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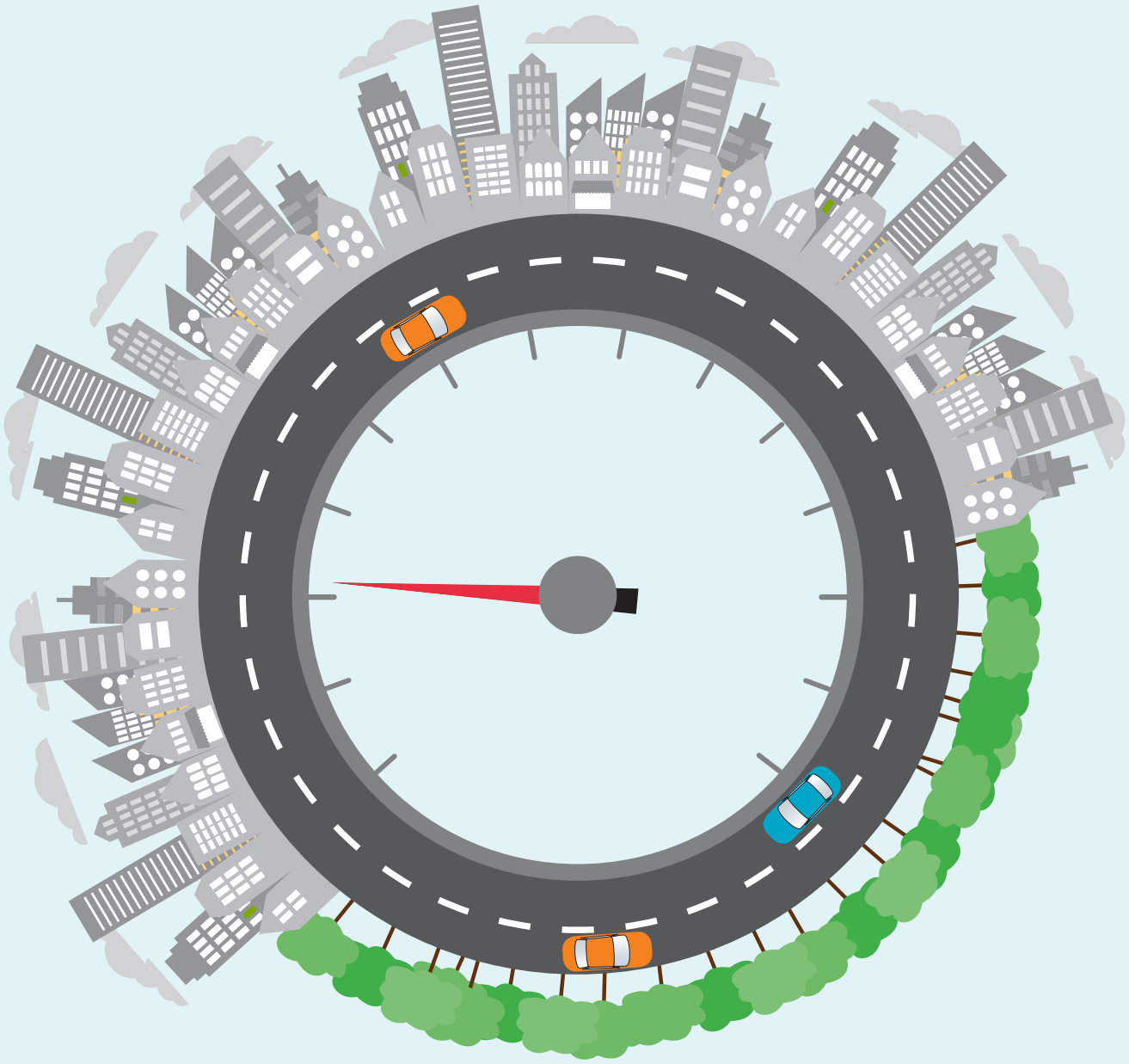

Ecologically Driven

Fuel Consumption in Theory and Practice

Contents

Between Theory and Practice

Dr Heinz-Jakob Neußer on Economical Driving

Dr Heinz-Jakob Neußer, Board Member of Management for the Volkswagen Brand and Head of Powertrain Development of Volkswagen Group.

There are many complaints that companies' consumption data does not match customers' consumption. What factors are relevant to our everyday consumption?
The legislature has introduced the New European Driving Cycle (NEDC) in order to compare the consumption of different vehicles. A car's actual everyday consumption is influenced by factors that are not taken into consideration for the NEDC rating. This causes discrepancies between consumption in theory and in practice. Among these factors are; weather conditions, traffic volume, the topography of the area or the sum of all the auxiliary equipment that is switched on. Additionally, the driver can very strongly influence consumption by driving in an anticipatory and defensive manner.

How is Volkswagen supporting its customers in learning to drive ecologically and economically?
With the Volkswagen Driving Experience, to give an example, we offer driving training. Think Blue Eco-Training is directed towards an environmentally sensitive driving style. Here, our customers can experience what ecological driving is about. Another option that we also offer is the Think Blue Trainer. It is an app that calculates the consumption of the journeys driven. On the basis of the collected data, the application can give helpful recommendations with the goal of improving your driving style – finding the ideal time to switch gears, for example.

A new test cycle called WLTP that is said to apply worldwide is being talked about: what would the consequences be if the EU decides to switch from NEDC to WLTP?
A switch to WLTP would most likely be closer to the customers' consumption because the percentages of city, road and highways are weighted differently, and higher velocities are driven. The current targets for CO_2 have, however, been defined based on the NEDC. This is why it is important to readjust these targets proportionally to the new cycle, if the WLTP is introduced.

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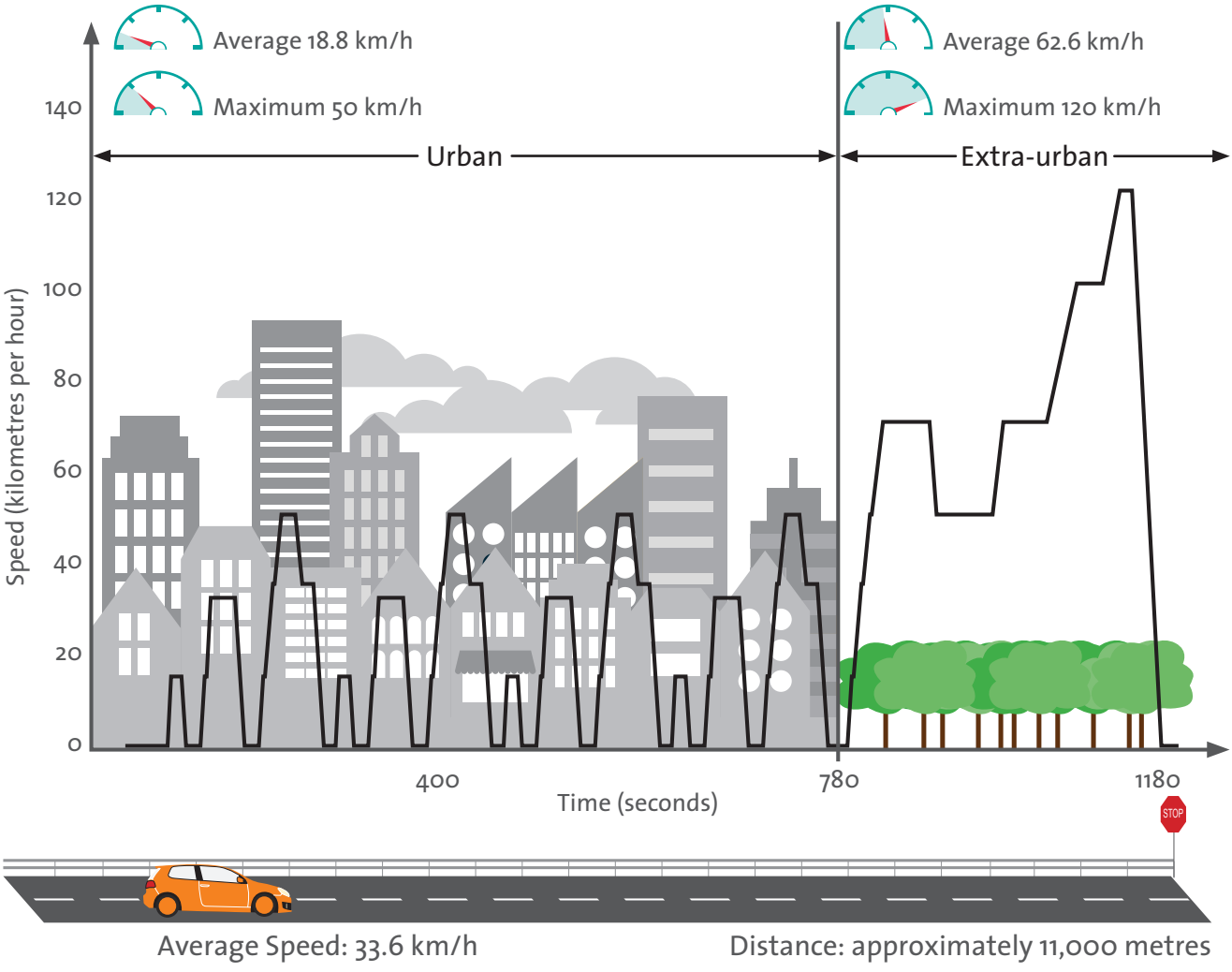
GUIDELINES

The New European Driving Cycle

How much fuel does a vehicle consume, how much CO_2 does it emit and which exhaust gases are released? All through Europe, these standardised values are determined using the New European Driving Cycle. In order to obtain approval for a new model, car manufacturers are required by law to determine its emissions and fuel consumption values using this test cycle. This generates the data in the catalogue that can provide reference points for a purchase decision, and is the basis for taxation.

Driving profile of the NEDC



Consumption and pollution levels are not assessed by the manufacturers themselves but under the supervision of an independent technical service, such as the TÜV (Technical Inspection Association).

The New European Driving Cycle simulates urban and extra-urban driving. Travel speed, gear shift points and test duration are defined in detail in the legislation.

Fuel consumption of the XL1 (in litres per 100 kilometres, combined): 0.9; power consumption (in kilowatt hours per 100 kilometres, combined): 7.2; CO_2 emissions (in grams per kilometre, combined): 21; efficiency class: A+.

Cars are tested in the laboratory as part of the NEDC. The wheels of the vehicle drive a dynamometer that generates driving resistance using an adjustable electric brake. All forces that can act on the vehicle in reality are simulated by the test bed. This includes both the inertia of the vehicle – a heavy vehicle is harder to move – as well as the aerodynamic drag and rolling resistance.

The Details:

Legal Requirements	Reason
The accelerations are moderate.	This way, all test vehicles can achieve the required acceleration.
The required test temperature in the laboratory is between 20 and 30 degrees Celsius.	This is the temperature range that can be set in the laboratory at reasonable expense.
Auxiliary equipment – such as the radio, heated rear window or air conditioning – is switched off.	During the measurement, only the auxiliary equipment that is needed for the operation of the vehicle is switched on. In addition, not all vehicles have, for example, air conditioning. An important goal of the NEDC is to ensure the comparability of the data across a variety of vehicles.
The tyre with the highest rolling resistance is used. Exception: if more than three tyre versions with different rolling friction coefficients are available, the tyre with the second lowest rolling resistance is used.	Rolling resistance has a significant influence on driving resistance. Tyres with lower rolling resistance cause reduced fuel consumption.

The NEDC has been valid since 1996. It was developed in the late 1980s with the goal of providing a standard for the measurement of exhaust emissions and fuel consumption. The test results, provided by today's cycle, offer motorists a guideline. This way, they can compare cars from different manufacturers.

Clear Objective

How the NEDC Makes Consumption and Emissions Comparable

Among drive concepts based on fossil fuels such as petrol, diesel or natural gas there are vehicles that run on electricity or bio-ethanol. Plug-in hybrid cars are even based on a combination of two drive concepts. They all go through the NEDC, and are thus made comparable for the customer.

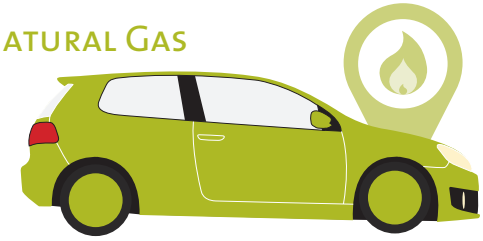
The NEDC records four values (urban consumption, extra-urban consumption, combined consumption, and CO_2 emissions combined) for each vehicle model tested. Fuel consumption and CO_2 emissions must be specified by the vehicle manufacturer in its advertising. While the CO_2 value allows a direct comparison of emissions, due to its consistency, fuel consumption is denominated in different units depending on the fuel used.

The consumption of different drives, taking the example of the Golf VII *

Petrol

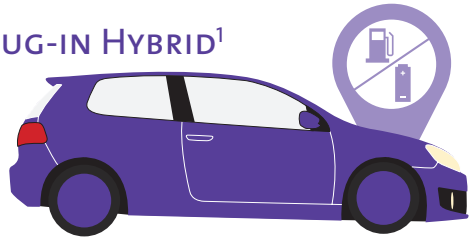
1. Consumption (combined): 4.7 l/100 km
2. Energy Cost**: 7.47 EUR/100 km
3. CO_2 Emissions (combined): 119 g/km

Natural Gas



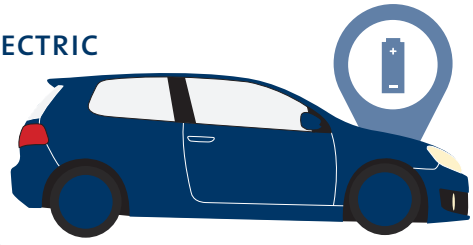
1. Consumption (combined): 3.4 kg/100 km
2. Energy Cost**: 3.54 EUR/100 km
3. CO_2 Emissions (combined): 92 g/km

Plug-in Hybrid[1]



1. Consumption (combined): 1.5 l/100 km + 11.4 kWh/100 km
2. Energy Cost**: 2.39 EUR/100 km + 2.95 EUR/100 km
3. CO_2 Emissions (combined): 35 g/km

Electric



1. Consumption (combined): 12.7 kWh/100 km
2. Energy Cost**: 3.30 EUR/100 km
3. CO_2 Emissions (combined): 0 g/km

1 Information for the electrical consumption and fuel consumption of externally chargeable hybrids includes a weighting with the concept-dependent electric range.

* Energy consumption of the Golf VII (in litres per 100 kilometres): combined between 5.2 and 3.2; CO_2 Emissions (in grams per kilometre): combined between 122 and 85.

** Average energy cost for premium petrol and natural gas in 2013, source ADAC (the German Automobile Club). Prices can vary regionally. Electricity price used as basis: 0.2589 EUR/kWh.

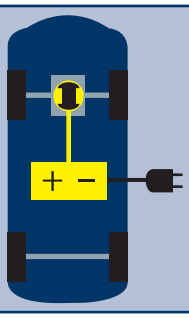
In terms of figures, the comparison paints a clear picture: the electric car is the most efficient, based exclusively on fuel consumption and fuel prices.

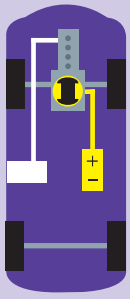
The Specifics of the Types of Drive in the NEDC

In order to give consideration to the different technical characteristics of all drive concepts, the vehicles do not pass the NEDC by the usual process. Each drive has its own program:

Electric

First, the vehicle goes through the NEDC until the battery is discharged. The distance travelled results in the range, in kilometres. In a second test, the electrical energy consumption in two consecutive test cycles is determined by recharging the battery. The recharged electrical energy is then allocated to the distance travelled in the test, and results in the consumption data being in kilowatt hours per 100 kilometres.



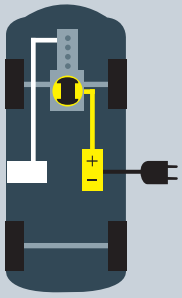


Hybrid

The pollutant emissions and fuel consumption of non-externally chargeable hybrid vehicles are assessed in the same way as conventional vehicles. In addition, the energy consideration is determined by the charge balance of the battery of these vehicles, and the fuel consumption in the test cycle is corrected if necessary. The fuel consumption is specified in litres per 100 kilometres, after this charge balance correction.

Plug-in Hybrid

To determine the electric range, the vehicle goes through the NEDC until the battery is discharged. The potential operating time of the combustion engine is not taken into consideration for this specification. Two NEDCs, one with a fully charged and one with a discharged battery, are started to assess fuel consumption, electric energy consumption and pollutant emissions. The results of both tests are weighted with respect to the electric range. The energy consumption of an externally chargeable hybrid is specified by the range-weighted fuel consumption in litres per 100 kilometres, and the range-weighted electrical energy consumption in kilowatt hours per 100 kilometres.



Natural Gas

Natural gas driven cars pass their NEDC the same as the traditional internal combustion engines. Their fuel consumption is measured in cubic metres per 100 kilometres. The car manufacturers denominate this value in kilograms. This is due to two regulations: the fuel consumption is given in cubic metres per 100 kilometres as part of the type approval process. The car energy consumption labelling requires vehicle manufacturers of natural gas-powered vehicles in Germany to specify fuel consumption in kilograms per 100 kilometres. It is sold by weight at the petrol station, too: compressed natural gas may only be sold in kilograms, not cubic metres, according to the German Weights and Measures Act.

It's in the Mix

Why the Theoretical Consumption Can Differ in Practice

The NEDC provides a reference point for the consumption and emissions of a car. It cannot make statements about realistic values. These consumptions depend to a high degree on factors which may be difficult or impossible to simulate or make comparable. Possible influencing factors in internal combustion engines are:

Driving Behaviour

Accelerating, changing lanes, accelerating again – the driver's foot has the greatest additional impact on consumption values. Anticipatory driving, adapted to the traffic situation, ensures significantly lower fuel consumption. When coasting in gear for example, a momentary fuel consumption of 0.0 litres is possible. The overrun cut-off interrupts the fuel supply to the motor at that moment. Also coasting while in neutral can significantly save fuel.

Weather

Most of the technical components run optimally only above a certain operating temperature: the lower the ambient temperature, the greater the difference to the optimal operating temperature. The reason for this is power loss due to friction. At low temperatures, such as during a cold start in winter, the components have a higher friction, causing higher consumption.

Trailer Operation

A trailer impacts in several ways, in terms of fuel consumption: not only does it increase the weight of the vehicle but it also alters its aerodynamic drag and rolling resistance.

Aerodynamics

Aerodynamic efficiency is a prerequisite for low fuel consumption, especially at higher speeds. Roof and bike racks have a negative effect on the air resistance of a vehicle. At a speed of 160 kilometres per hour, for example, they cause an increased consumption of up to two litres per 100 kilometres.

Weight

Each additional kilo costs fuel. Whether passengers or luggage, a fully loaded car has worse fuel economy than an empty vehicle. 100 kilograms of additional weight can cause an increase in consumption of up to 0.2 litres per 100 kilometres.

Topography

Significantly more fuel is consumed on hilly terrain than when driving on a flat road. One can minimise consumption by being mindful of not accelerating uphill, for example, or by coasting downhill.

Maintenance Condition

A well maintained engine saves fuel. Checking the oil level regularly, using low-viscosity oils and refilling on time, lowers overall consumption of the vehicle. A good five percent reduction can be achieved this way. Also, the air pressure in the tyres reduces consumption. Inflated tyres have lower rolling resistance and ease the load on the engine; up to five percent less total consumption is possible.

Auxiliary Equipment

Auxiliary consumers are all systems in the car that impact fuel consumption in addition to the drive unit. This includes air conditioning and heating, as well as the Infotainment system or the electrical power steering. The air conditioning counts among the auxiliary consumers with the highest influence on the consumption. It consumes up to two litres per 100 kilometres more, at low speed, in order to lower the interior temperature in the summer and keep it at a constant level.

Different Countries, Different Customs?

The Future of Test Cycles

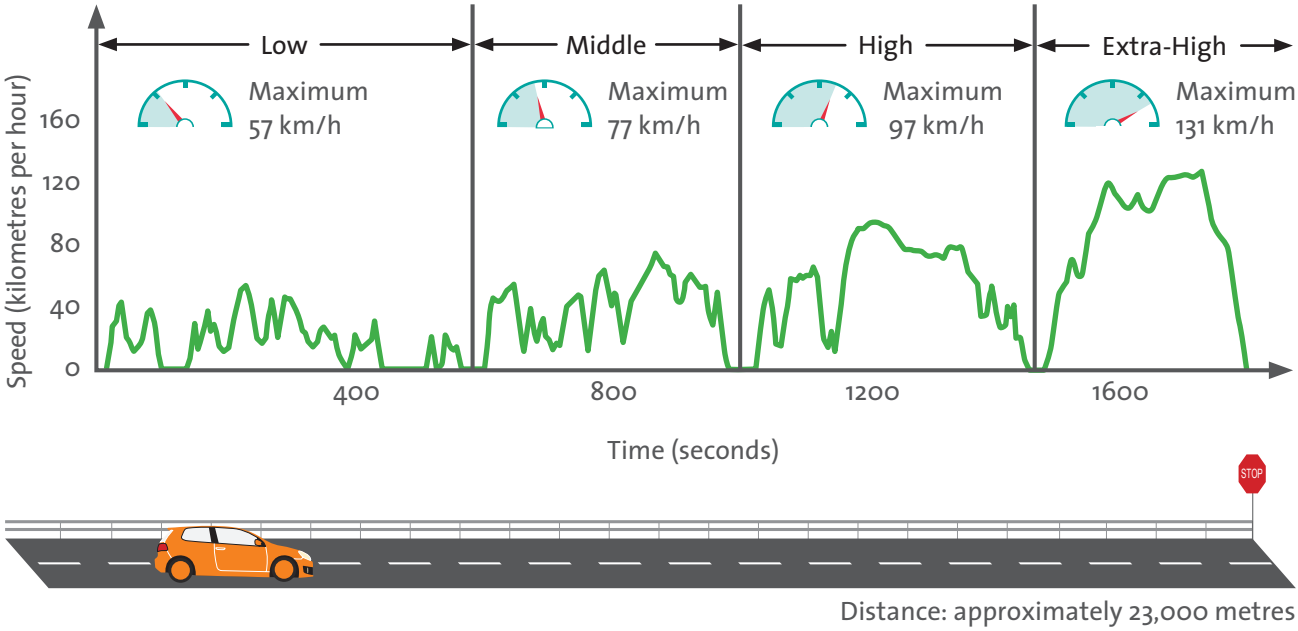
The NEDC test cycle has been developed for Europe and European traffic conditions. In other regions of the world different consumption measurement cycles apply, due to different traffic conditions. A UN Commission is currently working on a global standardised test cycle for passenger cars and light commercial vehicles, the World-Harmonized Light-Duty Vehicles Test Procedure (WLTP), with the declared goal of global comparability of technical products. It is still unclear in which markets the WLTP will be the new standard.

The NEDC, as a set of rules, has not only proven itself in Europe: even China, Argentina, Australia and South Africa use the European driving cycle, with some slight variations integrated in the regional legislation. India, for example, limits the maximum speed according to the maximum speed allowed outside her cities of 90 kilometres per hour.

But the NEDC is not always effective: in Japan and the US completely different test cycles apply, due to regional differences. For example, the island nation of Japan is characterised by major metropolitan areas; correspondingly, long-distance drives have a very small share in the Japanese Cycle JC-08.

The World-Harmonized Light-Duty Vehicles Test Cycle (WLTC)*

* The WLTC is the test cycle of the WLTP.



The world cycle consists of four parts Low, Middle, High and Extra High, each covering different speed ranges. In the current form of the test, the vehicle travels for a distance of about 3 kilometres in the Low part, approximately 5 kilometres in the Middle part, about 7 kilometres in High and about 7.7 kilometres in Extra-High. The average speeds of the WLTP are higher than those of the European driving cycle, also there is more dynamic acceleration and less traffic light phases. The aim of the WLTP is similar to that of NEDC; an objective measure to compare technical products. The European Commission intends to introduce the WLTP in 2017 in Europe. Until then, it is important to answer open questions. For example, that of the CO_2 targets. The previously existing political targets for 2020 of 95 grams of CO_2 per kilometre are based on the values determined by the NEDC. Independent laboratories and car manufacturers demand an adjustment of those values.