What will you be driving in 2040?

Sam Akehurst
Professor of
Advanced
Powertrain Systems

The challenges of a low emissions and CO_2 future

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What is a Powertrain?

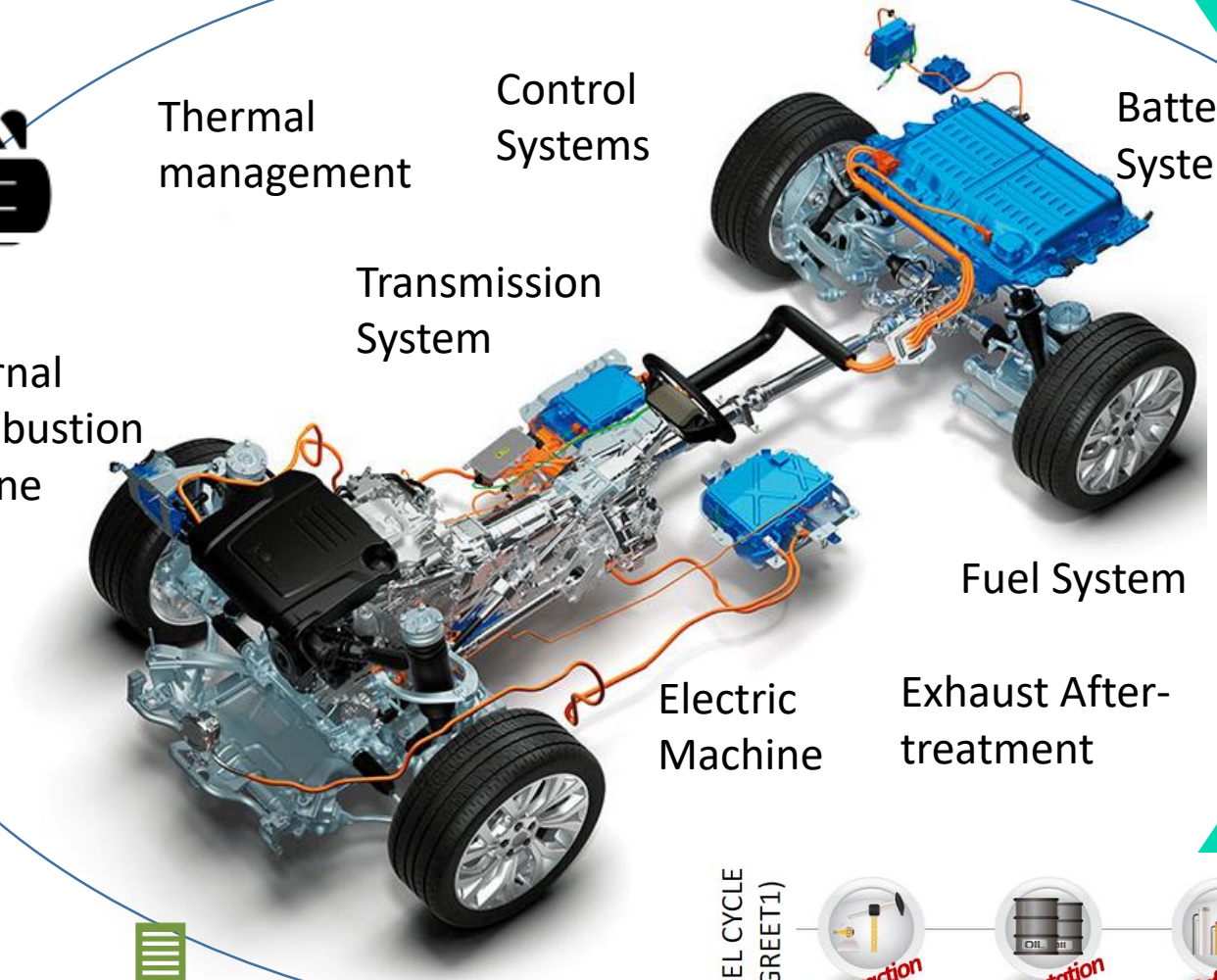
Thermal management

Control Systems

Battery System

Transmission System

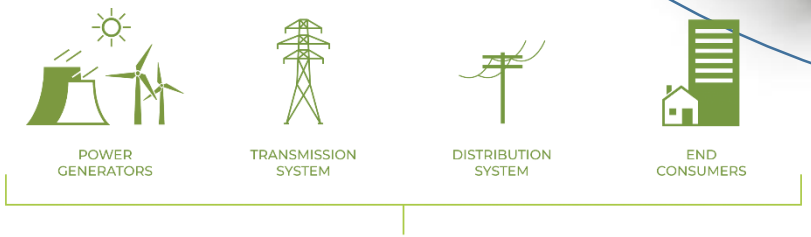
Internal Combustion Engine

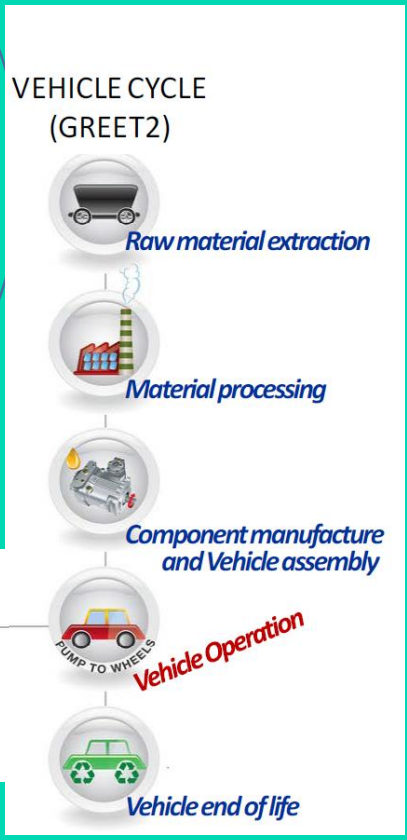


Fuel System

Electric Machine

Exhaust After-treatment





What were you driving 20 years ago?

Rover 100
K-series 1.0 L PFI engine
Range anxiety due to small fuel tank!

Year 2015 Ford S-Max 2.0L Diesel
Average fuel consumption ~45-55MPG
Euro6 Emissions compliant

Year 2000 Renault Megane 1.6L PFI
Average fuel consumption ~35MPG

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So What's the Big Problem?

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Pollution, Congestion, Global Warming

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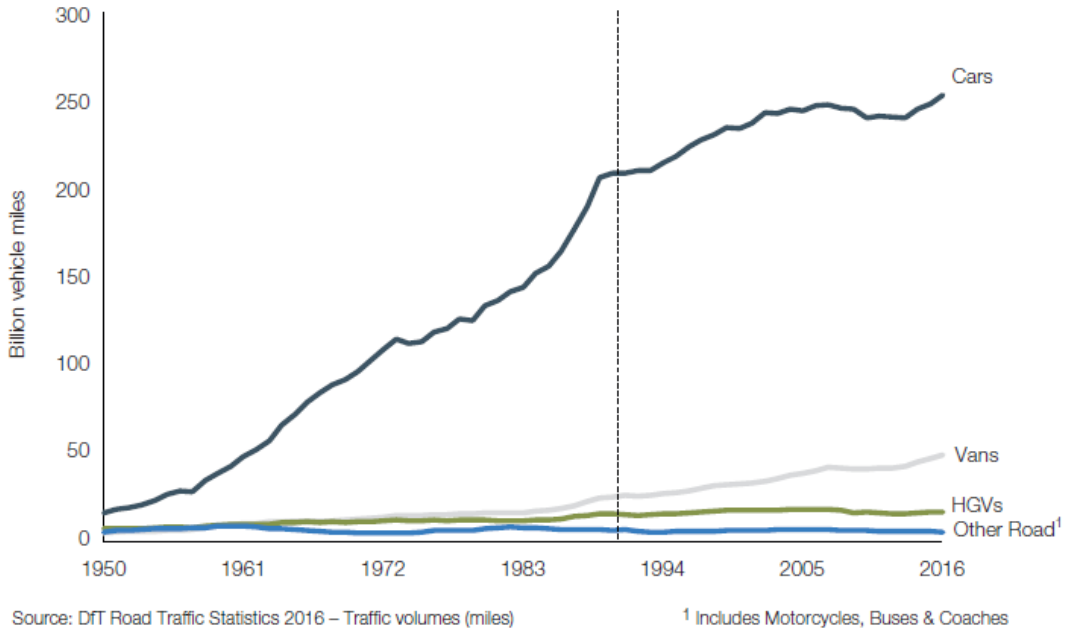
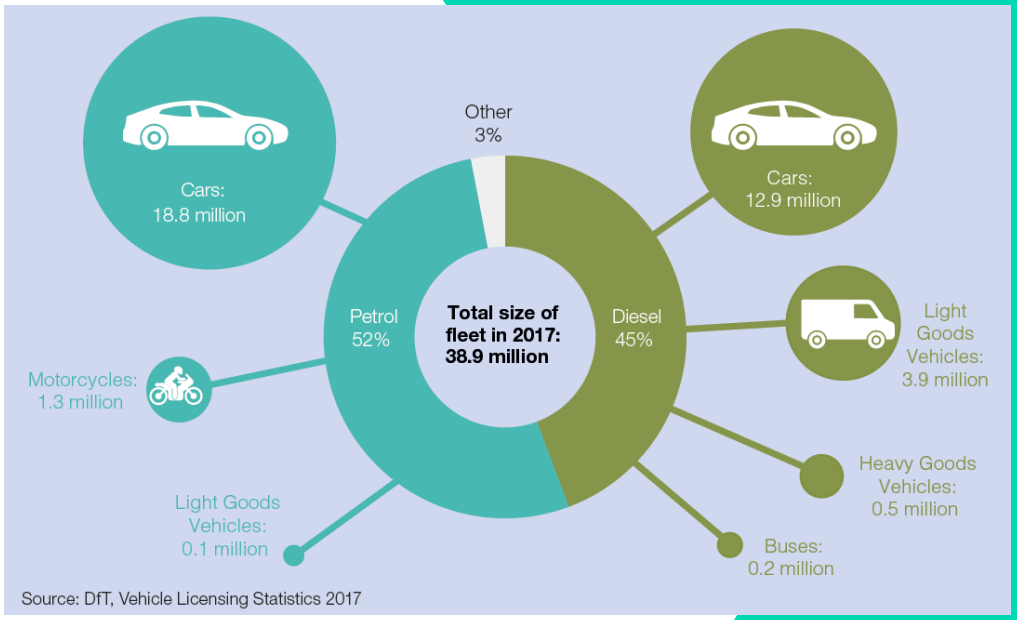
The Scale of the Challenge



Source: DfT Road Traffic Statistics 2016 – Traffic volumes (miles)

[1] Includes Motorcycles, Buses & Coaches



Source: DfT, Vehicle Licensing Statistics 2017

Globally

- 131.4 million births per year
- ~100million motor vehicles are made per year
- >200million engines are manufactured per year
- ~1.5x the human birth Rate!

In the UK in 2017 new vehicle volumes were

- 2.5 million cars
- 362,000 light goods vehicles
- 52,000 heavy goods vehicles
- 115,000 motorcycles

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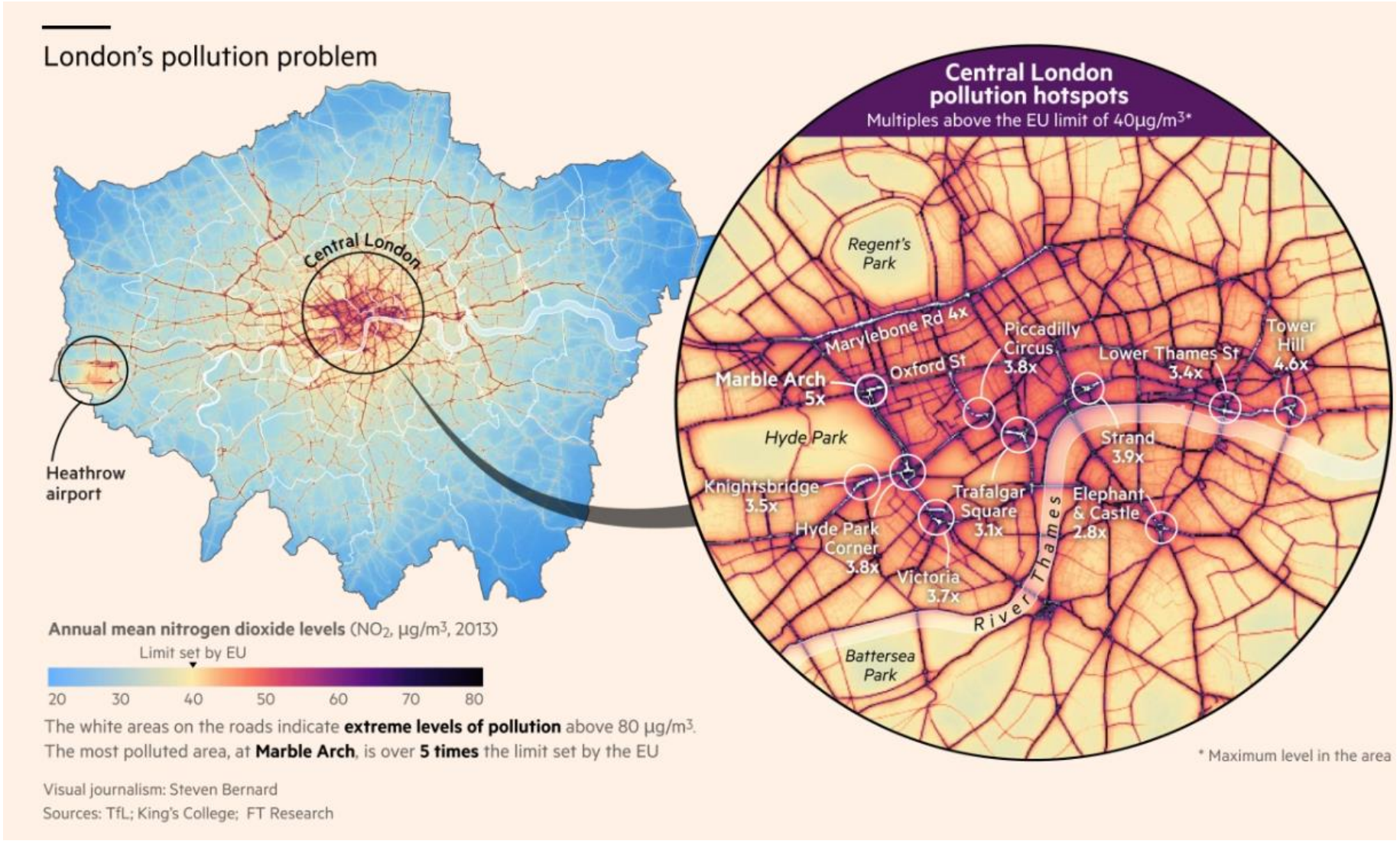
http://www.oica.net/category/production-statistics/2017-statistics/
IJER editorial: The future of the internal combustion engine, R D Reitz, H Ogawa, R Payri, et al. ,First Published September 24, 2019 Editorial, https://doi.org/10.1177/1468087419877990

So how bad is London?



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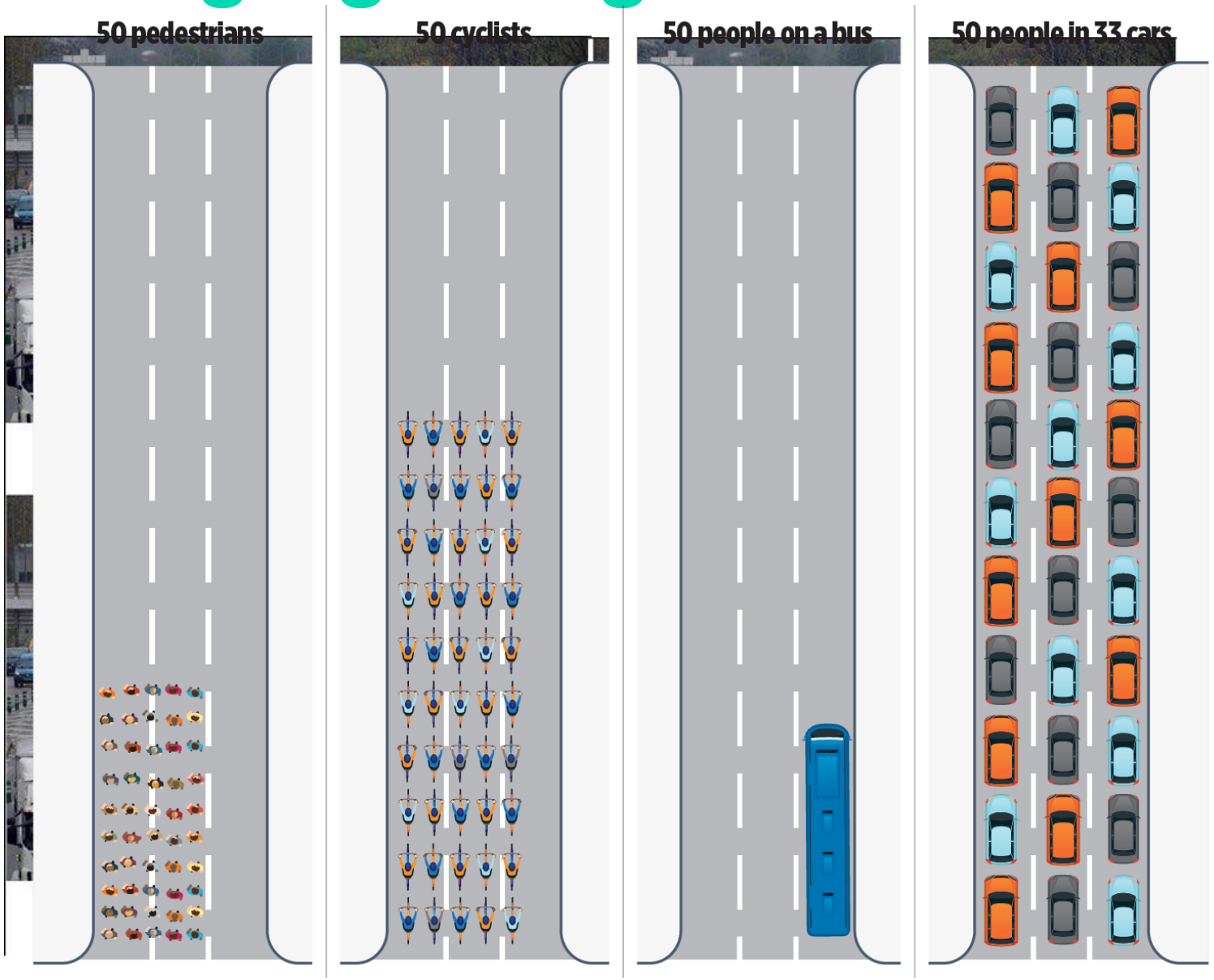
Managing Congestion



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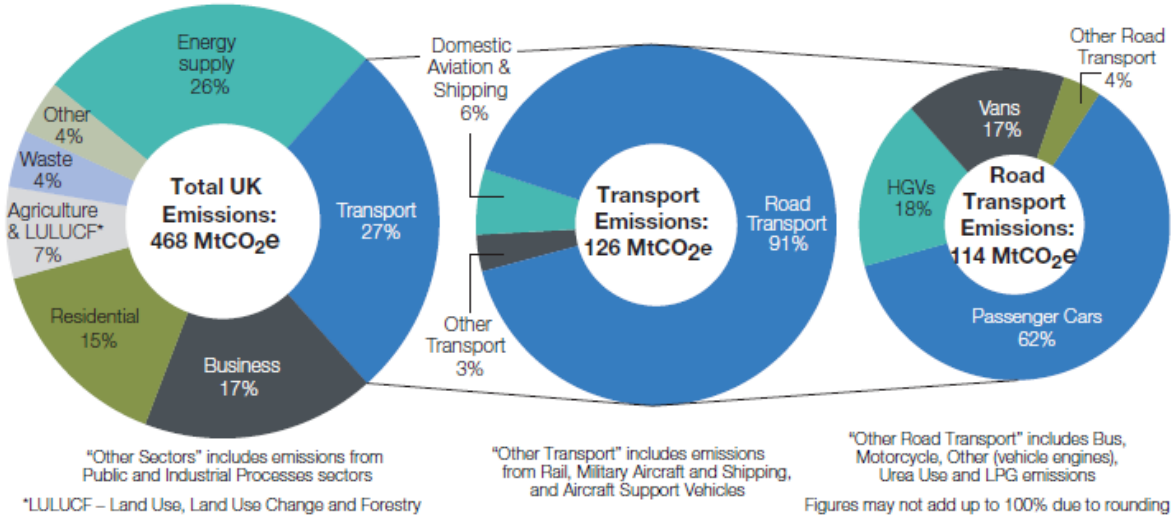
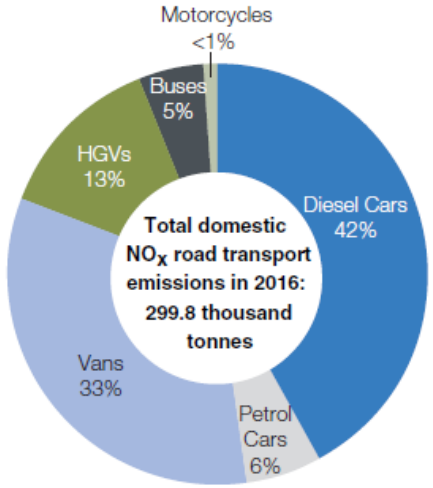
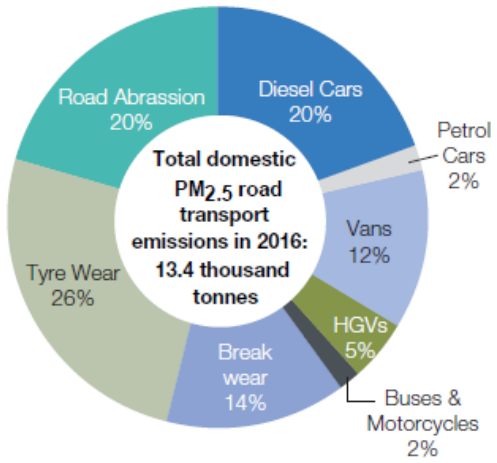
An emissions and a CO2 challenge?



Source: BEIS final UK greenhouse gas emissions 1990-2016





Source: National Atmospheric Emissions Inventory

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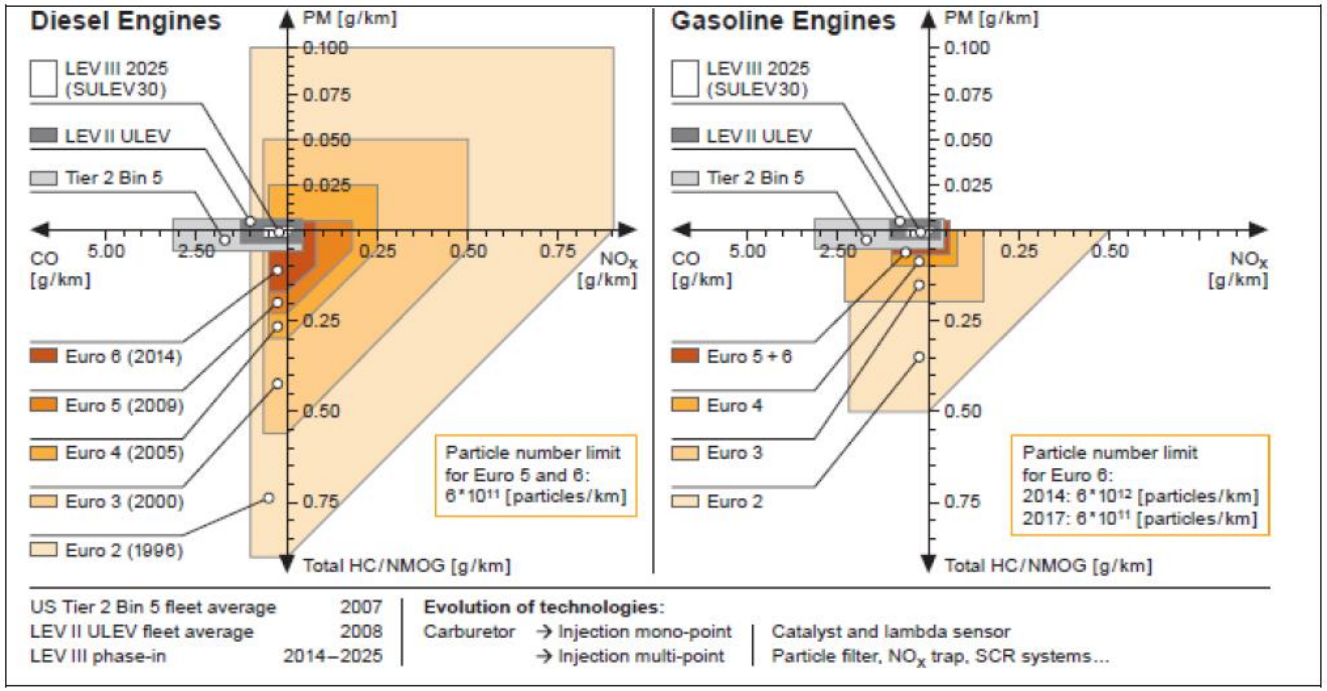
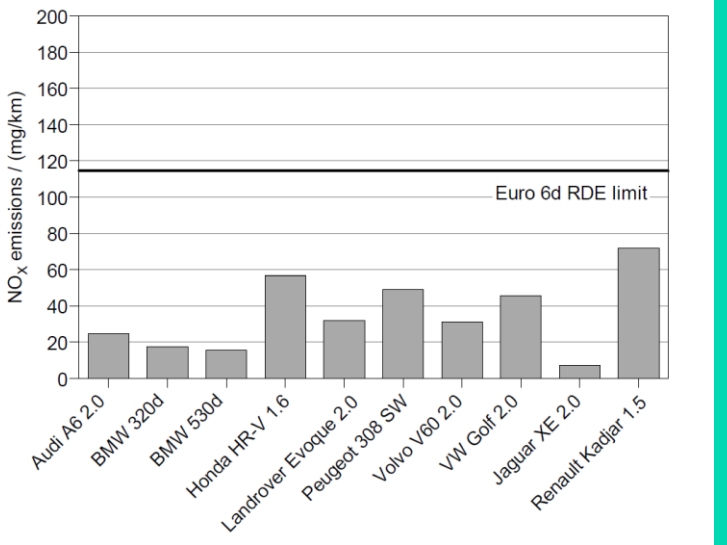
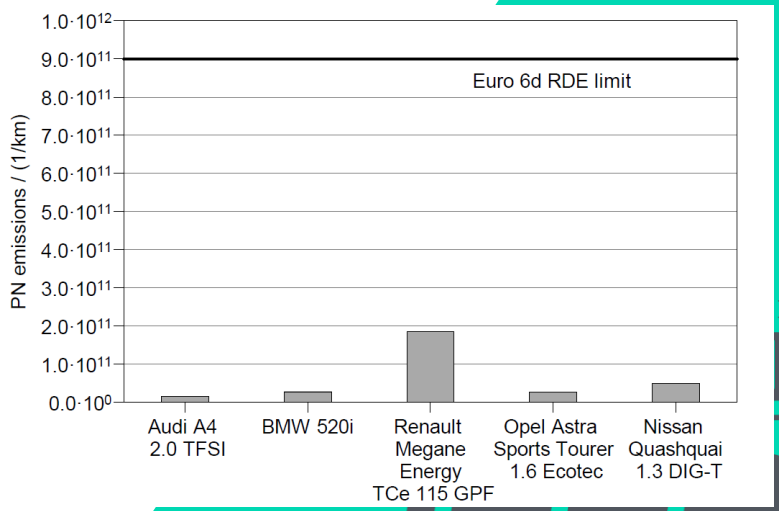
How clean is a modern car?







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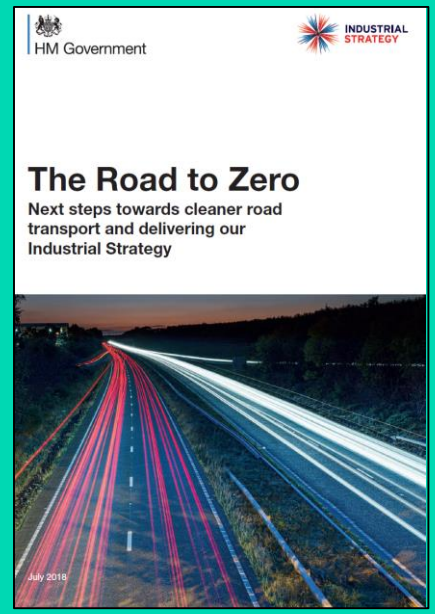
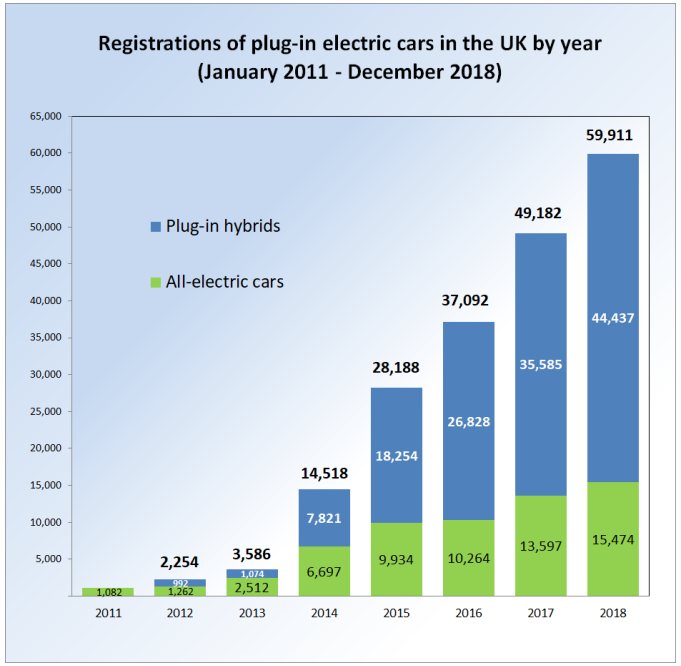
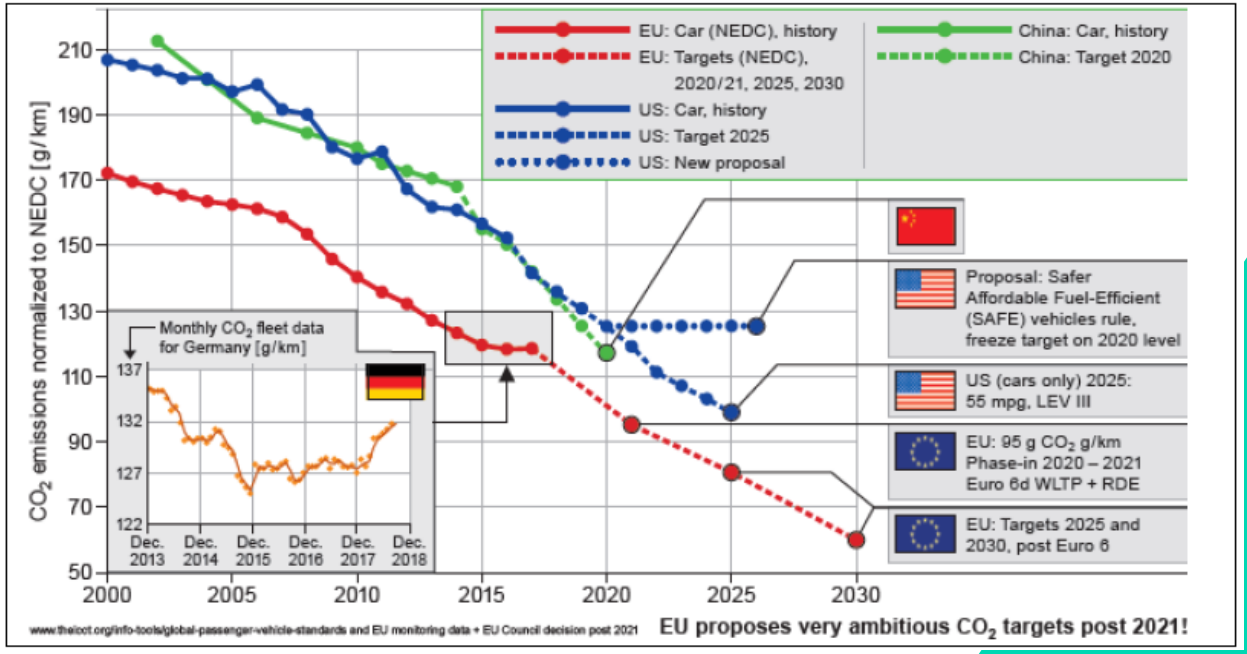
What is government policy?

- Reducing emissions from Vehicles already on our roads
- Average UK vehicle 8.1 years old- significant number stay in the fleet for >14years
- Encourage uptake of Low emissions vehicles
- All new cars and vans to be effectively zero emission by 2040
- End the sale of new conventional petrol and diesel cars and vans by 2040
- By 2050 we want almost every car and van to be zero emissions
- **Range extenders, plug-in and non-plug-in hybrids** are amongst the **cleanest vehicles** on the market and can bring significant environmental benefits.
- **Very little about Public transport!**







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So everything will be electric?

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Challenges for Electrification

- The road to electrification remains full of obstacles
- Range anxiety
- Infrastructure requirements
  - Decarbonising the electrical supply
- Consumer acceptance
- Cost, are BEVs commercially viable?
- Investment in Battery Production?

Battery Technology

- Model S/X 18650 Cell:
  - 18mm diameter, 65mm Height
  - Specific Energy Density: 240 Wh/kg
- Model 3 2170 Cell:
  - 21mm Diameter, 70mm height
  - Specific Energy Density: 247 Wh/kg
- Note this is the Cell capability not the pack capacity
- 126.7 Wh/kg, Model S, 159.5 Wh/kg in the Model 3
- Model S 52.8% packing Efficiency
- Model 3 64.6% packing Efficiency

So what does 1kWhr look like

- Rule of thumb 4.5-7km range/kWhr
- 57 x 2170 Cells
- 2Litres volume
- 5kg mass
- $200 cost + electricity used

- In Gasoline that energy is stored in 80g of mass or ~200g assuming current conversion efficiency
- ~250ml of volume
- Cost 35p including tax

Current Li-Ion Battery Technologies in Electric Vehicles and Opportunities for Advancements Energies **2019**, 12, 1074

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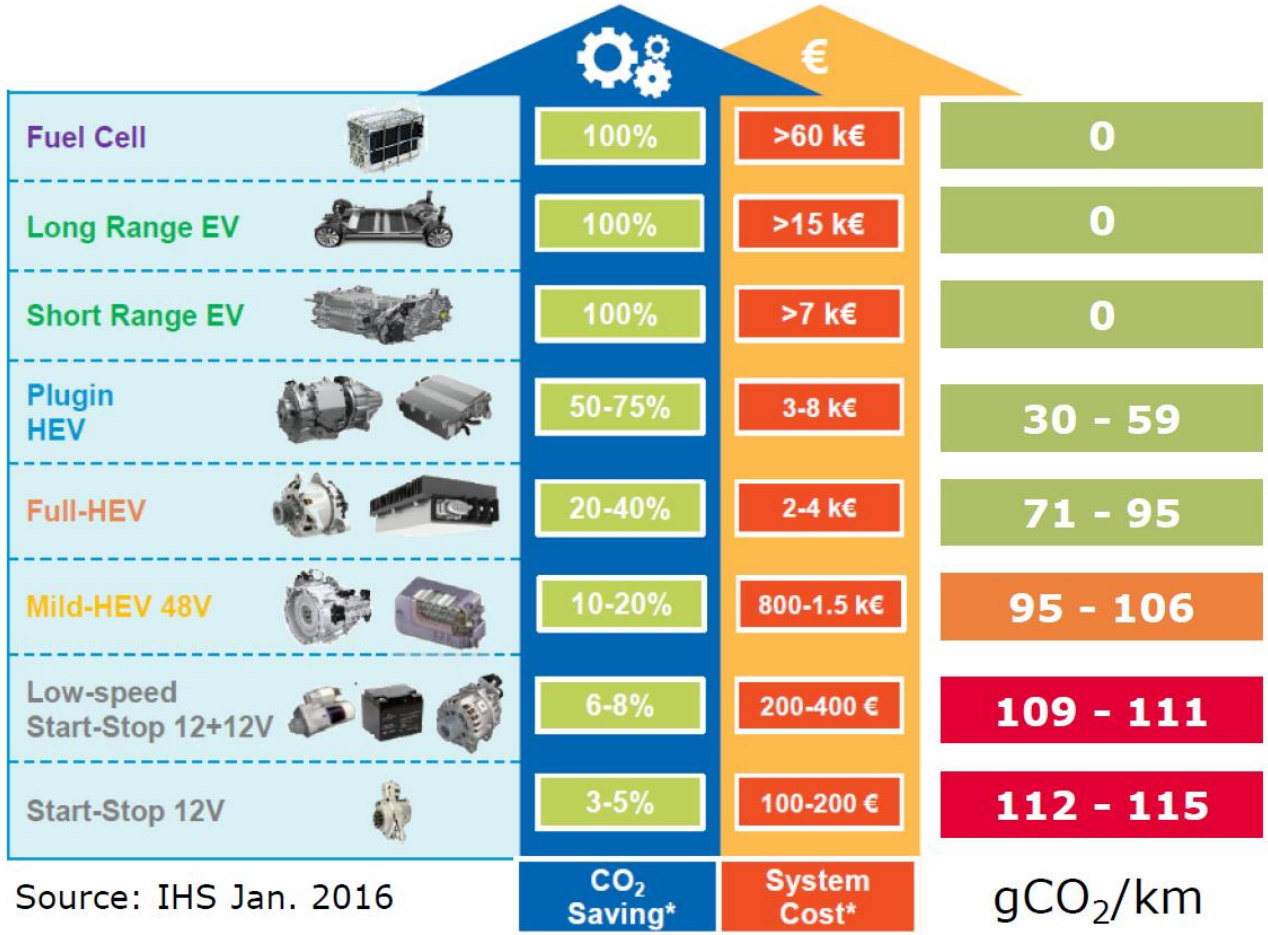
The cost of electrification



- EV incentives
  - Purchase grant up to £3.5k
- Cost of fuel duty
  - 2019-20 expected income of £28.4Billion
  - 3.5% of all tax receipts
- Vehicle excise duty
  - Generates ~£6.2Billion/annum

An electric Volkswagen e-Golf costs £32,730 before the grant, over £10,000 more than the popular Golf 1.6 TDi SE Navigation (£22,335).

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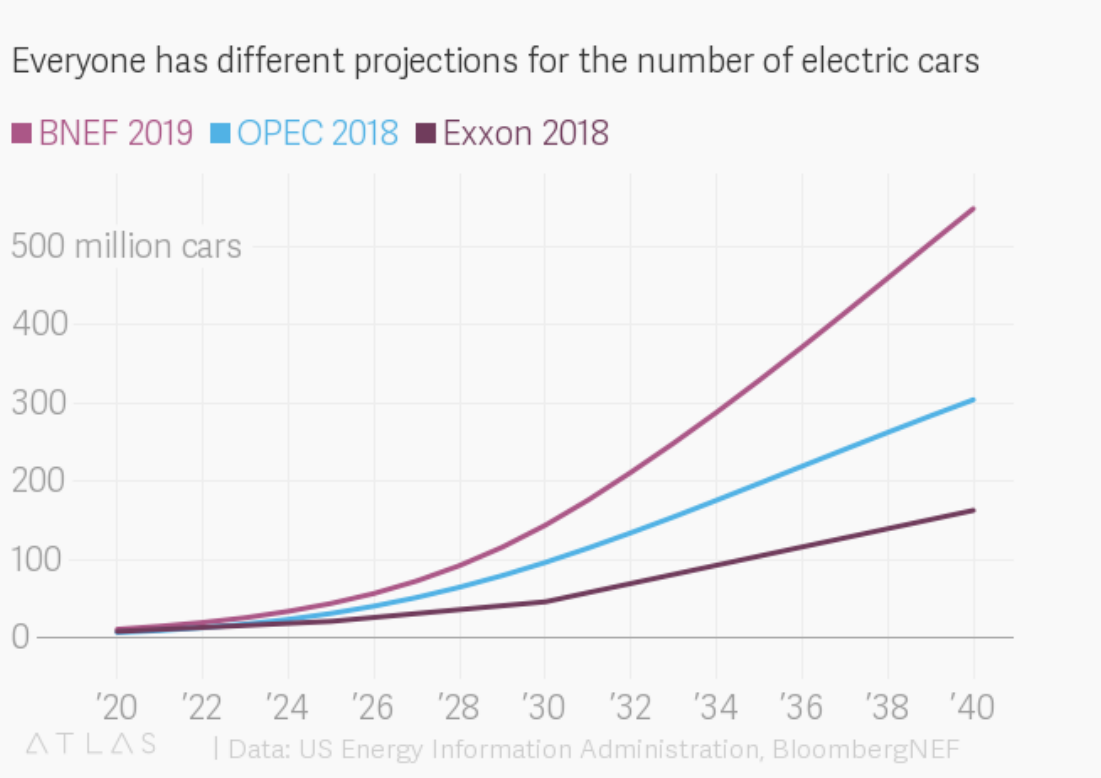
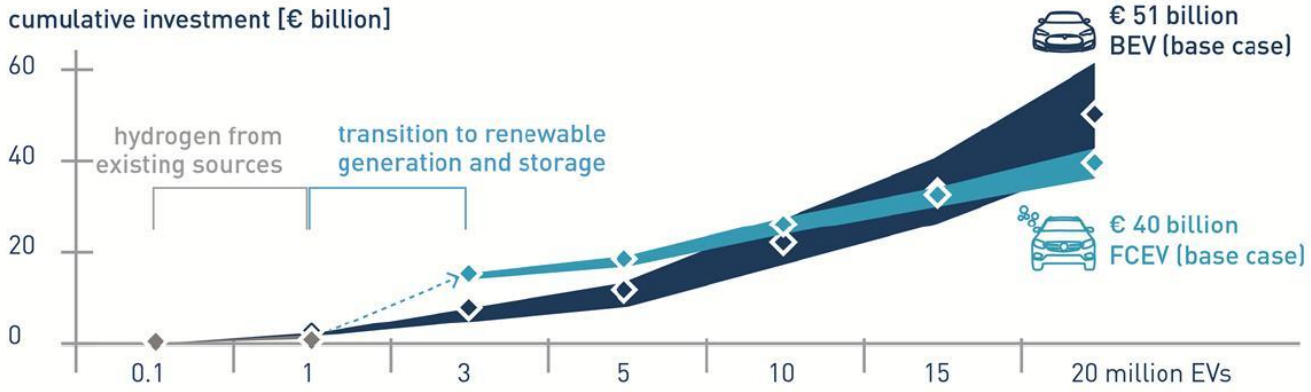
Predictions for EV Market?



- Predictions for 2040 spread from 162M total EVs (ExxonMobil) to 548M (Bloomberg New Energy Finance, BNEF).
- Predictions for 2030 (relatively near term) range from ~ 50M (ExxonMobil) to ~ 150M in 2030 (BNEF)
- Even for the most optimistic scenario results in one third of global vehicle stock being electric in 2040. Clearly points to the need to continue improving ICEs and hybridization.



Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles, Robinius et al. Energy & Environment, Volume 408, ISBN 978-3-95806-295-5

Where does our electricity come from?

EU28

Primary Energy Carrier
(incl. Upstream)

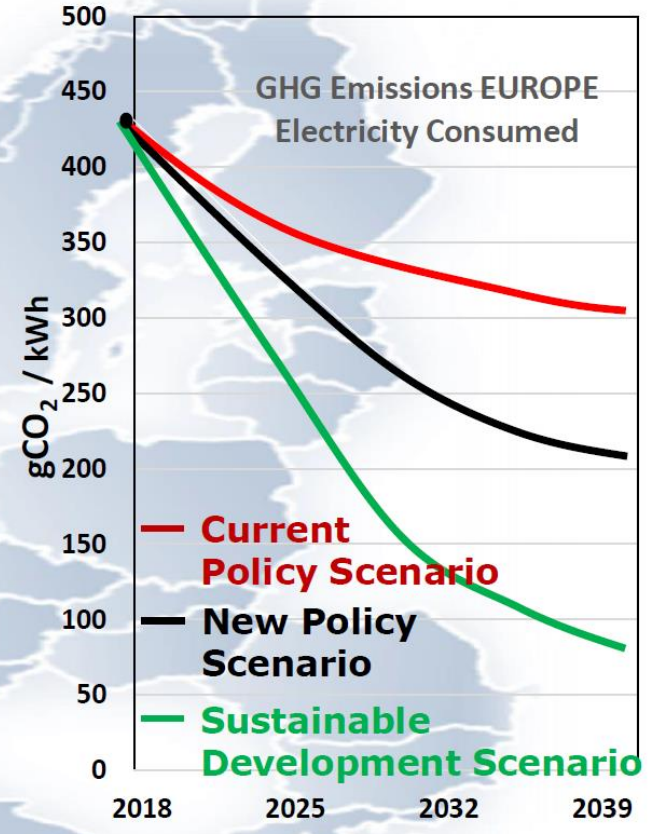
Electricity Production

340 gCO_2/kWh

Storage / Transport

Electricity Consumed

428 gCO_2/kWh



Based on data from IEA 2018 and European Commission, Joint Research Center (JRC), July 2017

Future Energy Carriers and their Impact on Powertrain Systems- G Fraidl et al. AVL List GmbH, 2019 JSAE/SAE, Powertrain, Fuels and Lubricants, Kyoto, August 26-29 2019

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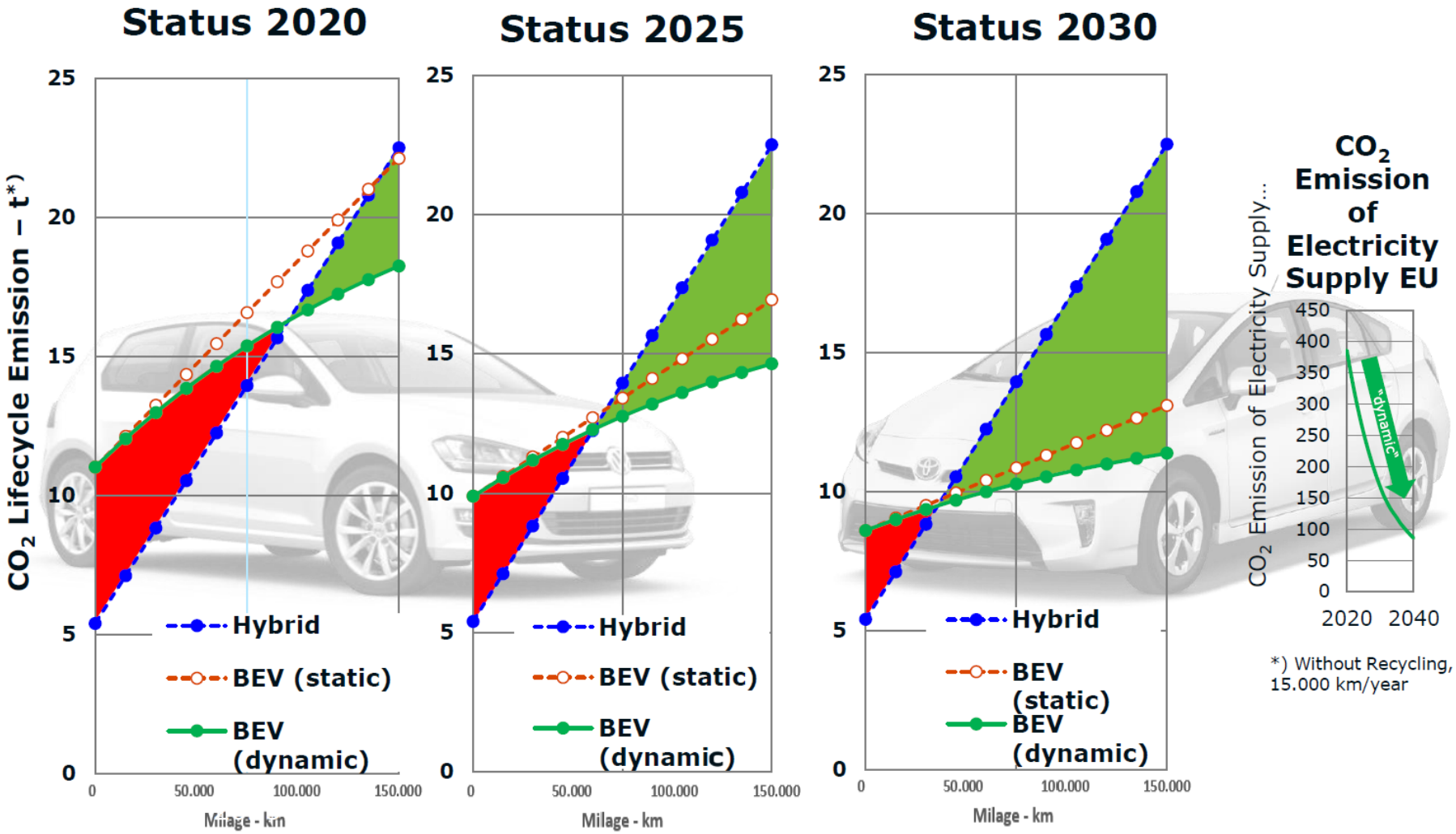
BEV vs HEV



*) Without Recycling, 15.000 km/year

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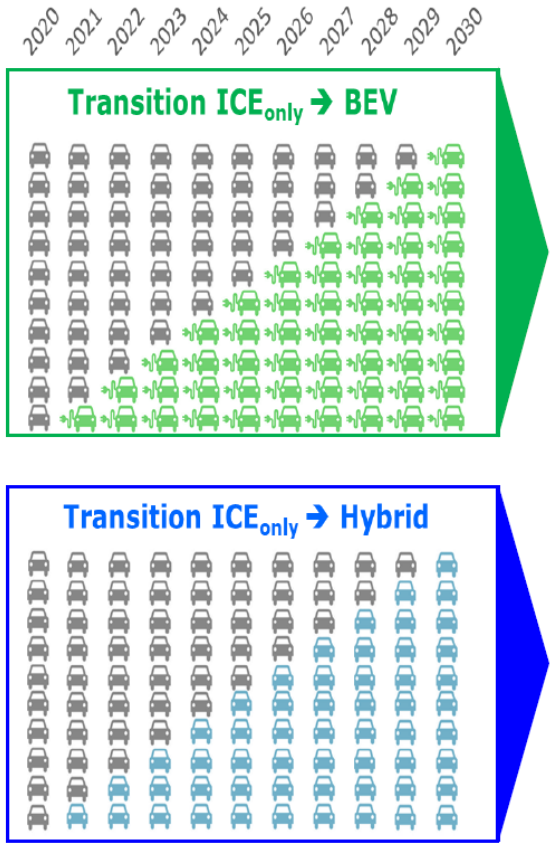
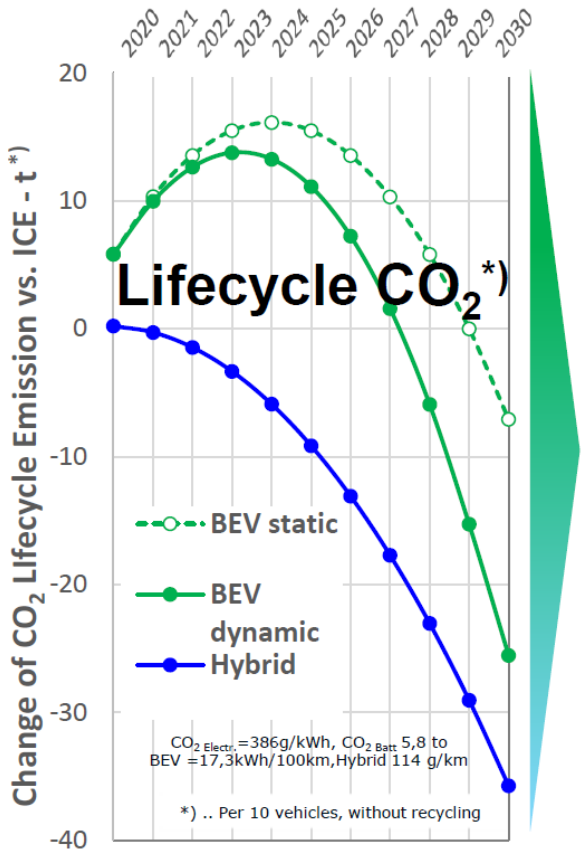
We do need to consider lifetime CO2

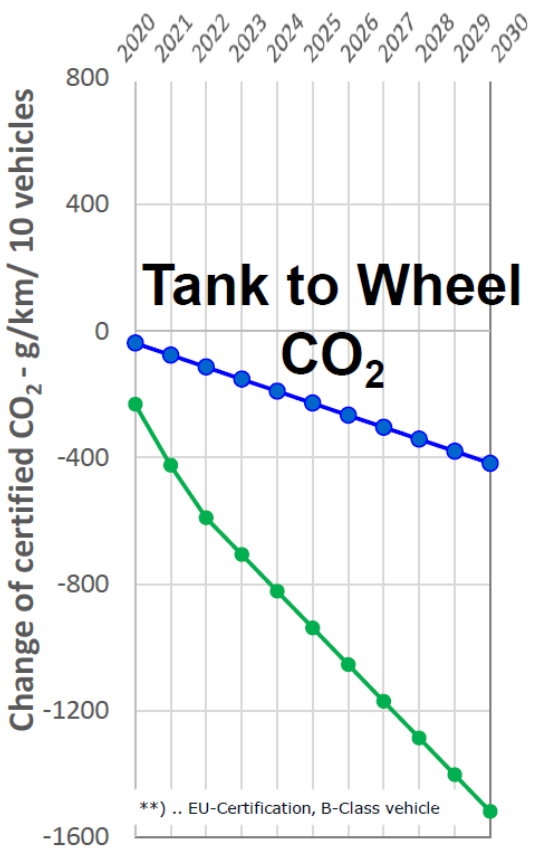
Replacement of ICE_{only}



Impact on Lifecycle CO_2*)



Impact on Certified CO_2)**



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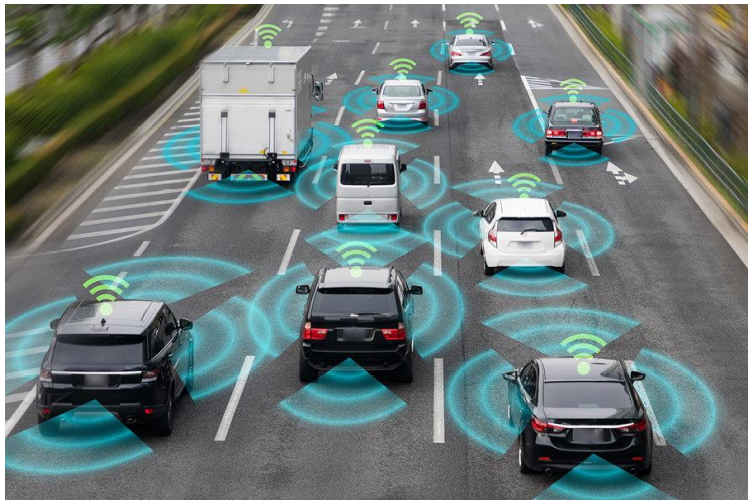
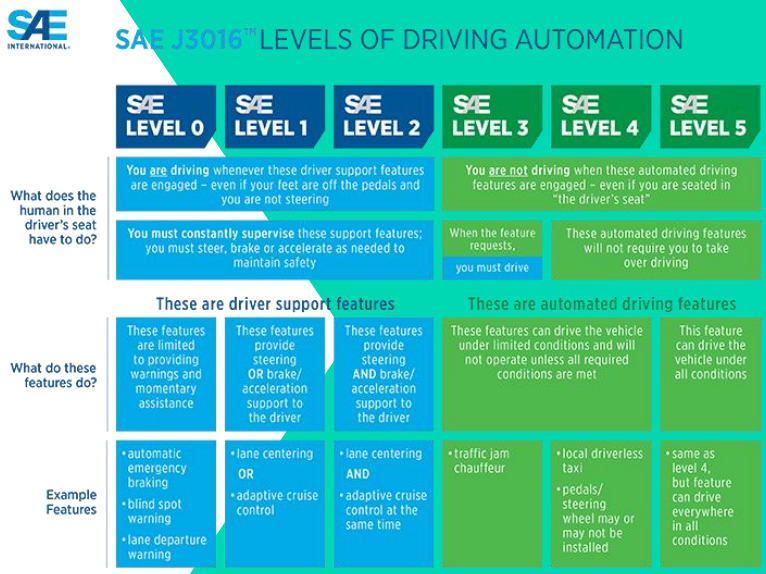
Connected Autonomous Vehicles



- Do we not already have autonomy as a service?
- Public transport, Taxi, car sharing
- Why when people struggle to adopt these concepts do they want autonomous cars?



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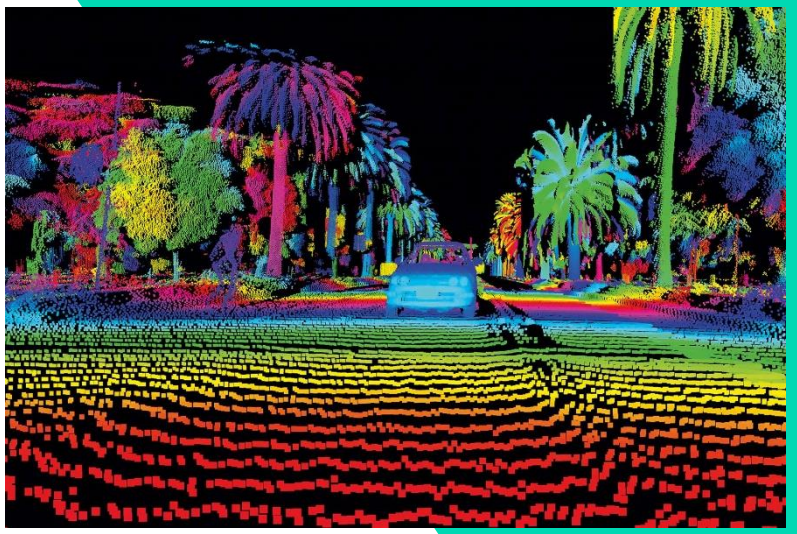
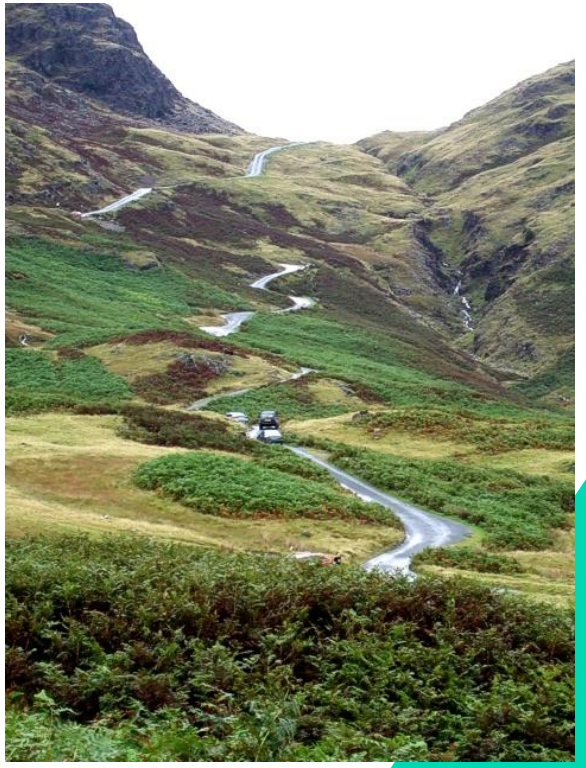
Challenges for Autonomy

- Hotel Loads
  - Computing loads are typically of the order of >2kW
  - Additional loads for sensors, LiDAR, Radar, cameras
- Large reduction in electric vehicle range caused by this
- Cost… LiDAR, was $75k, now $7.5k
- Edge cases
- Urban driving vs. rural driving





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So in Conclusion?

- The future is not clear
- Electrification is an essential part of the future but not necessarily full BEV
- To be effective we need a low carbon electricity supply (Nuclear?)
- The quickest way to reduce emissions is to replace existing aging vehicle fleet with new low emitting internal combustion engines
- The best use of limited battery resource is to deploy them in as many hybrids as possible and not in BEVs
- Fuels from renewable resources Bio or Synthetic (complete life cycle) are a rapid fix alternative
- Electrification will not solve congestion
- Autonomous vehicles are many years away

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So in Conclusion?

- Despite the representation in the media and Government policy, continued investment in IC engine research is essential to meet our climate control objectives
- To be economic vehicles need to be sold in a global market, but diversity in grid CO2 is huge and must be considered
- It is not clear if BEVs can be delivered successfully in a commercial environment without government incentives
  - Recent Dyson withdrawal
  - Tesla yet to make a consistent profit
  - Companies will potentially loose money on EVs to meet mandated CO2 targets
- Re-education of road users is essential but non-trivial
  - To drive less miles, use public transport, buy the correct vehicle
- Investment in public transport solutions would be good
  - Incentivise rather than penalise

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Thank you

https://www.bath.ac.uk/research-institutes/iaaps/

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