Baseline determination in the EU and China

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G20 Transport Task Group:

Deep Dive to Support Heavy-Duty Vehicle Efficiency Labeling and Standards Meeting #5

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Outline

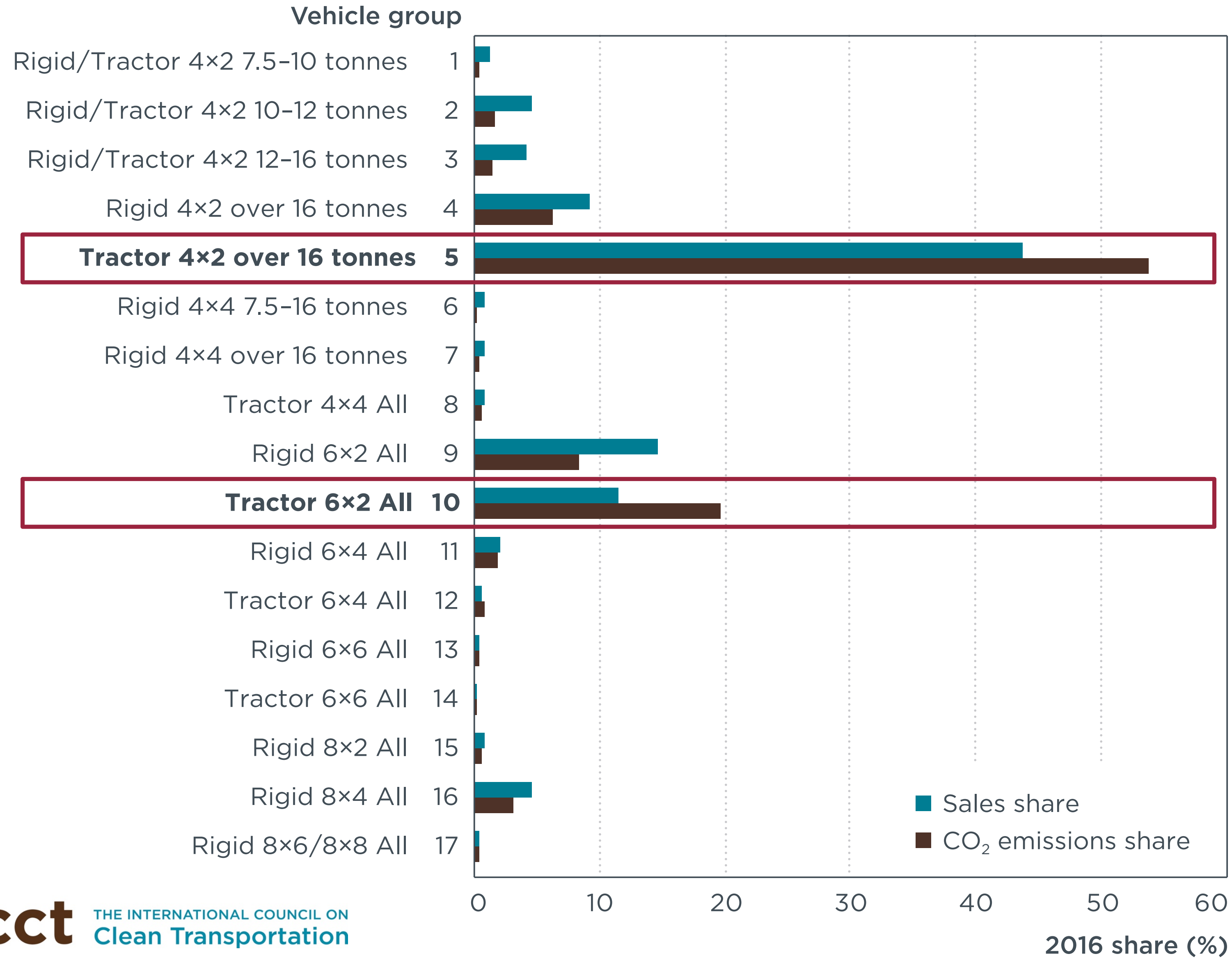
1. Base determination for ICCT studies

2. Baseline determination approach in the EU: Monitoring and reporting regulation

3. Baseline determination in China

ICCT’s approach to baseline determination

Tractor-trailers are the majority of HDV CO_2 emissions



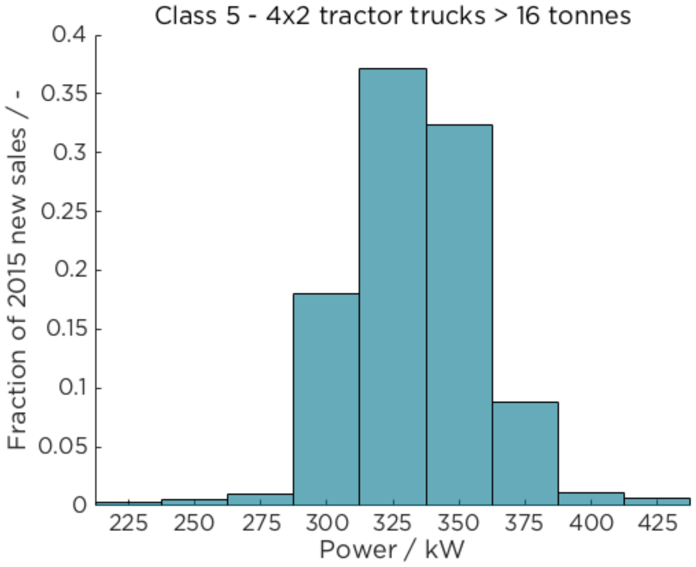
Vehicle groups 5 and 10 (i.e., tractor-trailers) account for over 70% on the CO_2 emissions of on-road HDVs

Source: Delgado, O., Rodríguez, F., & Muncrief, R. (2017). *Fuel Efficiency Technology in European Heavy-Duty Vehicles: Baseline and Potential for the 2020–2030 Time Frame*. International Council on Clean Transportation.

http://www.theicct.org/EU-HDV-fuel-efficiency-tech-2020-2030

Class 5 – 4x2, tractor trucks over 16 tonnes

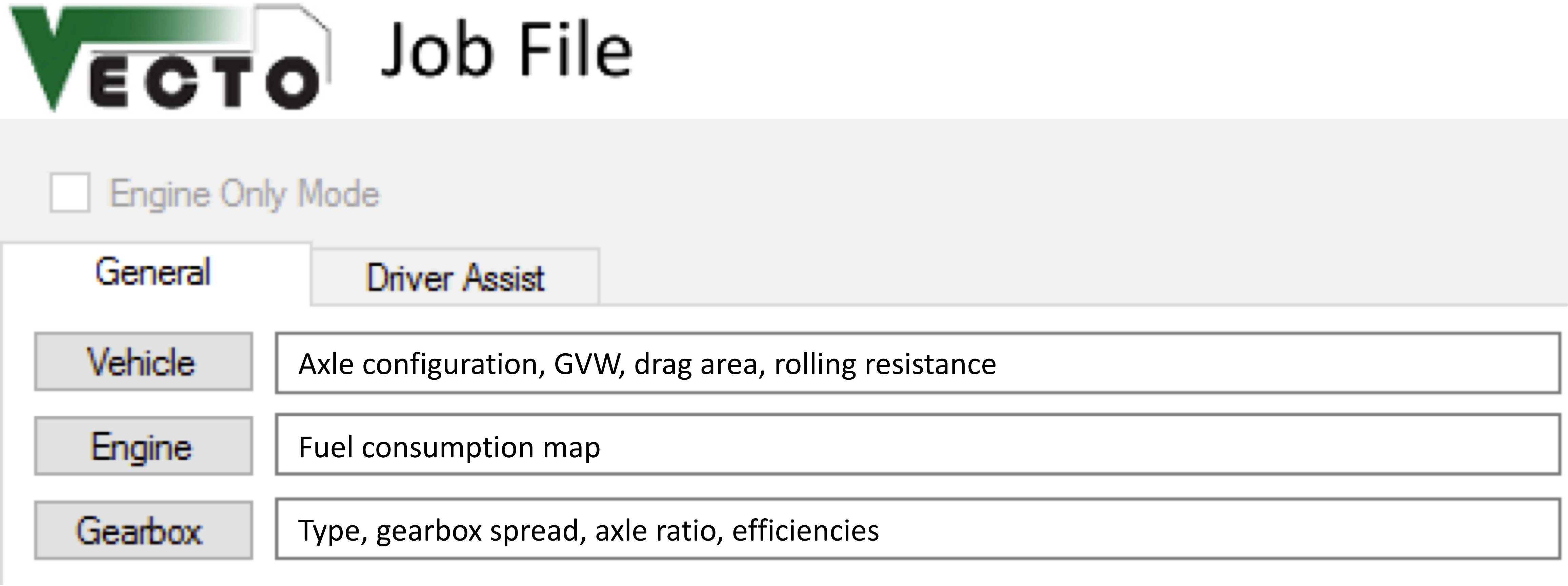
2015 new sales data supplied by © IHS Global SA



ICCT's approach to baseline determination

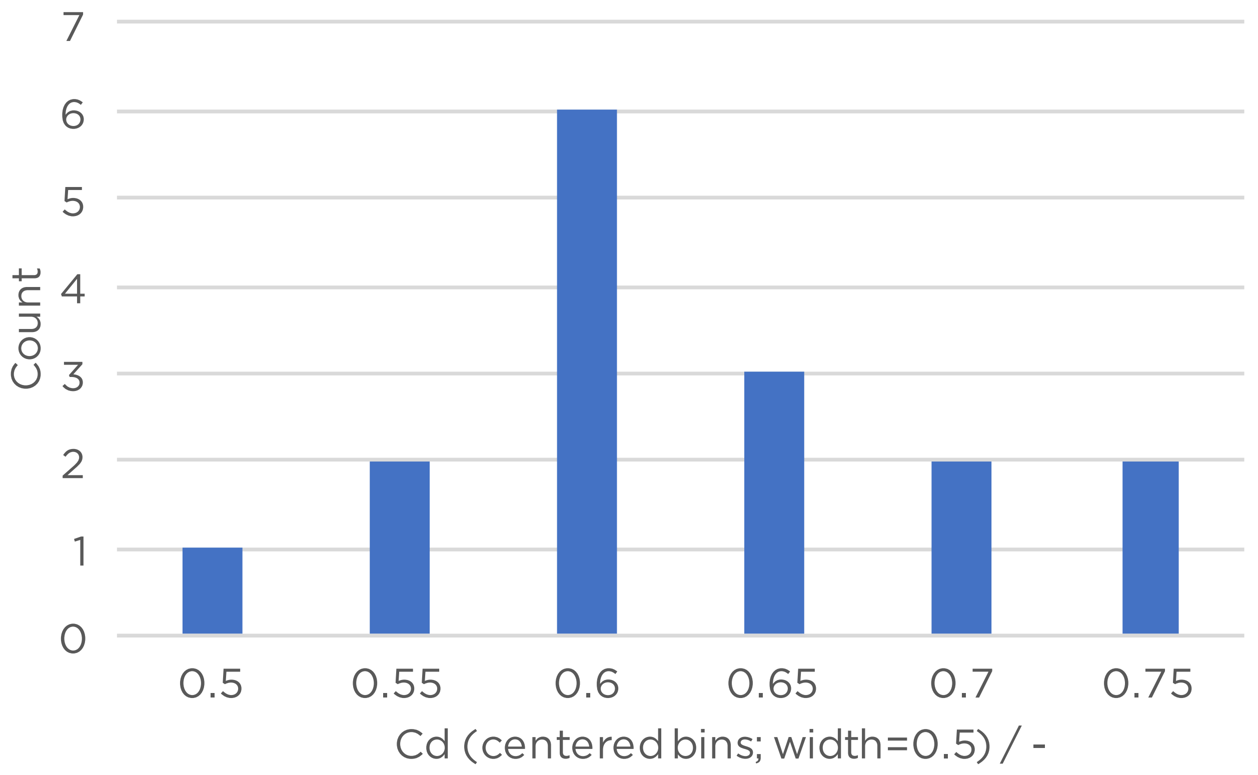
What are the main VECTO inputs and what do we know about them?

VECTO inputs



Drag Coefficient, Cd

Literature review of 16 different sources. Different methodologies for Cd determination: Constant speed, coast-down, and CFD

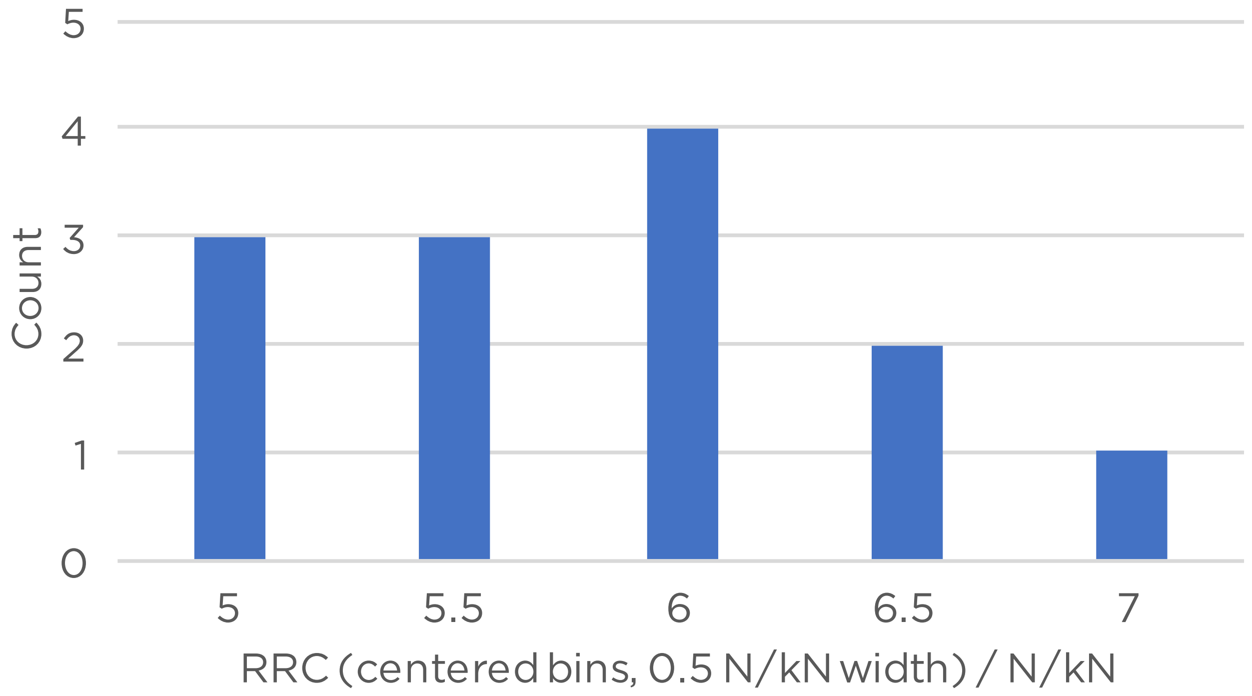


Cd	Notes	Source
0.72	Experimentally validated CFD analysis on a simplified but representative geometry	(Ekman, Gårdhagen, Virdung, & Karlsson, 2015)
0.53	Constant speed measurement of a Euro VI tractor-trailer as part of the HDV-LOT 3	(Dünnebeil et al., 2015)
0.59	Average of 7 coast-down measurements of a Euro V tractor-trailer	(Süßmann & Lienkamp, 2015)
0.59	CFD study of representative tractor-trailer with roof and side fairings and wheel-houses	(Salati, Cheli, & Schito, 2015)
0.63	CFD analysis of generic semi-trailer by FAT (Forschungsvereinigung Automobiltechnik)	(Luz et al., 2014)
0.64	Mid-point of the Cd range (0.49-0.79) identified for tractor-trailers	(Kopp, 2012)
0.6	Representative Cd value of a 40 ton tractor-trailer as identified in HDV-LOT 1	(Hill et al., 2011)
0.69	Constant speed testing of a representative Euro V tractor with a standard trailer	(Hausberger et al., 2011)
0.75	Average of coast-down measurements of 3 different trucks of 3 manufacturers	(Raja & Baxter, 2010)
0.75	Average of coast-down measurements of 5 different Euro V trucks of 5 manufacturers	(Stenvall, 2010)
0.65	Cd measurement from coast-down test of a 40 tonnes tractor-trailer on a closed track	(Roche & Mammetti, 2015)
0.61	Mean of 33 constant speed experiments at 90 km/h of a Euro V truck under 1° yaw	(Peiró Frasquet & Indinger, 2013)
0.55	Mean of 39 constant speed experiments at 90 km/h of a Euro V truck under 2° yaw	(Peiró Frasquet & Indinger, 2013)
0.5	Cd estimation for a tractor-trailer with a 10.2 square meter frontal area	(Håkansson & Lenngren, 2010)
0.58	Baseline assumption in the EU CORE project. CdA=5.82m^2, A=10m^2 is assumed	(Engström, 2015)
0.61	Cd measured from coast-down test for a selected tractor-trailer	(KGP, 2015)

Full references can be found in Delgado et al.'s (2017) report: *Fuel Efficiency Technology in European Heavy-Duty Vehicles: Baseline and Potential for the 2020–2030 Time Frame.* http://www.theicct.org/EU-HDV-fuel-efficiency-tech-2020-2030

Rolling resistance – RRC

Literature review of 13 different sources[1]



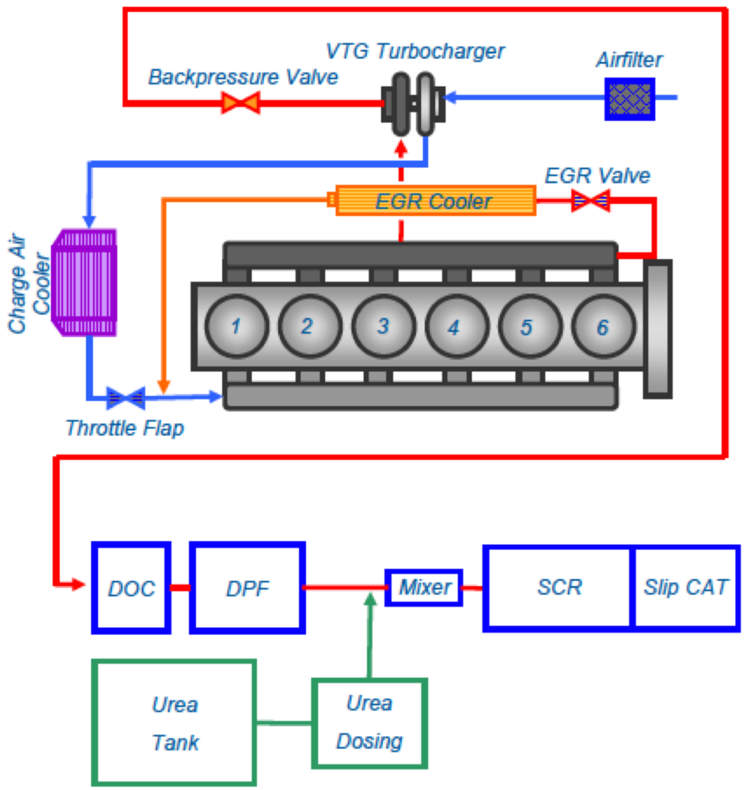
RRC (N/kN)	Notes	Source
6.13	2015 average of two large datasets with over 3000 tires and 2500 tire models	(Viegand Maagøe A/S, 2016)
6.2	Average of 7 coast down tests on a MAN 18.440 Euro V truck	(Süßmann & Lienkamp, 2015)
6.3	Weighted average based on market offer of online tire shops	(Dünnebeil & Keller, 2015)
6.02	Generic RRC for 40t tractor: 5.55 steer, 6.28 drive, 35/65 weight distribution	VECTO generic tractor-trailer vehicle configuration file
5.5	Typical vehicle specification from data collected for LOT2 and LOT3 reports	(Luz et al., 2014)
5.37	BC-BBB tire class distribution. RRC calculated using the upper-class limit	(Dünnebeil et al., 2015)
5.14	Average of coast down tests from five Euro V truck on a closed track	(Stenvall, 2010)
5.23	Average of coast down tests from three Euro V trucks	(Raja & Baxter, 2010)
5.48	Average of constant speed tests of two trucks with different trailers loads	(Hausberger, Rexeis, Blassnegger, & Silberholz, 2011)
6.8	Reference value	(Hill et al., 2011)
5.01	Coast down test of a 40-tonne tractor-trailer on a closed track	(Roche & Mammetti, 2015)
5.8	Baseline assumption in the EU CORE project.	(Engström, 2015)
6.31	Coast down test available to the ICCT	(KGP, 2015)

Full references can be found in Delgado et al.'s (2017) report: *Fuel Efficiency Technology in European Heavy-Duty Vehicles: Baseline and Potential for the 2020–2030 Time Frame*.
http://www.theicct.org/EU-HDV-fuel-efficiency-tech-2020-2030

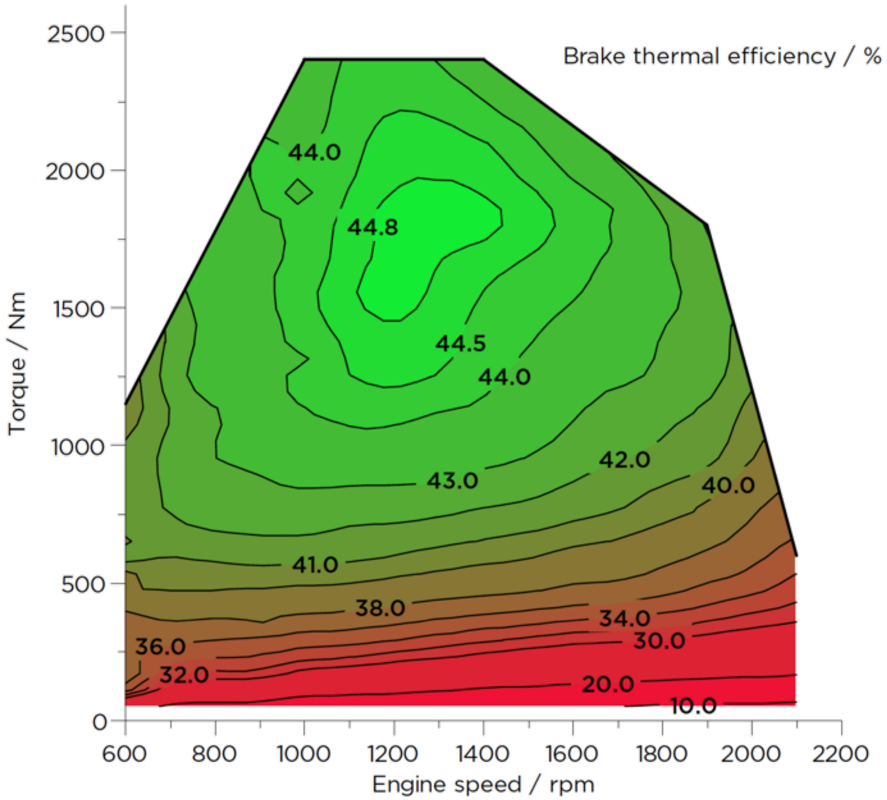
[1] Table with data, comments, and sources can be found in the supporting slides

Fuel consumption map – Class 5, AVL engine

Euro VI engine map purchased from AVL (engineering services provider)



Engine Data	
Swept Volume	12.8dm³
Max. Torque	2400Nm (1000-1400rpm)
Max. BMEP	23.6 bar (1000-1400rpm)
Max. Power	350kW (1500-1900rpm)
Emission Lagislation	Euro VI
NOx Engine Out Emission	5-6g/kWh (Low CO2 Mode)
Fuel Inj. Equipment	Common Rail (2000-2500bar)
Turbocharger	1stage VGT
Engine NOx Reduction	Cooled HP EGR
Peak Cylinder Pressure	~205bar



Transmissions and driveline

In the past decade automated manual transmissions have become the norm.

In the EU, the gear ratios follow a "geometric layout", that is, the ratio between consecutive gears is constant. Example:

$$\frac{N_{1st}}{N_{2nd}} = \frac{N_{2nd}}{N_{3rd}} = \cdots = \frac{N_{11th}}{N_{12th}} = 1.278$$

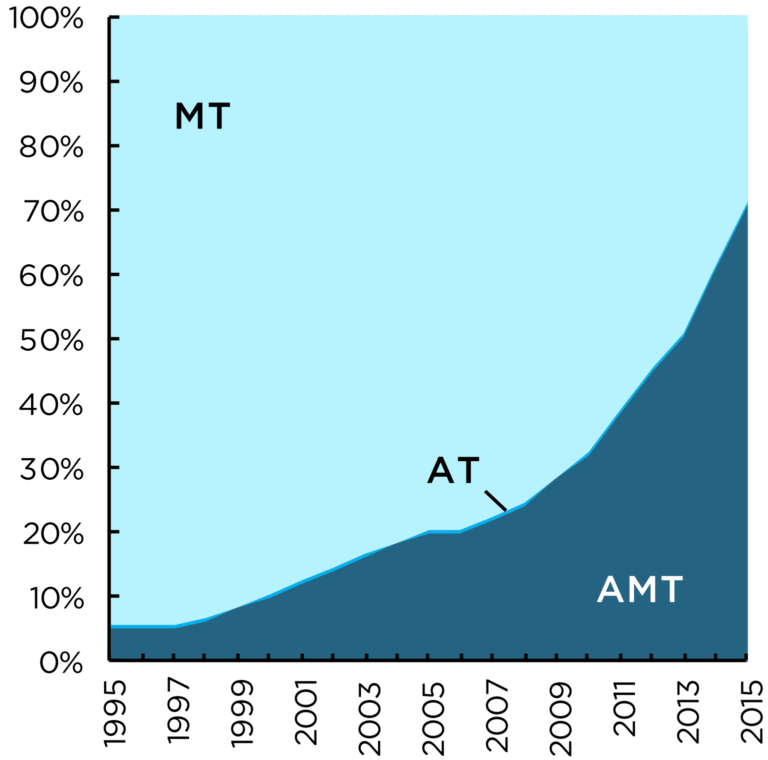
The relevant information is then the number of gears and the transmission spread (i.e. ratios for the 1st and last gear)

Axle ratio is linked to the engine's "sweet spot". For example:

Engine sweet speed	Axle ratio
1050	2.42
1100	2.54
1150	2.66
1200	2.77

Mechanical efficiencies of gear trains are well understood, and oscillate between 96% and 98%.

EU, HDV with GVW > 16 tonnes
Transmissions market penetration (%)

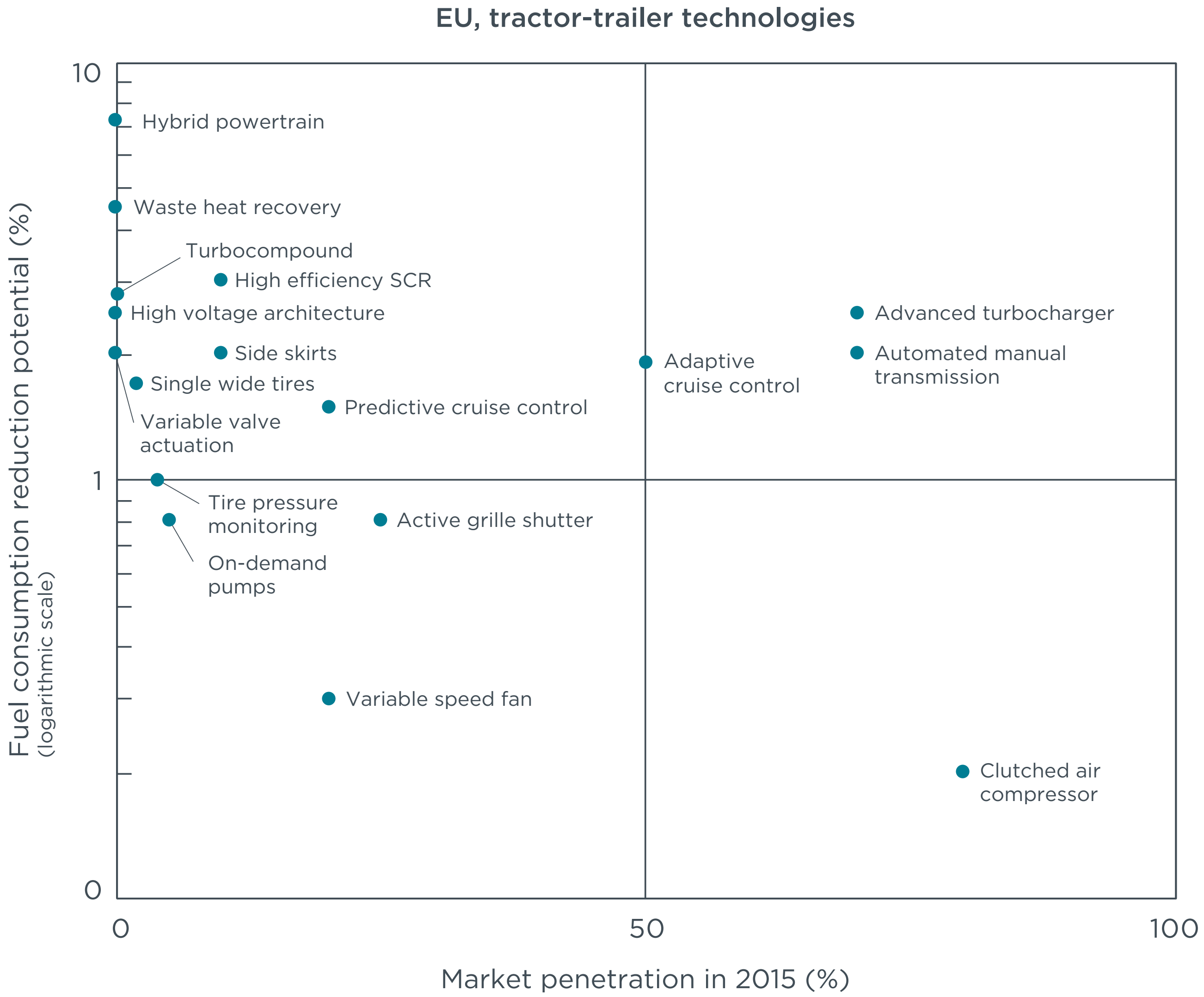


Rodríguez, F., Muncrief, R., Delgado, O., & Baldino, C. (2017). *Market Penetration of Fuel Efficiency Technologies for Heavy-Duty Vehicles in the EU, US and China*. International Council on Clean Transportation. http://www.theicct.org/market-penetration-HDV-fuel-efficiency-technologies

Technology penetration in tractor-trailers

There are a number of fuel saving technologies on the market that currently have low market penetration

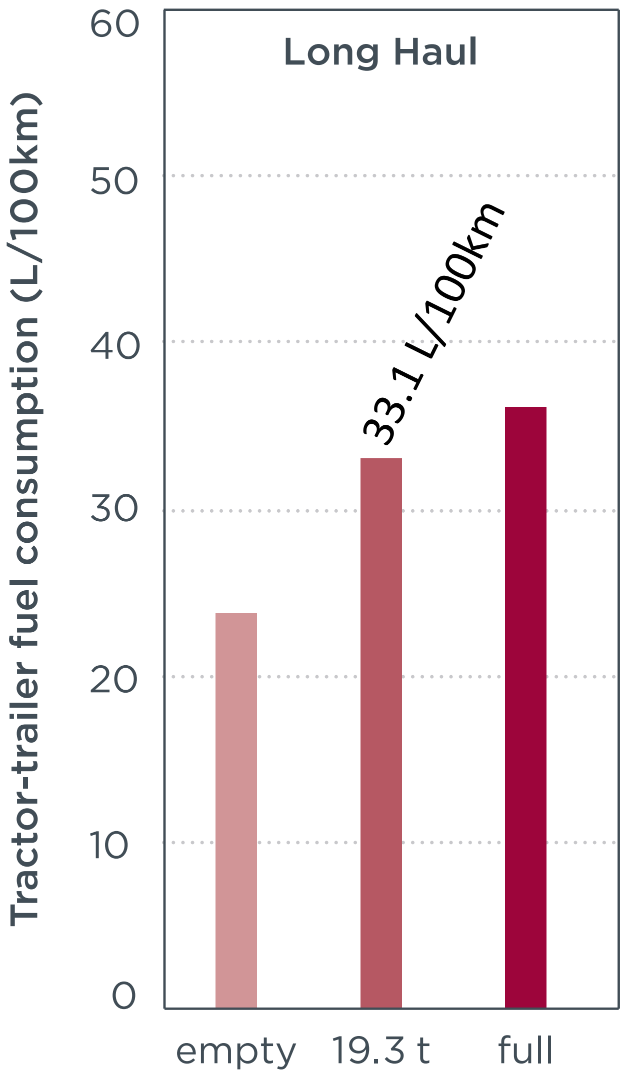
The baseline vehicle has advanced turbocharging for EGR control, automated manual transmission, variable air compressors and adaptive cruise control



Rodríguez, F., Muncrief, R., Delgado, O., & Baldino, C. (2017). *Market Penetration of Fuel Efficiency Technologies for Heavy-Duty Vehicles in the EU, US and China*. International Council on Clean Transportation. http://www.theicct.org/market-penetration-HDV-fuel-efficiency-technologies

Resulting 2015 baseline tractor-trailer

Baseline specifications	Tractor-trailer
Gross vehicle weight (t)	40
Vehicle curb weight (t)	14.4
Axle configuration	4×2
Aerodynamic drag area (m²)	6.0
Tire rolling resistance (N/kN)	5.5
Engine emissions	Euro VI
Engine displacement (L)	12.8
Engine power (kW)	350
Engine peak BTE (%)	44.8
Transmission type	AMT
Transmission gear number	12
Transmission gear ratios	14.93–1.0
Rear axle ratio	2.64
Accessory power (kW)	5.6



VECTO inputs and confidence of baseline data

VECTO input	Class 4	Class 5	Class 9	Class 10
Gross vehicle weight	++	++	++	++
Vehicle curb weight	++	++	++	++
Typical payload	++	++	++	++
Axle configuration	++	++	++	++
Engine Displacement	++	++	++	++
Engine fuel map	o	o	o	o
Engine full load curve	++	++	++	++
Transmission type	++	++	++	++
Transmission gear number	++	++	++	++
Transmission gear ratios	+	+	+	+
Transmission efficiencies	+	+	+	+
Rear axle ratio	o	o	o	o
Tire rolling resistance	+	+	+	+
Tire radius	++	++	++	++
Aerodynamic drag area	+	+	+	+
Auxiliaries	+	+	+	+

[green shading] High impact on fuel consumption

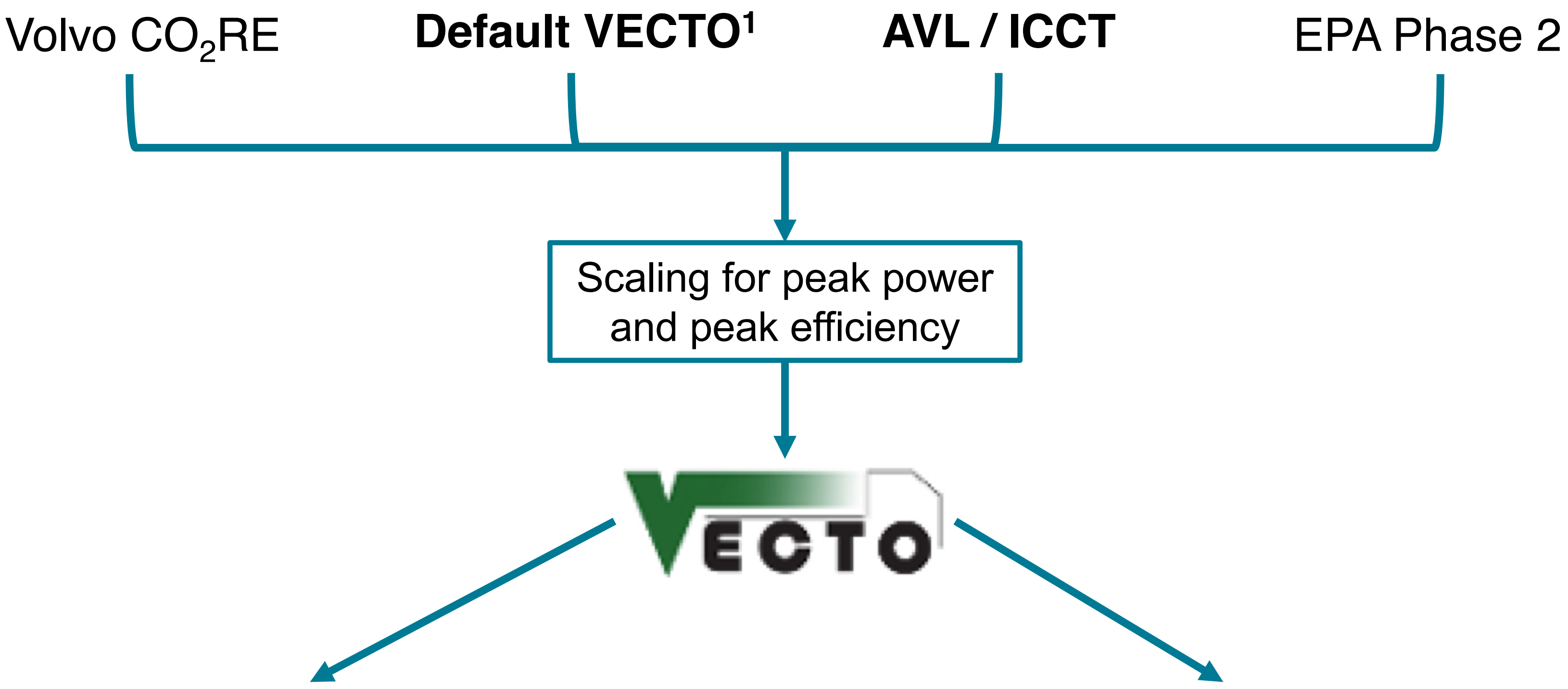
++ / + / o / - / -- Confidence in available data

The vehicle mass specifications are well determined by the CO_2 certification procedure

The engine fuel map has a large impact on fuel consumption, but are not publically available due to confidentiality. However, knowing the full load curve and the peak engine efficiency provides the necessary information for an accurate estimation (+/- 2%)

Rolling resistance and aerodynamic drag data can be found in the literature. The confidence in the values found will increase once we finish our testing program

Sensitivity to engine fuel map (Class 5 example)



Cycle	Payload [t]	Fuel map	FC [l/100 km]	Change [%]
Long-haul	19.3	VECTO	33.73	0.0%
Long-haul	19.3	AVL / ICCT	33.56	-0.5%
Long-haul	19.3	VOLVO	34.41	2.0%
Long-haul	19.3	EPA	34.29	1.6%

Cycle	Payload [t]	Fuel map	FC [l/100 km]	Change [%]
Regional	12.9	VECTO	36.43	0.0%
Regional	12.9	AVL / ICCT	35.78	-1.8%
Regional	12.9	VOLVO	36.19	-0.7%
Regional	12.9	EPA	36.15	-0.8%

ICCT's approach to baseline determination

Experimental validation of the baseline

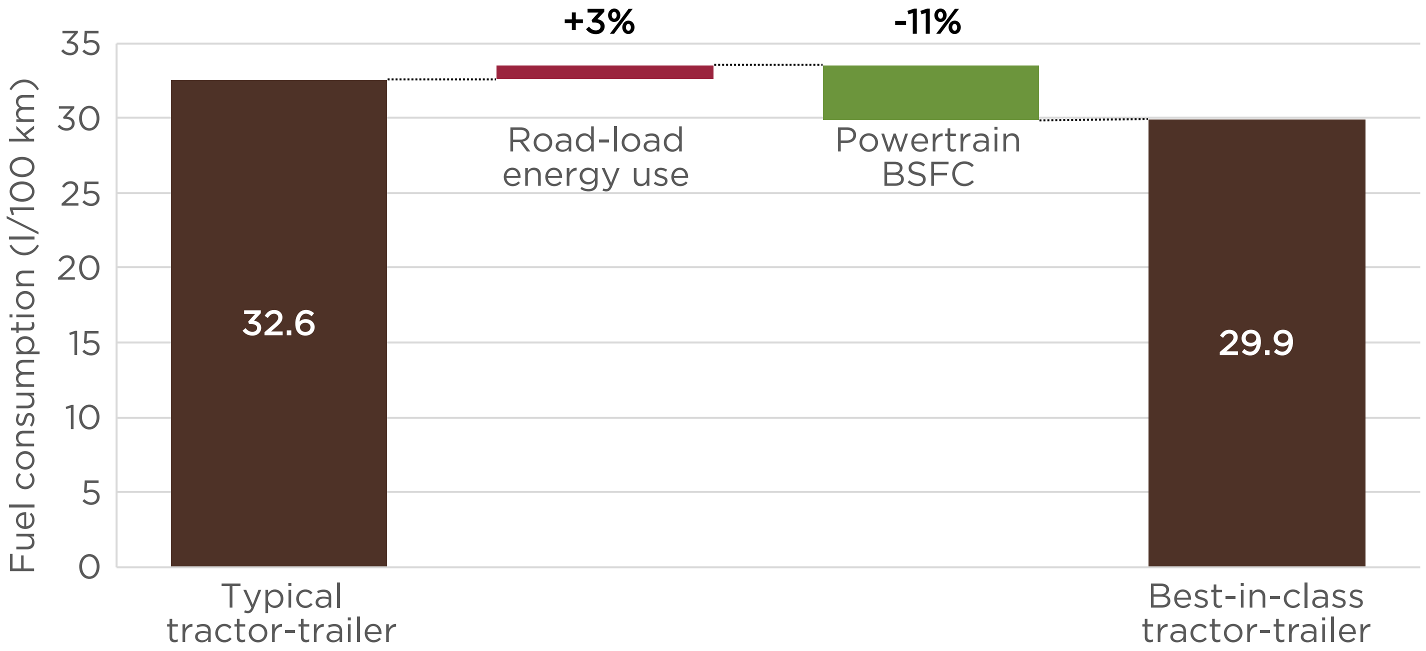
Track and chassis dyno testing commissioned by the ICCT

Just published: The fuel consumption difference between a typical and a best-in-class tractor-trailer is 9%

The ICCT commissioned TU Graz to conduct track and chassis dyno testing of a typical tractor-trailer, representative of the EU fleet, and a best-in-class (BIC) vehicle.

Over the Long Haul cycle, the **typical truck consumed 9% more fuel than the BIC truck**.

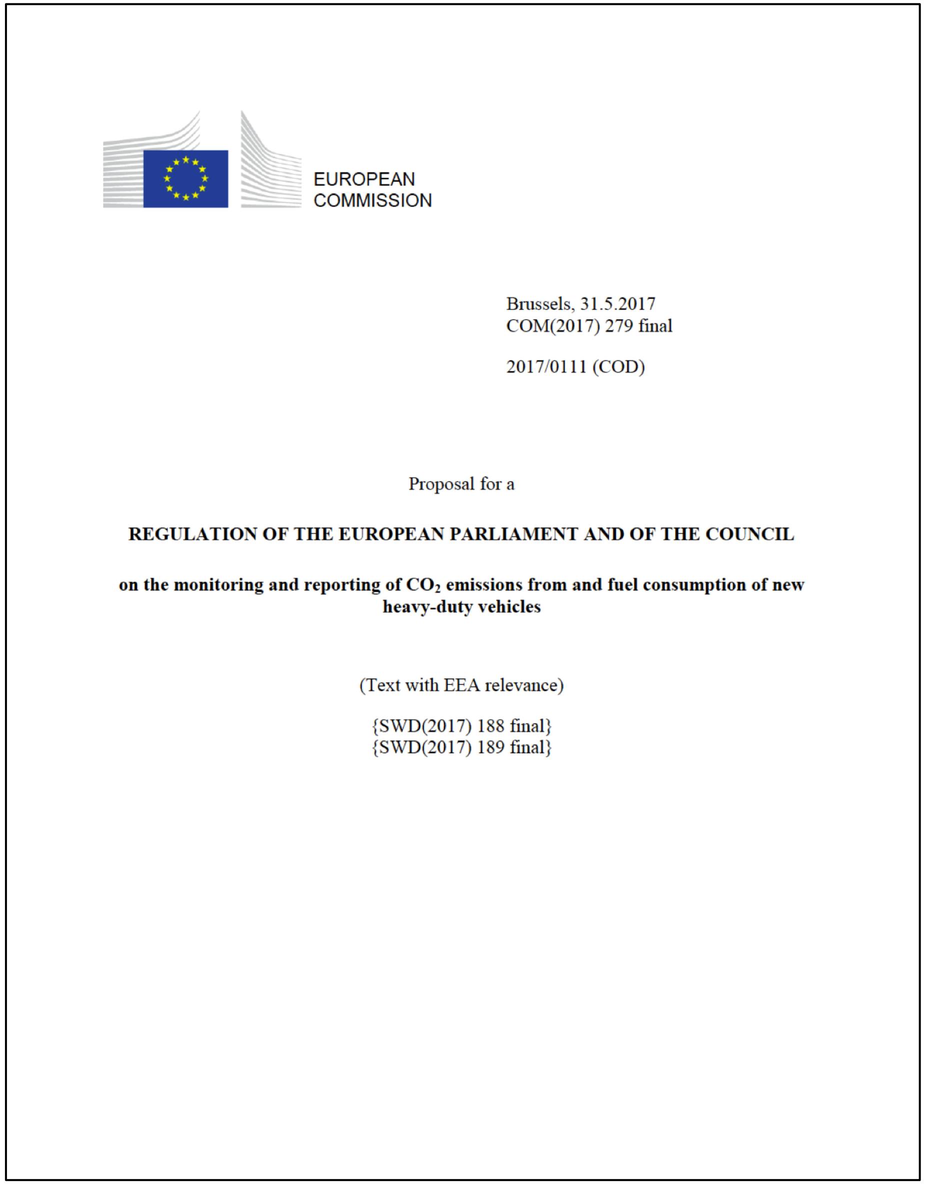
While the BIC vehicle required 3% more energy at the wheel, it had a powertrain 11% more efficient than the typical truck.



Rexeis, Martin, Martin Röck, and Stefan Hausberger. 2018. “Comparison of Fuel Consumption and Emissions for Representative Heavy-Duty Vehicles in Europe.” FVT-099/17/Rex EM 16/18-6790. Technische Universität Graz. https://www.theicct.org/publications/HDV-EU-fuel-consumption-and-emissions-comparison.

Baseline determination approach in the EU: Monitoring and reporting regulation

Proposal on monitoring and reporting CO2 emissions from HDVs.



EUROPEAN
COMMISSION

Brussels, 31.5.2017
COM(2017) 279 final

2017/0111 (COD)

Proposal for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on the monitoring and reporting of CO_2 emissions from and fuel consumption of new heavy-duty vehicles

(Text with EEA relevance)

{SWD(2017) 188 final}
{SWD(2017) 189 final}

- Member States to monitor and report registration data concerning all new HDVs registered.
- OEMs to monitor and report information related to CO_2 emissions and fuel consumption.
- The Commission to make reported data publicly available in a register, managed by the European Environment Agency.
- Proposed by the European Commission on 31 May 2017.
- European Parliament and the Council reached a provisional agreement on 27 March 2018.

Data to be monitored/reported from 2019 onwards

- Fuel consumption and CO_2 emissions for different mission profiles (driving cycles) and with different metrics (g/km or g/m^3km or g/t-km)
- Vehicle specifications:
  - Engine: Fuel consumption over the WHTC and WHSC. Power, rated speed, idle speed, displacement.
  - Aerodynamics: Air drag area (reported in 24 bins with a size of ~ 0.2 to 0.3 m^2).
  - Transmission: Type, number of gears, final ratio
  - Axle: Type, axle ratio
  - Tires: Dimensions and rolling resistance per axle
  - Auxiliaries: Technology used for cooling fan, steering pump, electric system, and pneumatic system

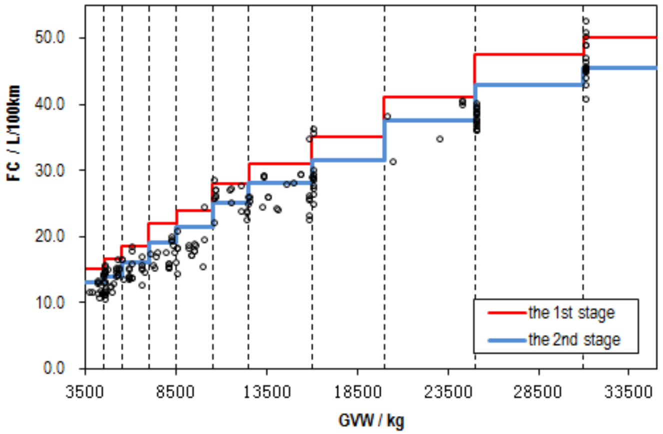
Baseline determination in China

Baseline determination in China

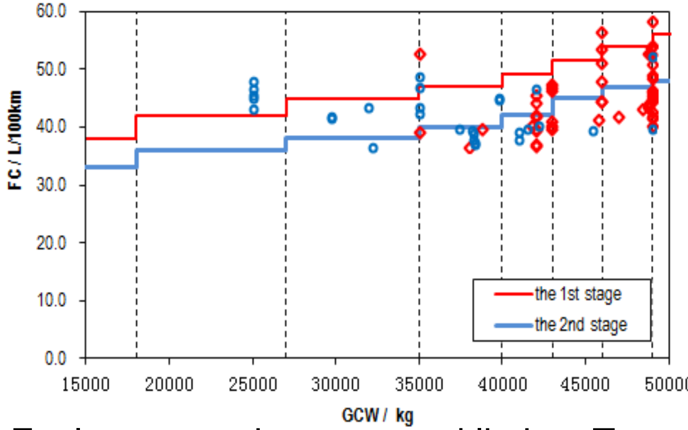
- Industry Standard (Stage 1) (2012-2014)
  - Categories: Trucks, Tractors, Coach Buses
  - 2010-2011 study: chassis testing/simulation of over 300 HDVs
  - Results were used as the basis for setting the standards
  - Stage 1 limits represent the baseline for Stage 2

- National Standard (Stage 2) (2014-2015)
  - New categories: dump trucks and city buses
  - MIIT/CATARC collected fuel consumption data from Stage 1 type-approvals and through additional testing and simulation on the latest models. Over 900 HDV models tested.
  - 10.5%-14.5% reductions from Stage 1

- National Standard (Stage 3) (2019-2021)
  - Same categories as Stage 2
  - Fuel consumption data from 3870 models
  - 12.5%-15.9% reductions from Stage 2



Fuel consumption tests and limits - Trucks



Fuel consumption tests and limits - Tractors

CATARC (2013) Development of heavy-duty vehicle fuel consumptions standards in China. https://www.theicct.org/sites/default/files/CATARC%20PPT_EN_1.pdf

Questions? Contact the HDV team at the ICCT

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