Prospects for ethanol, gasoline and diesel from real-world emissions testing

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The challenge

- Ever lower CO_2 targets have elicited many competing powertrain technologies and fuels
- In 20-30 year time horizon, passenger cars may well be extensively electrified
- Gasoline strives to reduce CO_2 without causing air quality problems
- Diesel struggles to reduce air quality issues without losing CO_2 advantage
- Cities and governments may take drastic action against diesels
- Consumer confusion is increasing

➢ This is a market and environmental problem

EMISSIONS ANALYTICS' PROGRAMME

Emissions Analytics' credentials

- Founded in 2011
- Headquartered in UK, with operations in London, Los Angeles and Stuttgart
- Specialist in PEMS testing and data analysis
- 1300+ vehicles tested
- Largest commercially available database of real-world emissions data
- Works with OEMs, Tier 1/2 suppliers, fuel and chemical companies, regulators, consultancies, consumer media

Equipment

- SEMTECH-DS and -LDV
- Portable Emissions Measurement System connects to tailpipe
  - Captures emissions for CO_2, CO, NO, NO_2, total hydrocarbons
  - At 1 Hertz
- Air temperature, pressure, humidity
- GPS for speed and altitude
- Engine data via CANBUS
- Fuel economy derived via carbon balance
- Weight addition 100kg


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E10 TEST PROGRAMME
DOWNSTREAM FUEL ASSOCIATION, UK

Objectives

- E10 is currently being evaluated for its contribution as a cost effective means by which the UK could meet its target of 10% of renewable energy by 2020, as set out in the Renewable Energy Directive
- E10 is currently available in a number of European countries, but there is a lack of publicly available information on its performance from a fuel economy and pollutant perspective. The DFA wanted to better understand the impact a change from E5 to E10 would have on the motorist and environment

➢ The objectives of this test programme therefore were to:

- ➢ Assess the effect on MPG of a switch from E5 to E10 in the UK car market
- ➢ Determine the effect on CO_2 greenhouse gas emissions
- ➢ Determine the effect on CO, and NO_x pollutant emissions

Fuel

- Fuels specially blended for this test by Coryton Advanced Fuels for DFA
- E5 designed to represent typical gasoline currently on the market
  - 95RON, 85MON
  - 4.8% ethanol
  - Fuel density: 0.7307 kg/L @ 15˚C
  - Molar ratios: 85:13:2 C:H:O
- E10 formulation to reflect most likely blend introduced
  - Match blended to avoid octane give-away
  - 95RON, 85MON
  - 9.8% ethanol
  - Fuel density: 0.7352 kg/L @ 15˚C
  - Molar ratios: 83:14:4 C:H:O

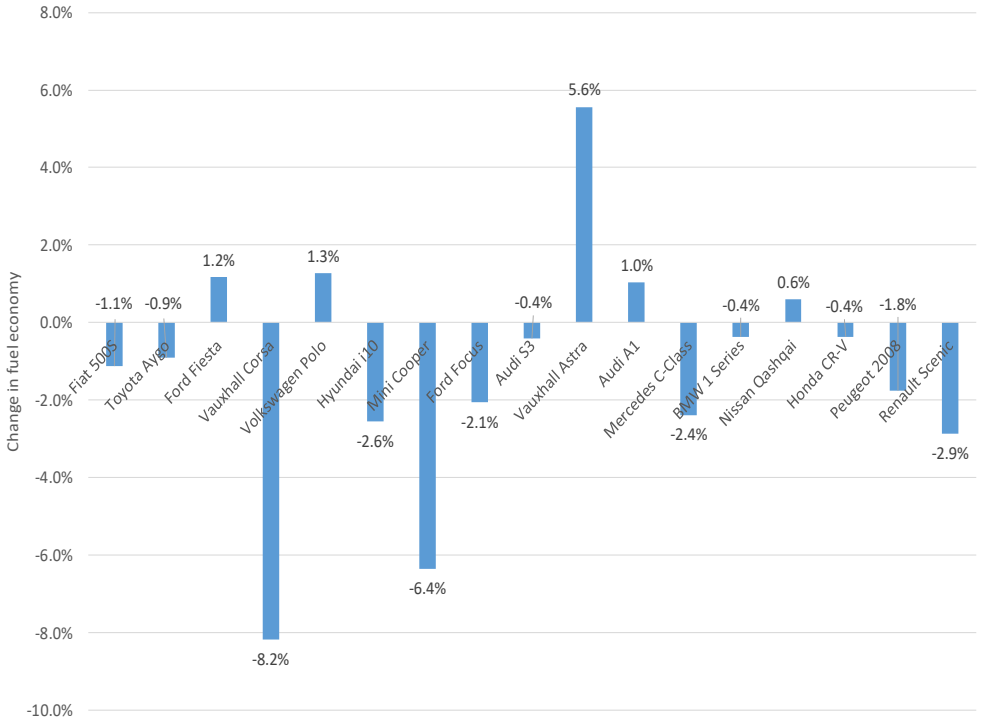
Criteria for vehicle selection

- Vehicle with high sales historically in the UK
- Up to three years old, with mix of Euro 5 and Euro 6 regulatory stages
- Spread across the main classes of vehicle
- Spread across range of manufacturers
- Range of engine sizes from downsized to mid-range
- Mix of direct injection and port fuel injection
- Spread of other engine technologies, e.g. variable valve timing, turbo charging

HEADLINE RESULTS

Fuel economy results

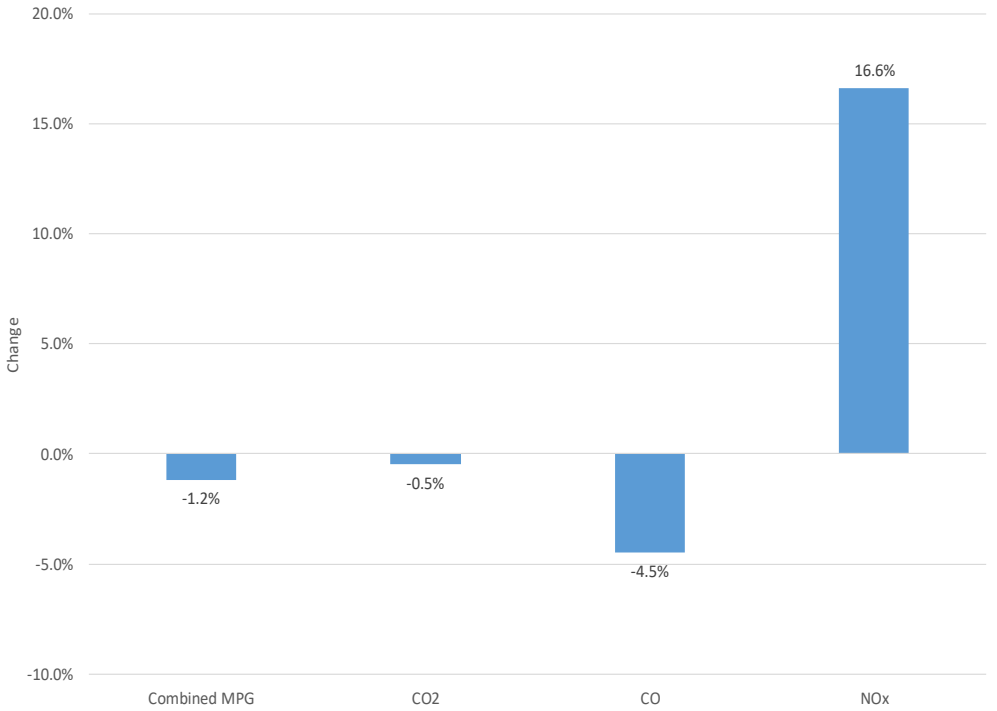
- Average 1.2% reduction in fuel economy
- 12 out of 17 showed falls in MPG, of which 9 were statistically significant
- 2 tests showed statistically significant increases in MPG
- Average result in line with energy content
- Minority show larger variations



* At 90% confidence level on a one-tailed test

MPG and emissions results

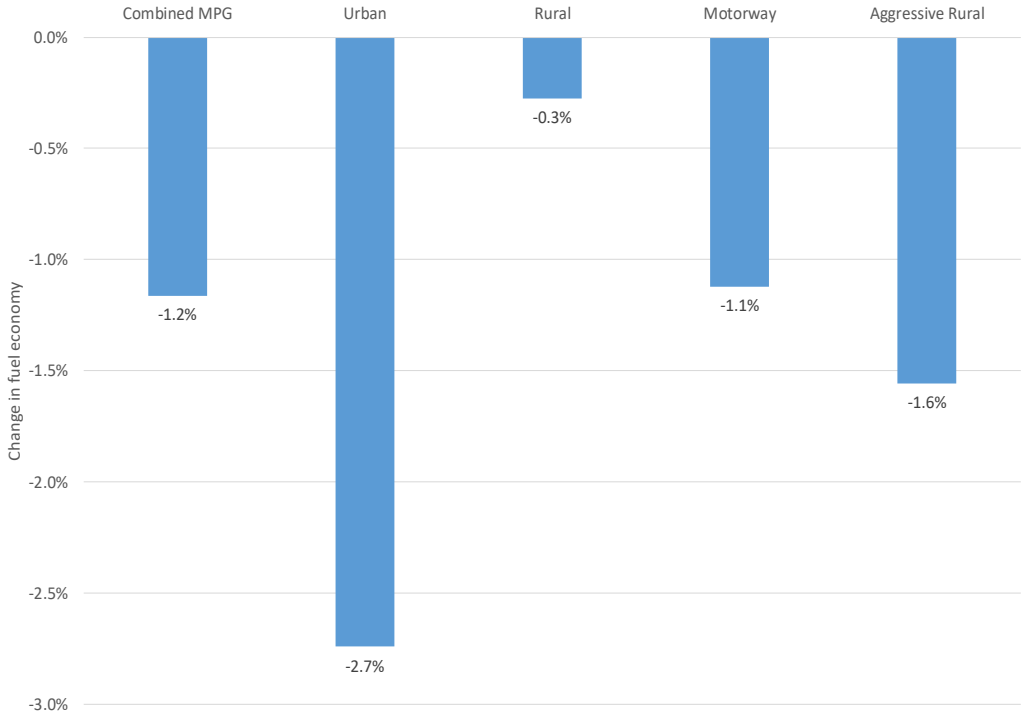
- 1.2% average MPG fall
- 0.5% average fall in CO_2 emissions
- 16.6% average increase in NO_x emissions
- 4.5% average fall in CO emissions, excluding outlier*



* Mini had valid results but atypical six-fold increase in CO distorts average and is excluded from CO results throughout

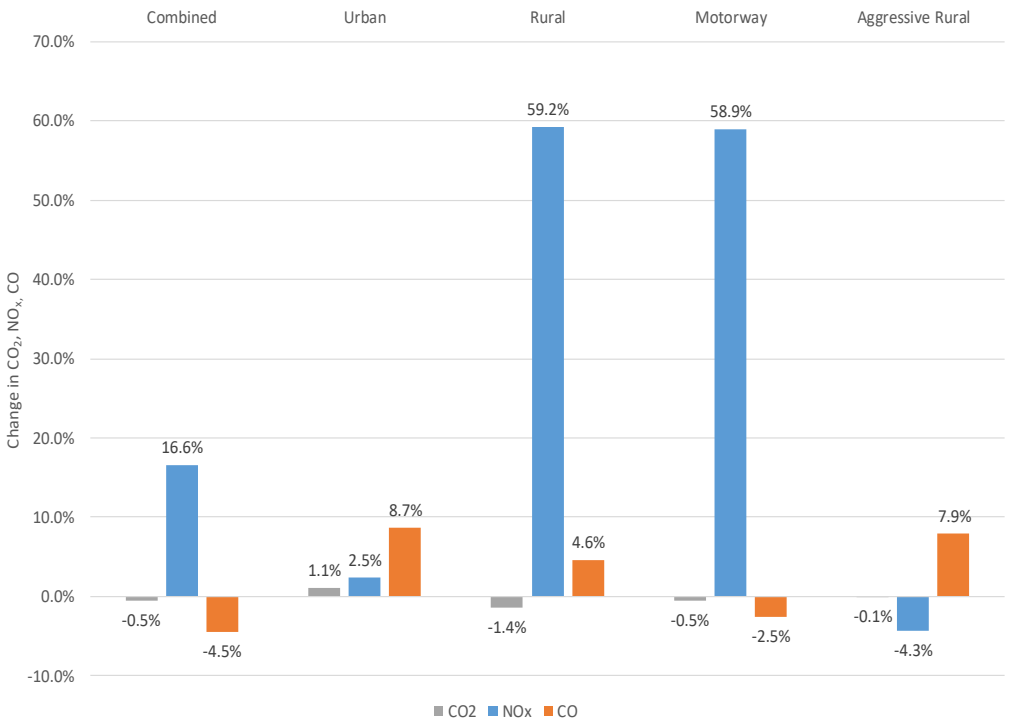
MPG effect by route type

- 1.2% average reduction in MPG
- Greatest effect in urban driving: down 2.7%
- Motorway and aggressive rural similar: down 1.1% and 1.6% respectively
- Smallest effect in normal rural driving: down 0.3%



Emissions by route type

- Urban driving shows increases in CO_2, CO* and NO_x
- Larger increases in NO_x in normal rural and motorway driving
- Average NO_x conformity factor (ratio to Euro 5/6 limit) rises from 1.0 on E5 to 1.1 on E10



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Summary

- Switching from E5 to E10 resulted in an average reduction in fuel economy of 1.2% across the 17 vehicles driven on the test cycle
  - Urban driving showed a 2.7% fall in MPG
- 12 out of 17 vehicles showed a fall in MPG
  - 9 of which were statistically significant
- Nitrogen oxides emissions were 16.6% higher on average
  - Bigger increases were seen for motorway and rural driving
- Carbon monoxide emissions were 5% lower, excluding one notable outlier

➢ Introduction of E10 will likely increase the cost of motoring, with certain vehicles and driving patterns leading to greater differences

WIDER MARKET CONTEXT:
#dieselgate AND BEYOND

Gasoline in context

- Gasoline vehicles typically have worse MPG, higher CO_2, higher CO but lower NO_x emissions than diesel engines
- They tend not to contribute to poor urban air quality in the way that diesels do, but at the expense of higher greenhouse gas emissions and higher running costs
- Emissions Analytics has tested over 800 vehicles to reveal typical performance:

Vehicle fuel	Average real-world fuel economy (MPG)	Official Euro 6 NO_x limit (mg/km)	Real-world Euro 6 NO_x emissions (mg/km)	Official Euro 6 CO limit (mg/km)	Real-world Euro 6 CO emissions (mg/km)
Gasoline	38.1	60	43	1000	516
Diesel	47.5	80	672	500	152

The diesel problem

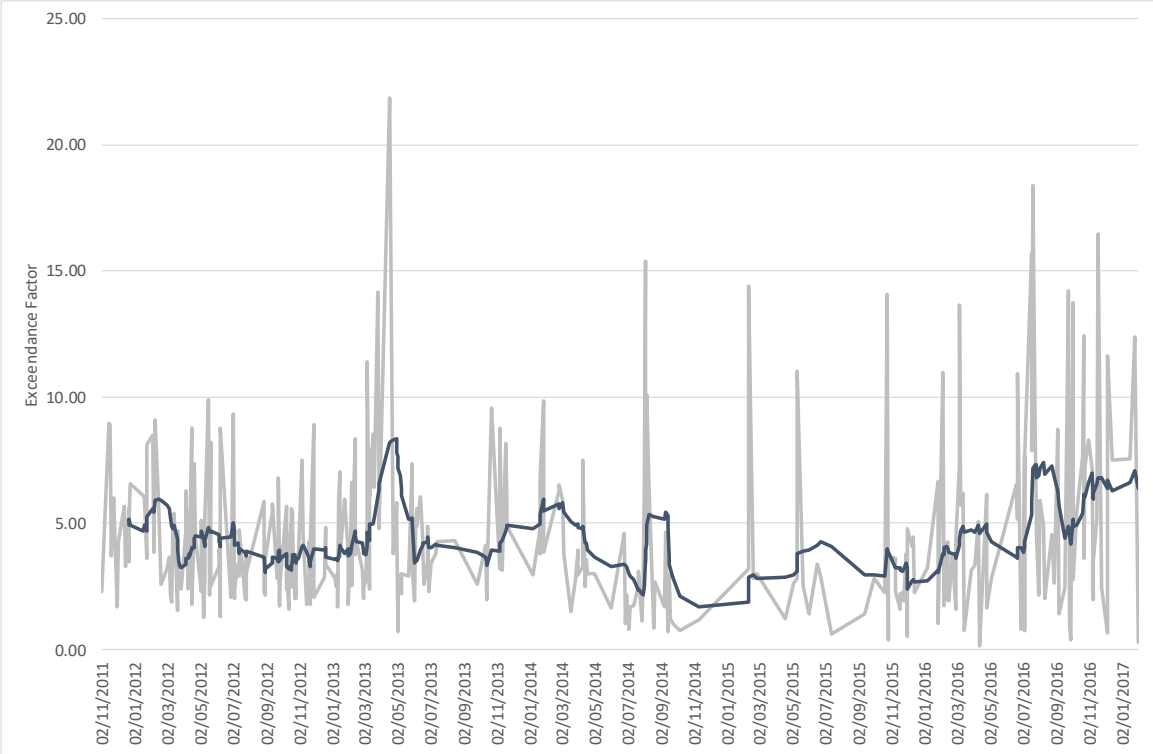
- Nitrogen oxide emissions are on average four times the legal limits in real-world driving
- Real-world MPG for model year 2016 vehicles is on average 29% below official figures
- Carbon dioxide emissions are on average 41% above official levels
- Performance differs significantly between models homologated to same standard

➢ The new regulations for MPG, CO_2 and NO_x will improve but not solve the problem

➢ What do cities do to improve air quality?

NO_x Exceedance Factor

- Average EF now ~7
- Rising since 2015, back almost to Euro 5 peaks
- Despite prospect of Real Driving Emissions
- Growing variability
- Use of thermal management and hot re-start strategies?
- Beating first phase of RDE in 2017?



WILL DIESEL SURVIVE?

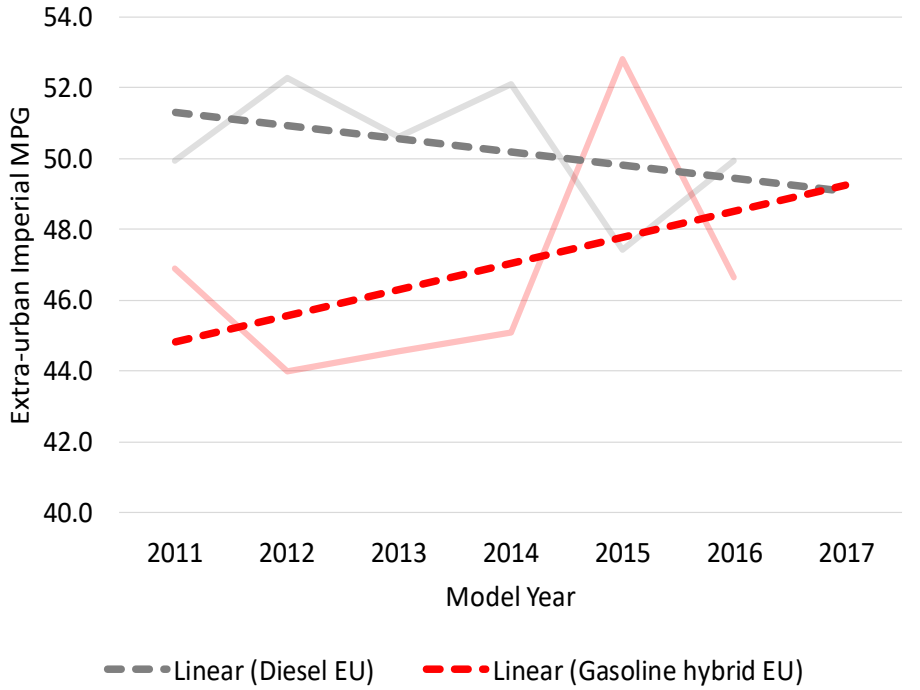
Four commercial factors

	Fuel efficiency	Depreciation	In-use CO_2	NO_x, CO
Diesel				
Gasoline				
Gasoline HEV				
PHEV – short trip				
PHEV – long trip				
EV				

- Diesel's position is threatened unless low NO_x can be demonstrated

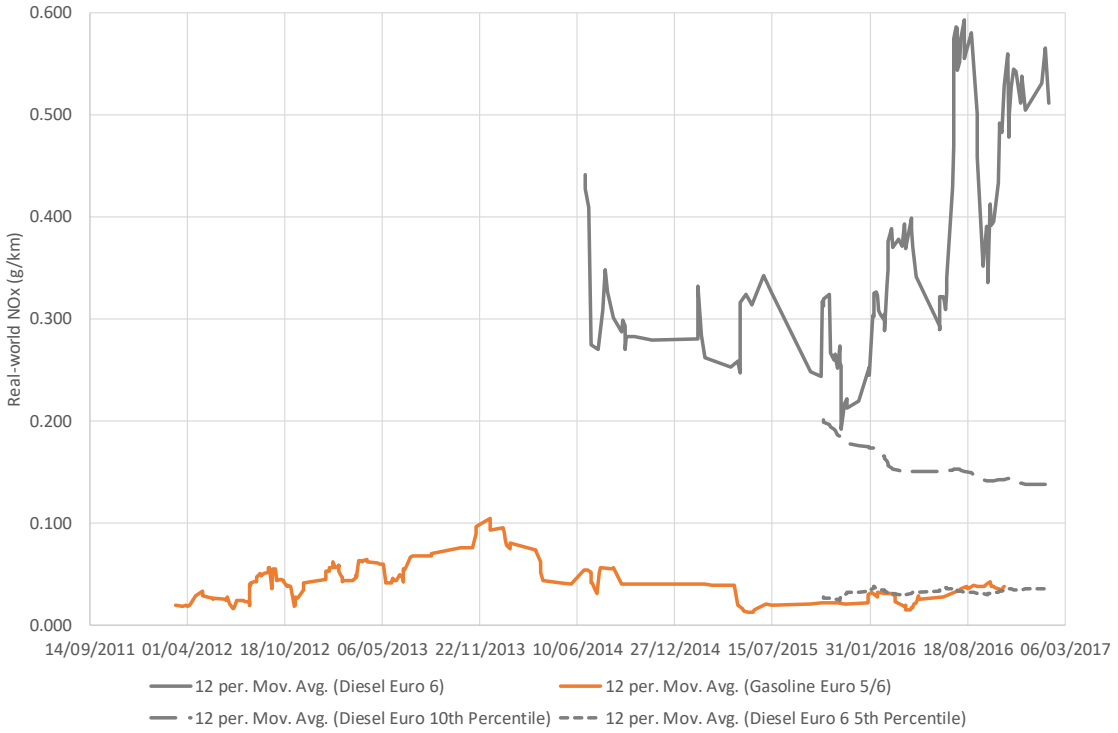
Advance of gasoline HEVs

- HEVs historically had urban MPG advantage
- May overtake diesel in motorway driving this year
- Further advanced in US
- Even now, has emits less CO_2 than like-for-like diesel



Can diesels be clean?

- Average Euro 6 diesel 13 times average gasoline car
- But cleanest diesels (5% percentile) are as clean as the average gasoline
- Has been the case for almost 2 years
- Not being able to discriminate within Euro 6 is significant market failure



INDEPENDENT RATINGS LABELS

EQUA Index

- Vehicle rating scheme based on their real-world emissions and fuel economy
- Non-statutory complement to new Real Driving Emissions regulations
- Discriminates between high and low emitters, even within Euro class – not just pass/fail
- Ratings are published and into the public domain for free at www.equaindex.com
- Manufacturers, fleets and consumer media can adopt as independent, voluntary standard
- Equivalent to New Car Assessment Programme (Euro NCAP, Global NCAP)
- Authoritative advisory board

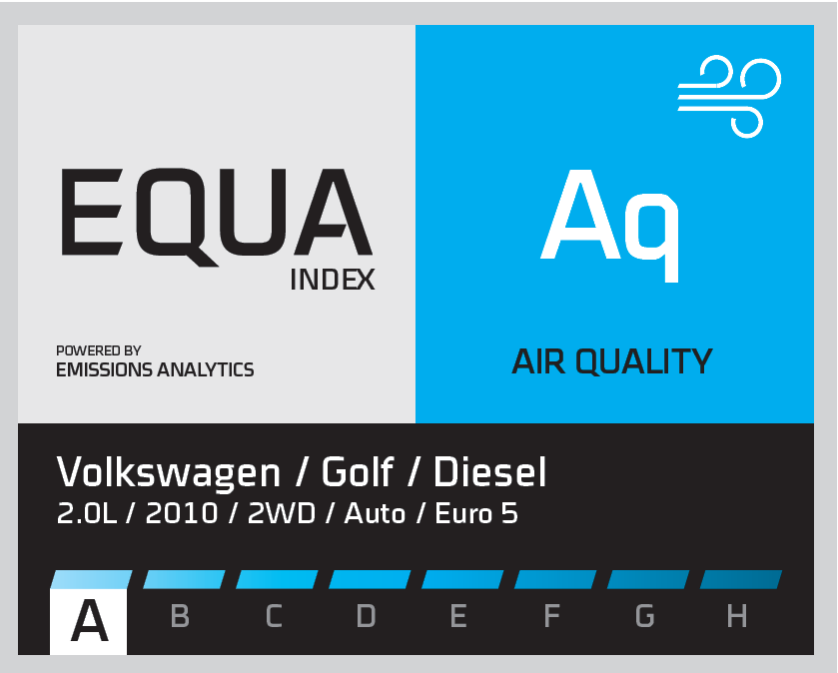
➢ Robust, independent standard needed to measure and incentivise actions to bring about air quality improvements

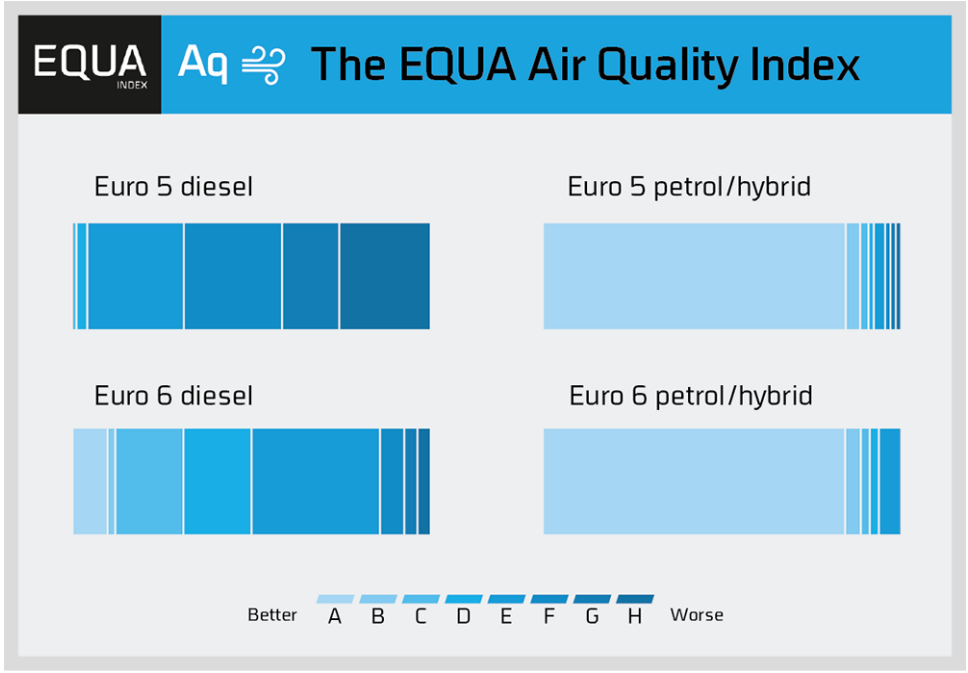
Rating bands

EMISSIONS ANALYTICS

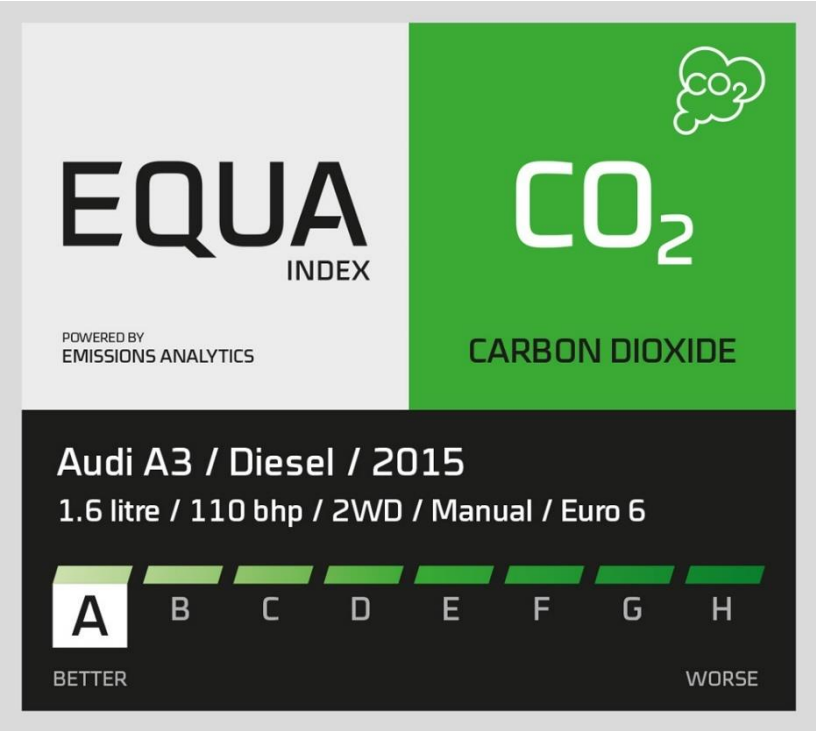
Rating	Lower bound (g/km, exclusive)	Upper bound (g/km, exclusive)	External reference point
A	0.00	0.08	Meets Euro 6 limit for diesels, and meets Euro 4 limit for gasoline
B	0.08	0.12	Meets 1.5 Conformity Factor under Euro 6 Real Driving Emissions regulation
C	0.12	0.18	Meets Euro 5 limit for diesels (and similar to 2.1 Conformity Factor under Euro 6 Real Driving Emissions regulation)
D	0.18	0.25	Meets Euro 4 limit for diesels
E	0.25	0.50	Meets Euro 3 limit for diesels
F	0.50	0.75	No comparable Euro standard: roughly equal to 6-8 times Euro 6 limit
G	0.75	1.00	Roughly equal to 8-12 times Euro 6 limit
H	1.00	None	Roughly equal to 12+ times Euro 6 limit

EQUA Aq


EQUA
INDEX
POWERED BY
EMISSIONS ANALYTICS
Aq
AIR QUALITY
Volkswagen / Golf / Diesel
2.0L / 2010 / 2WD / Auto / Euro 5
A
B
C
D
E
F
G
H

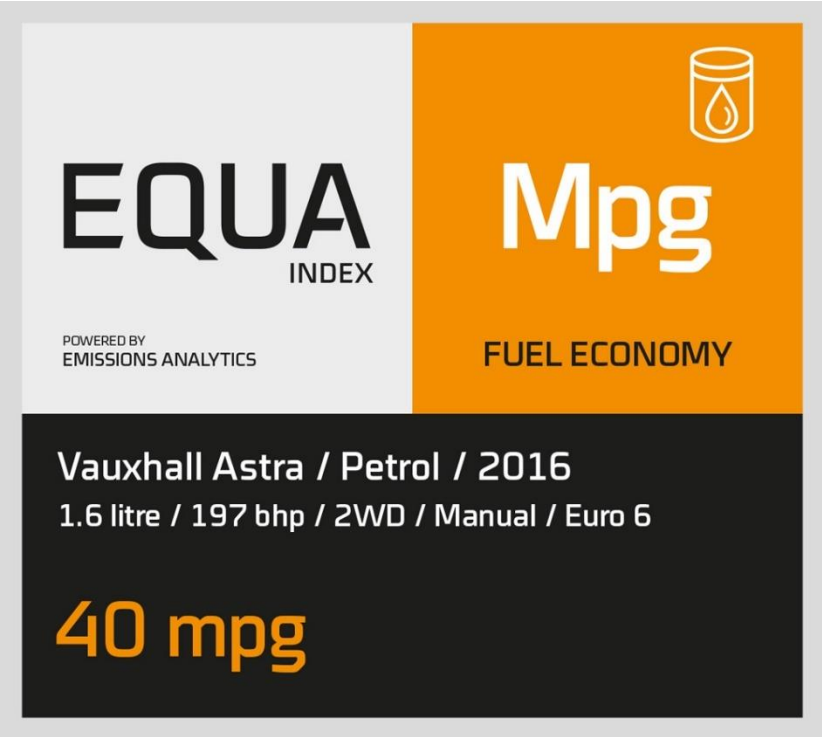

EQUA
INDEX
Aq
The EQUA Air Quality Index
Euro 5 diesel
Euro 5 petrol/hybrid
Euro 6 diesel
Euro 6 petrol/hybrid
Better
A
B
C
D
E
F
G
H
Worse

EQUA CO_2



- "A1" to "H5"
  - A to H for absolute emissions
  - 1 to 5 for proximity to official – "honesty"
- 39% average CO_2 excess – 189 g/km
- 16% higher emissions from petrol compared to diesel
- 1.5 litre engines better than most highly down-sized
- 2.0-3.0 litre engines most honest

EQUA Mpg, EQUA 100



- MPG values for almost all vehicles on sale in last five years
- Over 70,000 model variants
- Remainder extrapolated using new proprietary model of real-world MPG, based on technical characteristics of vehicles

➢ Comprehensive alternative to official system

Future of diesel?

- The EQUA Aq Index has now rated 15 diesels as A
- Means that 80mg/km is met even in real-world driving
- Conformity factor of <<1 possible
- Bigger cars tend to be cleaner – 48% of 4x4s get EQUA Aq A-C

- ➢ Is it too late?
- ➢ Governments and cities will have strong influence in outcome

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