Vehicle Electrification:
You'll Get a Charge Out of This!

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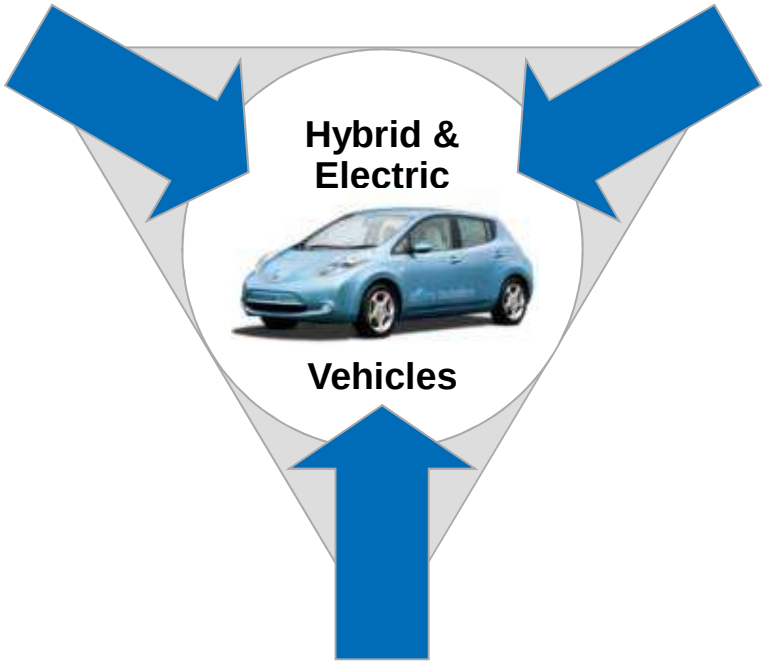
Interest in vehicle electrification is being driven by governments and markets alike

Governments

- CO_2 reduction to support national targets

- Energy security

- Urban air quality



Manufacturers

- Regulated fleet CO_2
- Attractive products
- Technology expertise

Consumers

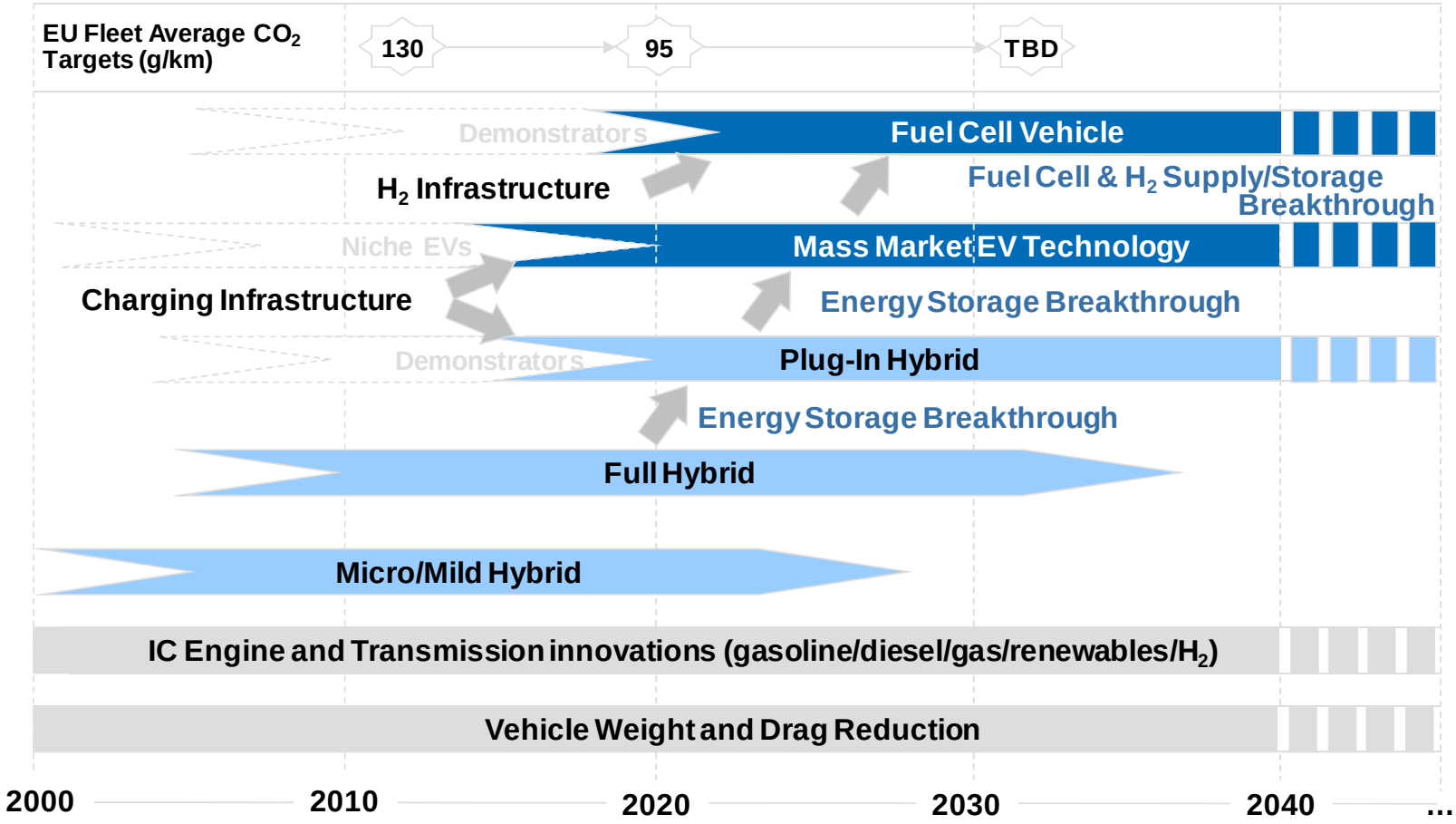
- Environmental awareness & 'green' fashion

- Technology appeal

- Fuel costs

- Incentives

Broad consensus exists on the path of evolution that low CO_2 powertrains must follow – electrification and EVs are a key element



- NAIGT roadmap for future automotive powertrain
- Represents UK OEM consensus

The future of the automotive powertrain is largely driven by legislation rather than consumers or even technology

There is unlikely to be a single revolutionary winning technology

Source: http://www.berr.gov.uk/files/file51139.pdf

OEMs are already implementing powertrain and vehicle level changes to reduce CO_2 of conventional products...

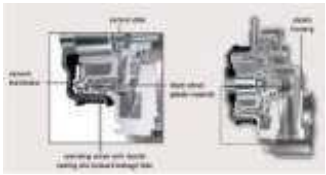
OEM Approaches to CO_2 Reduction

Base Engine Updates
Combustion + Air System Match
Minor Friction Improvements


Calibration for CO_2
Often with some compromise to NVH

Downspeeding
Longer Final Drive Ratio

Thermal Management e.g.
Map Controlled Coolant Temp
Switchable Piston Cooling
Switchable Water Pump



Modest Downsizing
e.g new VW 1.6L Golf

Reduced Rolling Resistance Tyres

Energy Management
e.g. Smart Alternator,
Adaptive PAS


Stop-Start

Auto Start-Stop

Aero Improvements
e.g ride height,
reduced/active grill

Vehicle Weight Reduction

Source: Ricardo Research

... as seen in many of the eco-products launched by OEMs over the last few years

Most OEMs are now producing “eco labels” or vehicles offering more eco-variants of engine/vehicle ranges to highlight their fuel-efficient technologies	**BMW EfficientDynamics**  **5-Series EfficientDynamics**	**Citroën AIRDREAM+**  **C3 AIRDREAM+: 99 g/km CO_2**	**Fiat EcoDrive** **Integrated software to analyse driving pattern and efficiency**
Ford ECOnetic  **Fiesta ECOnetic: 98 g/km CO_2**	**GM Ecotec**  **Chevrolet Malibu: 33 mpg (US) hwy**	**Kia EcoDynamics**  **Ceed EcoDynamics: 110 g/km CO_2**	**Mercedes-Benz BlueEFFICIENCY**  **C-Class: 127 g/km CO_2**
Renault eco2 **Label certifies manufacture, in-use emissions and recycling**	**Seat Ecomotive**  **Ibiza Ecomotive: 92 g/km CO_2**	**Toyota Optimal Drive**  **Auris with Optimal Drive: 136 g/km CO_2 (reduction of 17% on standard)**	**Volkswagen BlueMotion**  **Golf BlueMotion: 99 g/km CO_2**

Source: OEM websites and press releases

What is a plug-in vehicle (PIV)?

The “electrification spectrum”

1. **Hybrid Electric Vehicle (HEV)** ✗
2. **Plug in Hybrids** ✓
   - Range Extended HEV
   - Range Extended EV
3. **Electric Vehicle (EV)** ✓



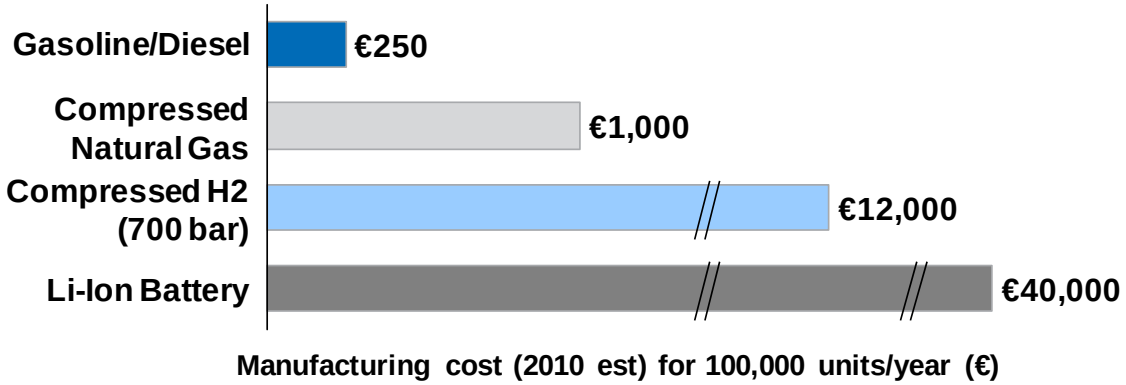

Increasing electric power & battery size

- Parallel hybrid as in Toyota Prius
  - Increasing electric capacity
  - Electricity generated on board by IC engine
- RE-HEV batteries can be directly charged from the grid, allowing significant electric range (e.g. 9-40 miles)
- However IC engine is primary power unit, required for full vehicle performance
- EV mode is primary mode – electric motor sized for full power
- IC engine power pack has no mechanical connection to wheels, is used as generator to maintain battery charge once depleted
- No IC engine or power pack
- On the fly charging or energy replacement for long journeys

Source: Ricardo analysis

Batteries not currently cost-competitive with other fuels – greatest challenge is to reduce cost whilst retaining life and reliability

Onboard Fuel Tank System Cost (550 km range)

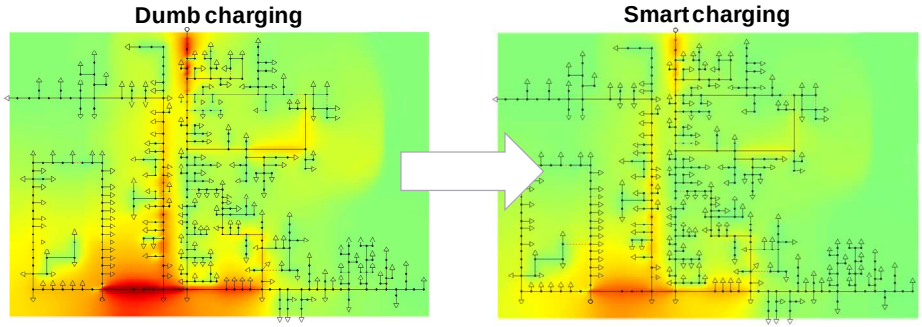


- Assumes:
  - 300 mile range Li-ion battery (60 kW.hr)
  - Assuming €500/kW.hr & 80% DoD
  - Full range electric vehicle unlikely in short-medium term

- Other key battery challenges:
  - Low energy density – adds significant weight to each vehicle
  - Limited life – currently below the levels that consumers are likely to demand
  - Limited charge acceptance rate – for many chemistries insufficient for fast charging
- Current battery limitations are driving creative mitigation approaches
  - Alternative business models
  - Battery second life
  - Subsidies
  - Range extended HEVs & EVs

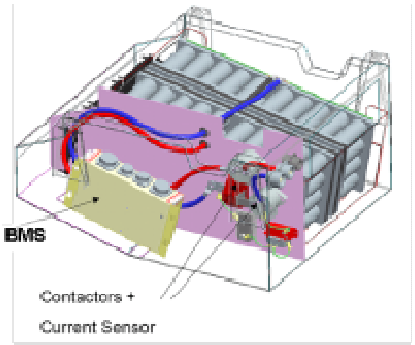
Other challenges

- Consumer acceptance
  - Real-world energy consumption of EVs strongly influenced by driving style and ancillary loads
  - Actual range vs. “range anxiety” – what are the real infrastructure requirements?



- Grid capacity
  - Capacity of local distribution networks emerging as critical issue for large scale PIV deployment
  - Need for “smart charging”

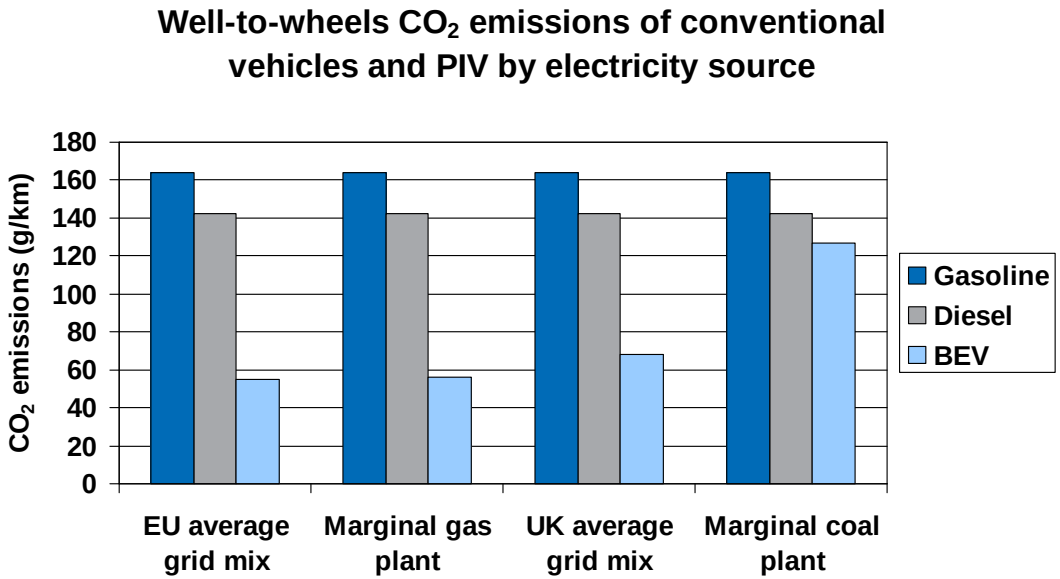
- Materials availability
  - Concern being expressed over cost and dependability of supply of key materials
  - May limit growth rate



Source: TEPCO, MERGE, Ricardo analysis

Source of electricity has significant impact on PIV emissions – "greening" of electricity grid essential to ensure significant benefits

- Electric vehicles do not (necessarily) have zero CO_2 impact!
- Valid comparison with conventional vehicles only possible on a "well-to-wheels" basis
  - Results depend on generation source
  - Wide variation across Europe
- Marginal emissions for coal generation plant similar to diesel



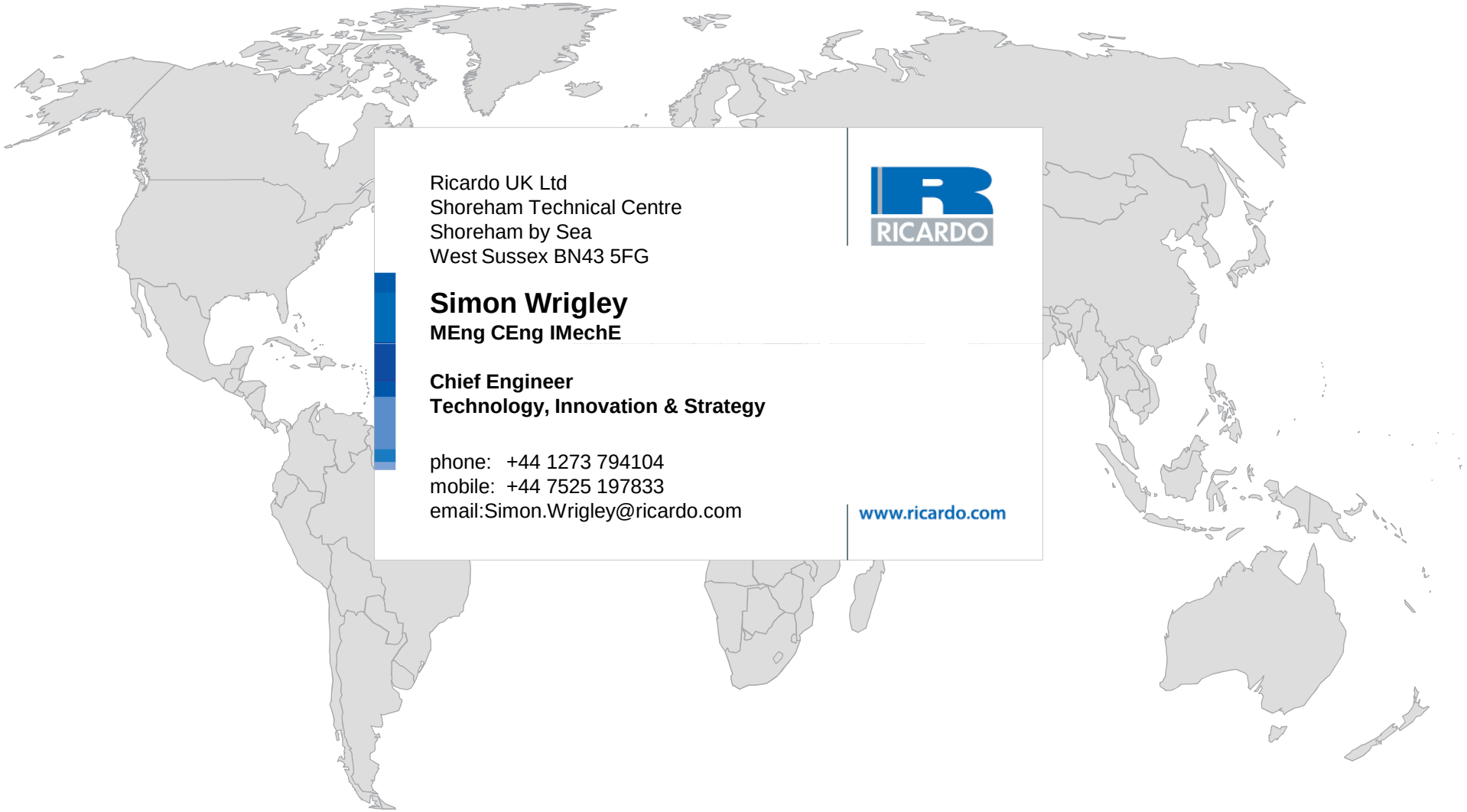
- European average CO_2 intensity similar to highly efficient CCGT plant
- Targetted improvements in grid CO_2 intensity will improve PIV g/km towards 2020-2030
  - However limited improvement in benefit vs. (improving) conventional cars
- For some fuels note that *global* NOx, SOx and PM10 emissions levels "per km" can be several times higher than *local* emissions from conventional cars...

Source: DECC, Eurelectric, JEC Consortium, Ricardo Analysis

If PIVs can achieve market success, they have the potential to bring significant benefits – what must happen to enable this?

Battery technology	• Continued improvement in costs, energy density & life • Mitigation measures • Transitional incentives
Consumer acceptance	• Charging infrastructure deployment • Better systems to manage range • Psychological research, incl. “range anxiety” • User familiarity…
Distribution network capability	• Identification of critical infrastructure issues • Smart grid to manage demand
Grid ‘greening’	• Increasing renewables in power generation • Common assessment methodologies

Thank you for your attention



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