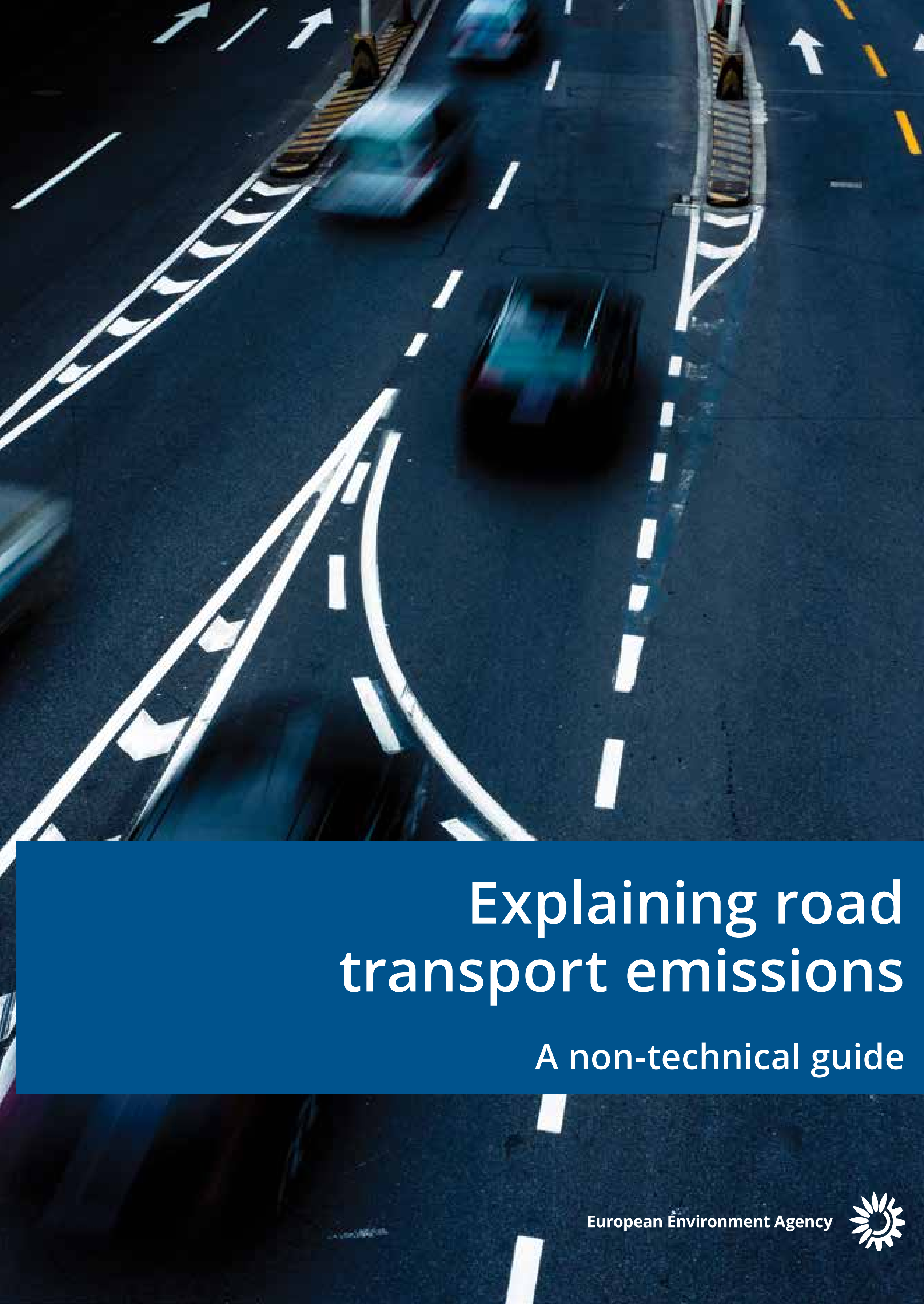


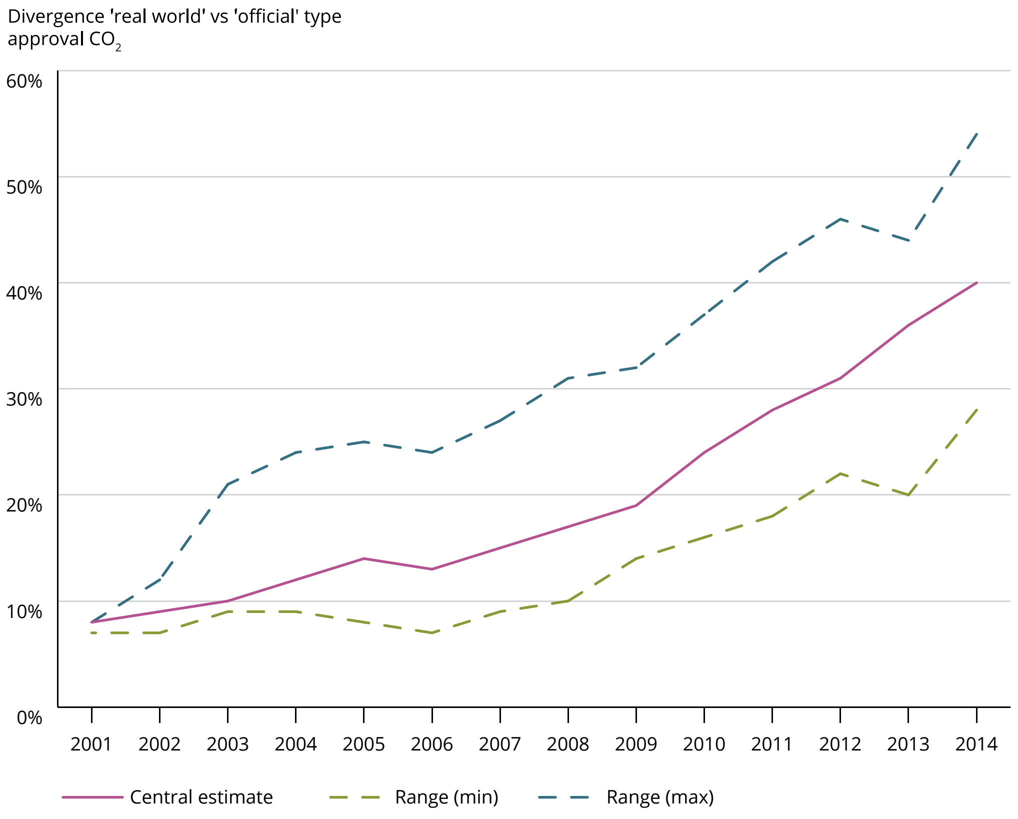
Explaining road transport emissions

A non-technical guide

European Environment Agency

A comparison of fuel consumption data from more than half a million private and company vehicles across Europe has shown how this discrepancy between type approval and real-world values has grown over the last 12 years (ICCT, 2014b; ICCT 2015a). In particular, the gap has increased considerably since 2007, when the binding EU average CO_2 target for passenger cars was first proposed. While the average discrepancy between type approval and on-road CO_2 emissions was below 10 % in 2001, by 2014 it had increased to around 40 %. Moreover, while the average discrepancy between type approval and real-world values was initially similar for diesel and petrol vehicles, since 2010 the difference between the two technologies has increased: for conventional diesel vehicles, the gap is 5 % greater than for conventional petrol vehicles.

Divergence of real-world CO_2 emissions from manufacturers' type approval CO_2 emissions



Source: ICCT, 2015a.

The biggest difference was observed for hybrid cars. Data for hybrid vehicles are available from 2010 onwards and the discrepancy between type approval and real-world CO_2 emissions is about 40–45 %. This larger difference may be explained, to some extent, by the fact that hybrids usually have automatic transmissions, which the study showed tend to consume about 40 % more fuel under real-world conditions than under type approval testing. The average difference for vehicles with manual transmissions was 33 %.

Several other European studies have shown the magnitude of the gap between NEDC legislative and real-world CO_2 emissions. All studies confirm this gap: the average discrepancy between type approval and on-road CO_2 emissions is in the range of 10–40 % (ICCT, 2013; JRC, 2011b; ICCT, 2014b).

The COPERT model: estimating road transport emissions:

COPERT (COmputer Programme to calculate Emissions from Road Transport) is a widely used software tool for calculating real-world air pollutant emissions (CO, NO_x, VOC, PM, NH_3, SO_2, heavy metals) and GHG emissions (carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4)) from the road transport sector (Emisia, 2015). Supported by the EEA and the EU's Joint Research Centre (JRC), it is used by many countries both inside and outside Europe for estimating and reporting official emissions data from the road transport sector.

COPERT calculates emissions as a product of activity data (i.e. mileage) and speed-dependent real-world emission factors. Emissions factors are separated into exhaust emission factors — split into those produced during thermally stabilised engine operation (hot emissions) and those occurring during engine start from ambient temperature (cold-start and warming-up effects) — and diffuse emissions factors, i.e. non-methane VOC emissions due to fuel evaporation and non-exhaust PM emissions from tyre and brake wear.

Emission factors for more than 240 individual vehicle types are included in the model, including for:

- passenger cars;
- light-duty vehicles;
- heavy-duty vehicles (including buses);
- mopeds; and
- motorcycles.

Emission control technologies (e.g. 'Euro' standards) are included for each of these vehicle categories — additional user-defined technologies can also be included.

Explaining the gap between real-world and legislative emissions

The existing gap between real world and test cycle emissions is mainly due to three factors (T&E, 2015; TNO, 2012):

- An outdated test procedure that does not reflect real-world driving conditions, as described in earlier sections;
- Flexibilities in the current procedures that allow manufacturers to optimise the testing, and thereby achieve lower fuel consumption and CO_2 emission values;
- Several in-use factors which are driver dependent (e.g. driving style) or independent (e.g. environmental conditions).

Test flexibilities

Flexibilities exploited by manufacturers during the NEDC test cycle can be broadly grouped into two categories: those relevant to the initial coast-down test and those relevant to the type approval test itself.

As described earlier, the coast-down measurement involves driving a vehicle up to a certain speed, and decelerating it in neutral gear until it stops. The vehicle's speed and travelled distance are constantly recorded during the test. Coast-down testing is used to determine the appropriate resistance levels (or 'road loads') to use on the dynamometer for a given vehicle model in the type approval test.

For this coast-down testing, a number of flexibilities exist:

Wheel and tyre specification. The legislation allows some flexibility in the choice of wheels and tyres that are to be used during the test. This flexibility may be used to optimise rolling and aerodynamic resistances of the vehicles by selecting low-rolling resistance tyres and low-width wheels and tyres.

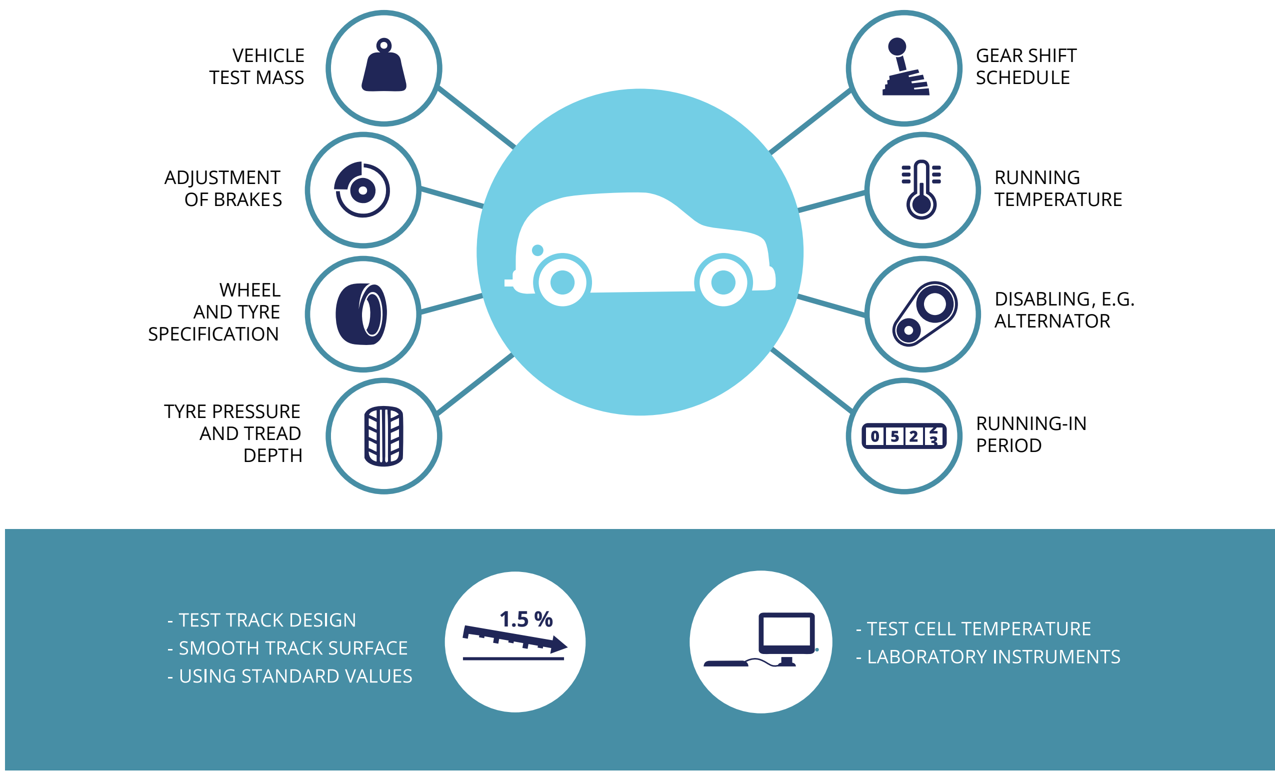
Tyre pressure. The legislation specifies that tyre pressure should be set according to the manufacturer's specifications for the use considered and should be set when the tyres are 'cold'. However, the exact temperature is not specified in the legislation. Therefore, there is some flexibility, which allows manufacturers to overinflate tyres compared with 'normal' use, resulting in a lower rolling resistance.

Adjustment of brakes. The legislation allows some adjustments to vehicle brakes in order to eliminate 'parasitic drag', namely losses from unintentional braking. This flexibility may be used to further improve coast-down performance.

Vehicle preconditioning. The legislation specifies that the vehicle should be brought to normal running temperature in an appropriate manner. This 'normal running temperature', however, is not defined. Hence, there is some flexibility, which allows manufacturers to optimise vehicle temperature during the testing, resulting in a lower rolling resistance.

Running-in period. The legislation specifies that the vehicle should be tested after having been run-in for at least 3 000 km. The tyres should be run-in for the same distance or have a tread depth between 90 and 50 % of the initial tread depth. Hence, there is some flexibility, which allows manufacturers to use tyres with minimum tread depth to reduce rolling resistance.

Flexibilities in the NEDC test approval procedure



Source: T&E, 2015; TNO, 2012.

Test track design. The legislation defines the characteristics of the road on which the vehicle is tested. The road surface is, however, not specified; hence, there is some flexibility in optimising the road surface, as a smooth surface results in lower rolling resistance than a rough surface.

Using all the above flexibilities, an improved coast-down result leads to reduced resistances over the NEDC test and hence lower fuel consumption. Test results from a recent study conducted for the European Commission (TNO, 2012) show that the estimated CO_2 benefit from utilising all flexibilities within the allowable limits relating to the coast-down test is about 4.5 %. The reduced resistances are also likely to help manufacturers reduce NO_x and PM emissions during the NEDC testing.

Volkswagen and 'defeat devices'

In September 2015, the United States Environmental Protection Agency (USEPA) announced that it had issued a notice of violation of vehicle emission limits against Volkswagen. This occurred after the USEPA, together with the Californian Air Resources Board, had investigated a variety of four-cylinder diesel passenger cars manufactured by Volkswagen and found that the on-road performance of these vehicles emitted up to 40 times more NO_x than permitted by the US emission standards.

Volkswagen subsequently admitted to using 'defeat devices' in the USA to artificially lower NO_x emissions during testing of these diesel vehicles. The defeat devices comprise computer software that can identify when a vehicle is being tested by monitoring various parameters such as speed, engine operation, air pressure and external conditions (i.e. temperature and humidity). When the engine software recognises the vehicles is undergoing a test, engine operation and the performance of the vehicle catalyst change to ensure that the pollution standards were respected. However, once on the road, the emission control systems were reduced or switched off resulting in significantly higher emissions under 'normal' operating conditions. Volkswagen has subsequently confirmed it has also sold diesel vehicles in Europe containing the same defeat device software.

Subsequently in early November 2015, the USEPA issued a second notice of violation after discovering certain additional larger diesel vehicles manufactured by Volkswagen Group also appeared to use defeat devices. Separately, Volkswagen Group has also publicly confirmed that the fuel consumption and CO_2 emission values it has published for some models are incorrectly stated. The company is presently reviewing which models are specifically affected.

At the time of writing, several Member States have announced that they plan to independently investigate the on-road emissions of Volkswagen diesel vehicles, as well as those from other manufacturers. The new real emissions testing procedure (RDE), which will be adopted soon in the EU, will also provide a valuable check to the on-road performance of vehicles compared with laboratory testing.

Optimising NEDC test conditions — changes in emissions of selected pollutants

Fuel type	CO_2	NO_x	PM	CO	HCs
Petrol	↓	↓	↓	↑	↑
Diesel	↓	↓	↓	↑	↑

For the NEDC type approval test itself, the main permitted flexibilities that manufacturers may take advantage of are:

Vehicle test mass. The reference mass is the mass of the unloaded vehicle increased by 100 kg, which corresponds to the mass of the driver and the fuel. The definition of reference mass depends on which parts of the vehicle are considered to be fitted by the manufacturer and which are fitted at a later stage as aftermarket or car dealer options. This flexibility allows manufacturers to reduce vehicle testing mass by specifying items as dealer-fitted optional extras, resulting in lower resistances in the chassis dynamometer.

Wheel and tyre specification. The legislation specifies that standard wheels, tyres and tyre pressures should be used. There is some flexibility in defining what are standard wheels and tyres for a specific vehicle model. This allows manufacturers to optimise the overall vehicle configuration for testing, for example by selecting low-rolling resistance tyres and a high tyre pressure and specifying that this is the standard vehicle setting.

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Laboratory instrumentation. The legislation specifies the measurement accuracy and tolerances for a range of instrumentation equipment. These tolerances can be used for calibrating the equipment towards one end of the allowable range. Examples are the temperature, atmospheric pressure and humidity of the test cell, accuracy of the gas analysers, etc.

Test cell temperature. The legislation specifies a range of temperatures in the test cell before and during the test. A higher temperature generally reduces friction in the engine and vehicle components. This flexibility in temperature selection improves efficiency, thus reducing CO_2 emissions.

Dynamometer load. Use of the coast-down curve is not the only option for simulating road load during the type approval test. The legislation provides the option of using standard 'table values' commonly referred to as the 'cookbook' method. This method does not include a measurement of aerodynamic or rolling resistance for the vehicle being tested, but contains only typical factors. This flexibility allows manufacturers to use the 'cookbook' for testing vehicles that have relatively high aerodynamic and/or rolling resistance, for example vans or all-wheel drive vehicles.

Gear shift schedule. The legislation defines the gear number and shift points of the NEDC test. However, the use of higher gears is allowed if a vehicle cannot reach a speed of 15 km/h in first gear. The use of higher gears generally decreases fuel consumption, as higher gears allow the engine to operate more efficiently owing to lower engine rotational speeds.

Driving technique. It is very difficult for a driver to exactly follow the speed trace of the NEDC. To account for this, the legislation allows a tolerance of ± 2 km/h between the actual and the target vehicle speed. This flexibility allows experienced drivers to use these limits to their benefit, by following the lower limit at constant speeds and by achieving smoother accelerations.

Other reasons for divergences

The different flexibilities of the type approval test discussed above are not the only factors responsible for the observed differences between laboratory measurements and real-world emissions. Other factors, discussed below, also contribute to this effect.

The use of on-board electrical equipment, such as heated seats, window defrosters, air-conditioning units for cabin heating and cooling, and entertainment systems, may require significant additional amounts of energy to operate. All of these systems are switched off during the type approval test and hence their impact is not taken into account in the fuel consumption reported by car manufacturers.

The condition of the vehicle in real-world driving might also be completely different from when the vehicle is type approved, and lead to increased fuel consumption and hence emissions. For example:

- additional passengers and cargo result in the vehicle becoming heavier, reducing fuel economy;
- accessories for carrying cargo such as roof racks or rear-mount cargo boxes increase wind resistance — the additional resistance increases with vehicle speed;
- lower than recommended tyre pressure increase rolling resistance.

Driving behaviour and conditions have a significant effect on fuel economy. Although 'normal' driving is difficult to define, 'aggressive' driving (speeding, rapid accelerations and braking) will use significantly more fuel. Speeds above 90 km/h increase fuel consumption substantially. Other external factors, such as fuel quality, weather conditions and road surface, can also affect fuel economy.

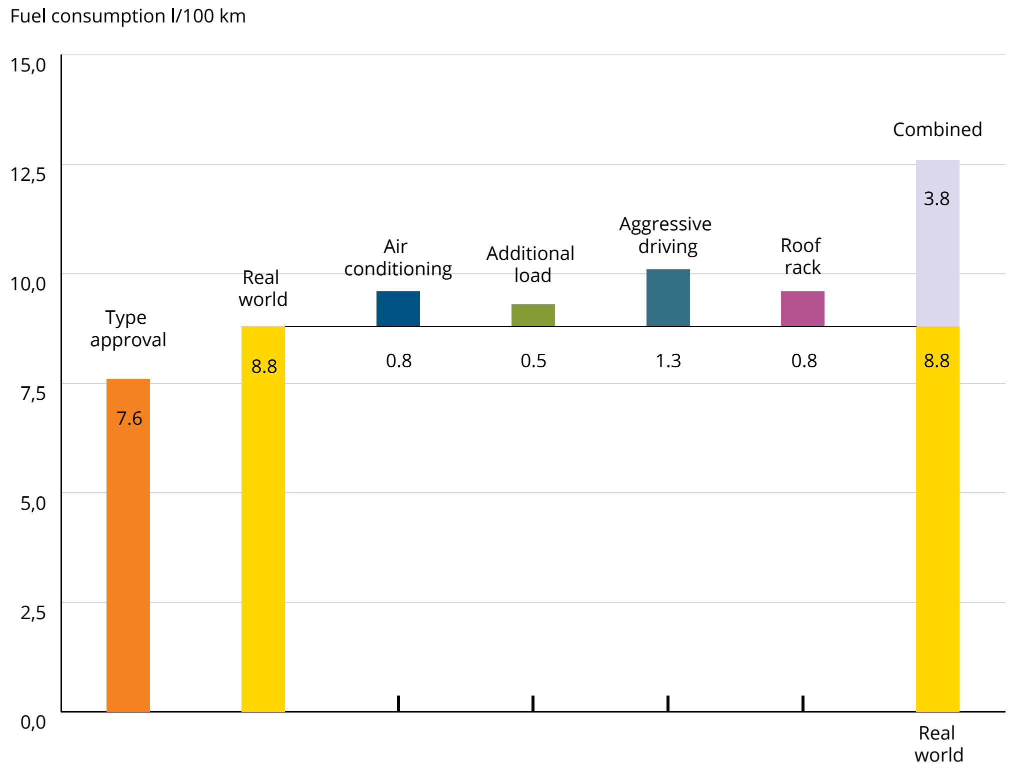
- Engine and transmission friction increases at low ambient temperatures owing to cold engine oil.
- Hot and humid conditions increase the power demand of the air-conditioning unit.
- In winter, it takes longer for the engine to reach its most fuel-efficient temperature. This affects shorter trips more, as the car spends more of the trip at less-than-optimal temperatures.

The following figure shows the potential impact on fuel consumption of selected factors for a typical mid-sized petrol car (AVL, 2015). While clearly representing a 'maximum' driving scenario, it serves to illustrate the significant penalty in fuel consumption that different vehicle and driving conditions can have. Such a vehicle, having an official fuel consumption value of 7.6 L/100 km, is estimated to have a real-world fuel consumption of around 8.8 L/100 km, i.e. 16 % higher than the official value. In addition, the effect of selected parameters can also be estimated using vehicle simulation software:

- turning the air-conditioning unit on;
- the additional load of four passengers and luggage;
- demanding driving with a 30 % increase in average speed and rapid accelerations and braking;
- adding a roof rack, resulting in a 15 % increase in aerodynamic coefficient and another 20 % increase in frontal area.

Overall, under these operating conditions, real-world CO_2 emissions for this vehicle might be as high as 12.6 L/100 km, around 65 % higher than the tested measurement.

Impact of selected vehicle and driving conditions on fuel economy for a typical mid-sized petrol car



Note: The combined value of all these parameters does not equal the sum of the individual values, as their effects are non-linear.

Source: AVL, 2015.