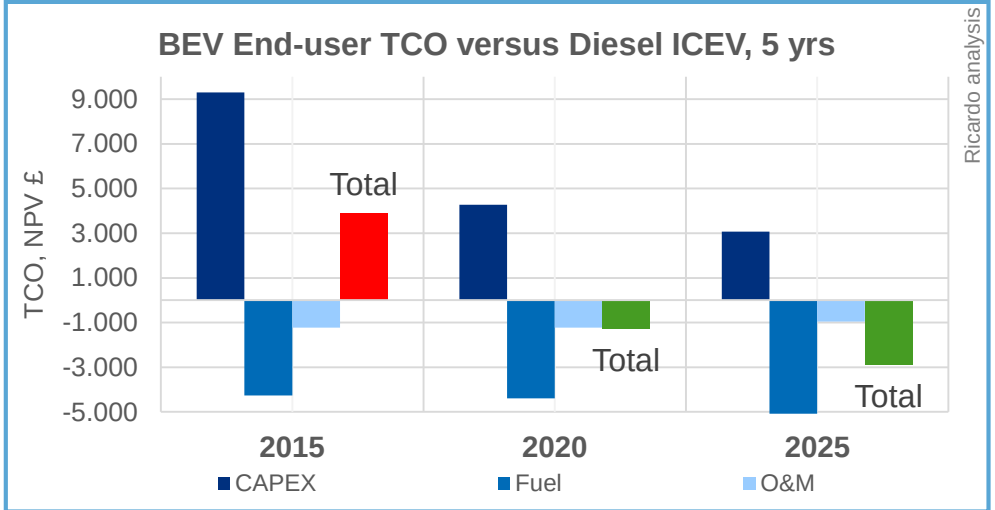


Registrations in Europe



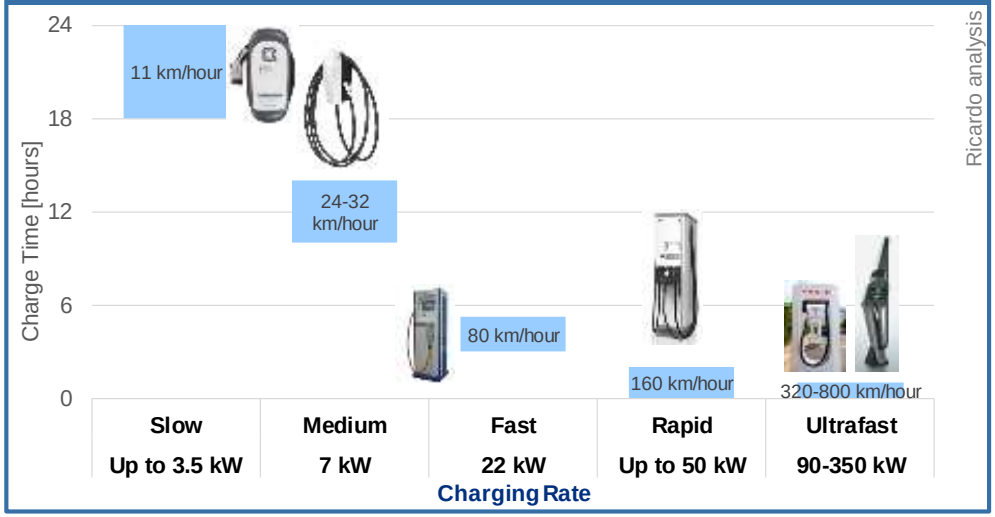
Notes: compared to 2.9% for HEVs

Av. van end user total cost of ownership, 5 yrs

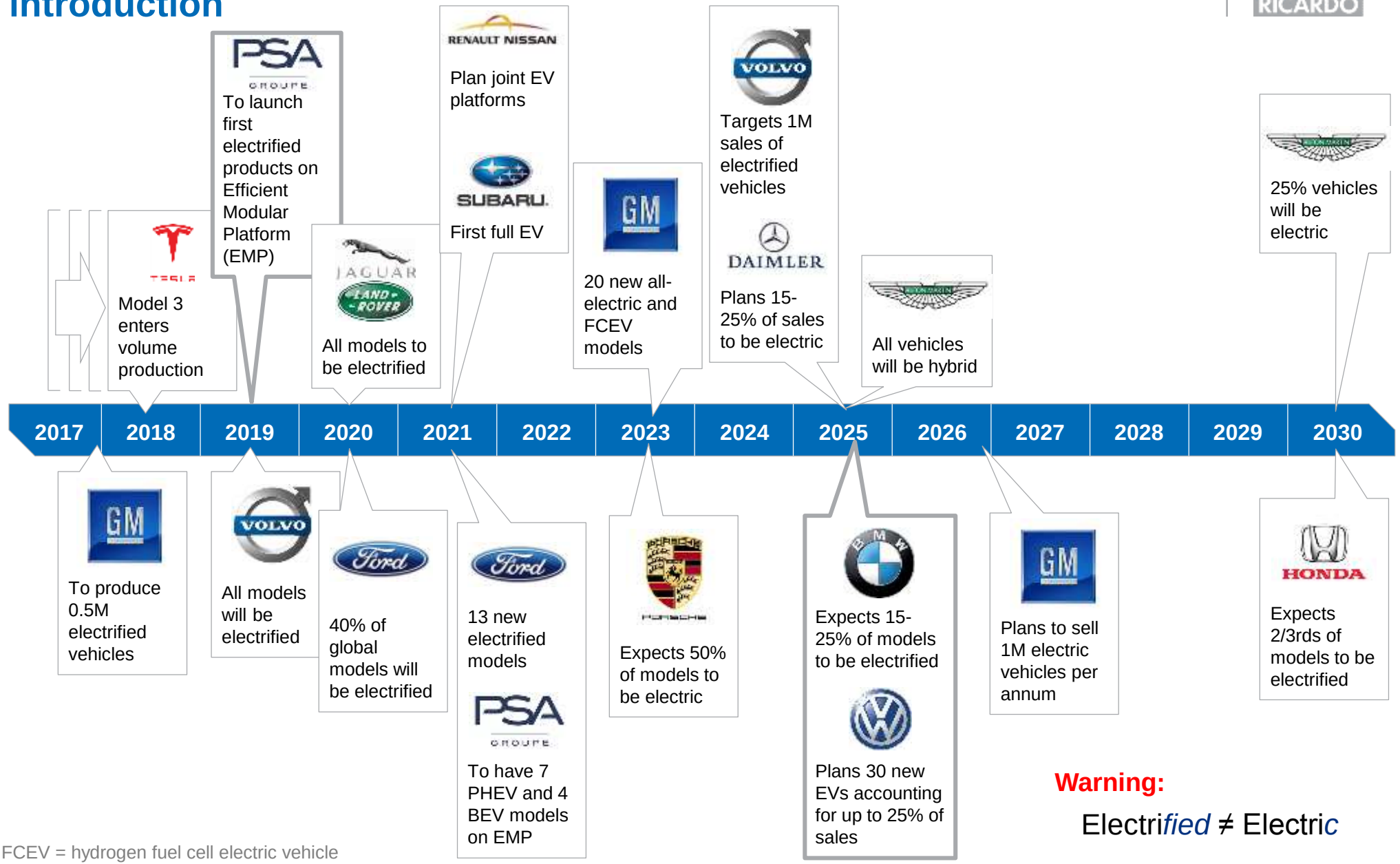


Notes: Assumes 10% discount rate for Net Present Value of future costs/savings

Charging infrastructure



OEMs state they are committed to electrified and electric vehicle introduction

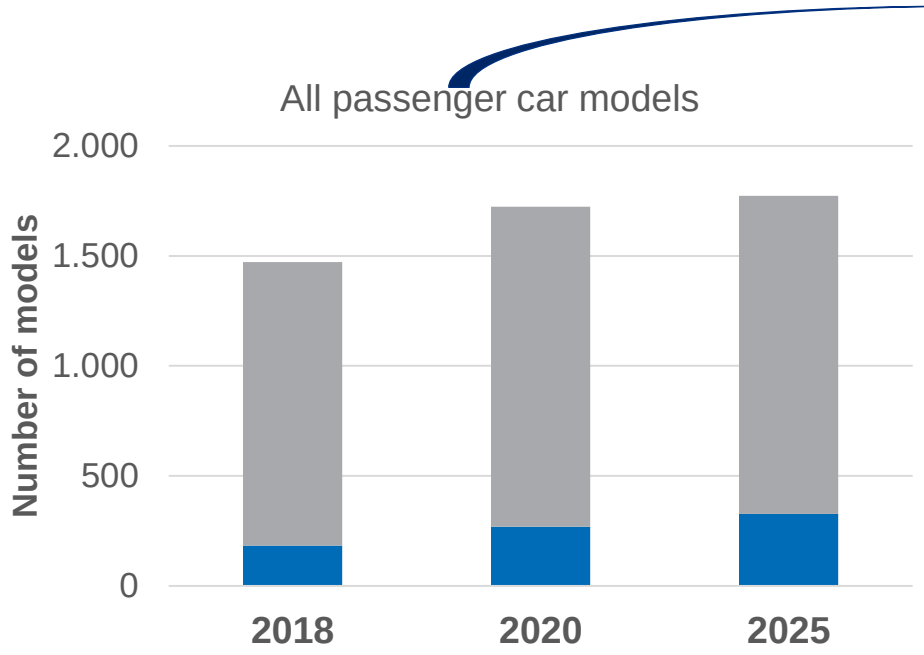


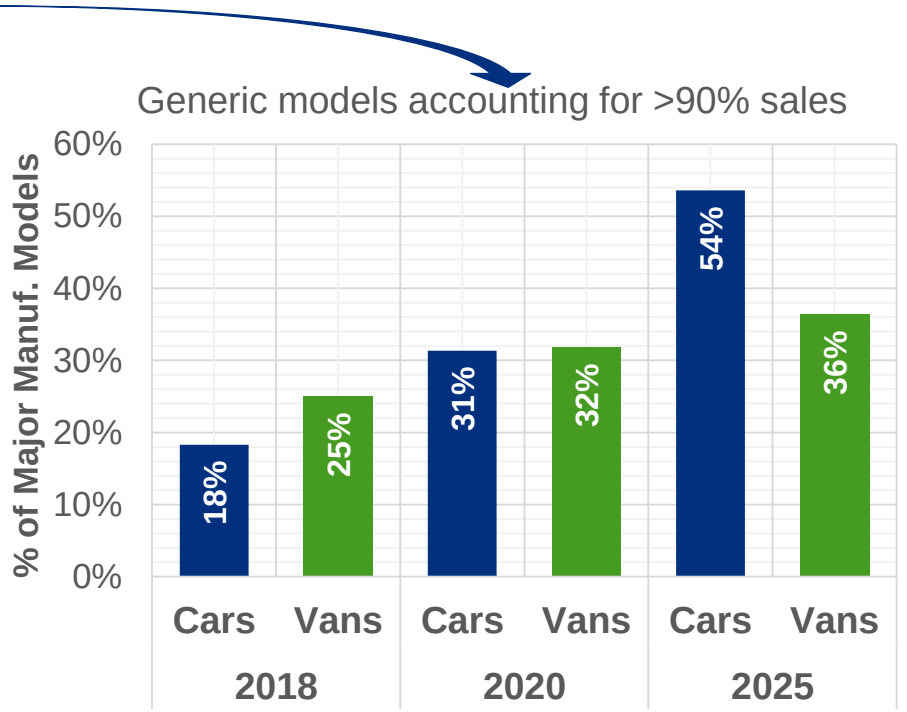
Warning:

Electri*fied* ≠ Electri*c*

FCEV = hydrogen fuel cell electric vehicle

By 2025 it is expected that over 50% of the car models responsible for the majority of EU sales will have electric (BEV / PHEV) versions

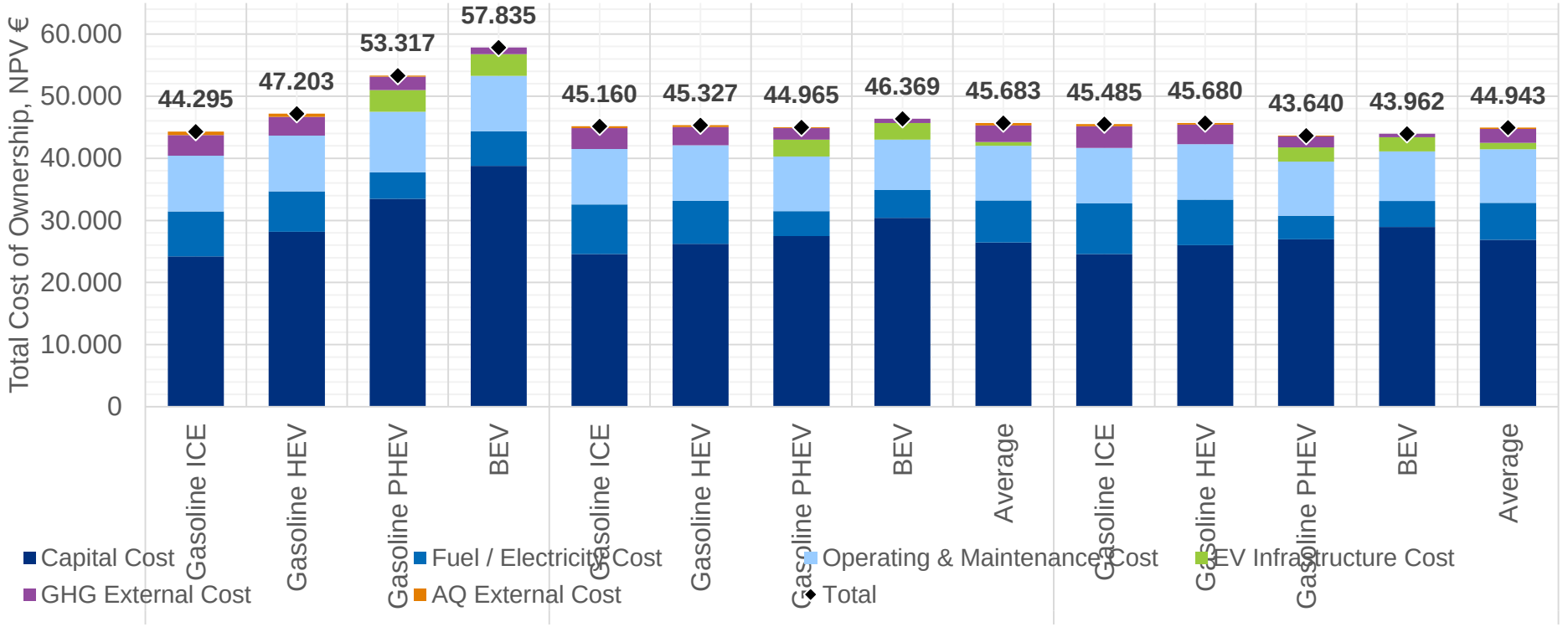




- Currently most manufactures have limited model availability, with only one or two models in only certain consumer segments
- Based on OEM launch and strategy announcements this is expected to change dramatically:
  - >50% car models responsible for the majority of sales are expected to have electric versions
- Market incentives and infrastructure provision underlie the success in key EU markets to date

xEV Total Cost of Ownership is expected to reach parity with ICEVs after 2025; including external costs enhances improvement benefits

Societal (lifetime) Total Cost of Ownership by powertrain, passenger cars



- Various analyses suggest end user cost parity for electric vehicles may occur between 2025-2030
  - This is also supported by Ricardo's internal analysis
- Analysis of TCO from the societal perspective also suggests parity when including external costs
- Ricardo's analysis suggests the societal perspective average net benefits are greatest at over 40% reduction ambition, versus the baseline, when also including GHG and AQ external costs*

* *Source*: https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ldv_post_2020_co2_en.pdf

The overall conclusion is that there remains very significant cost-effective potential for improvement in LDV CO_2 emissions

- There are many technical options available to improve efficiency of conventional powertrains and also alternative low or zero emission / electric powertrains (xEVs)
  - Utilisation of 'off-cycle' technical options could reduce real-world reduction costs
- There have been questions raised on the future role of diesel for cars with respect to cost/CO_2 reduction/air pollutant emissions considerations:
  - Some OEMs discontinuing diesel options from market (e.g. Toyota, Porsche, FCA)
  - The rise of mild / 48V hybrids is widely expected to fill 2020 gap at similar/lower cost
  - However, overall net reduction potential by 2030 may be impacted → more xEVs
- xEV powertrains cost is rapidly reducing, the number of available models increasing – anticipated to cover over half of models accounting for >90% EU sales by 2025
  - Some suggest further investment in engine improvements/R&D may be limited
- Analysis of the total cost of ownership (TCO) for average new vehicles shows:
  - Greatest net benefits to end-users and society for 30% reduction for cars
  - Also there are still net benefits even up to 50% reduction versus the baseline case
  - Including accounting for GHG and AQ pollutant damage costs significantly improves the TCO net benefits from the societal perspective for higher ambition levels

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