

# The European Commission's science and knowledge service

Joint Research Centre

## VECTO - Overview

2018 VECTO Workshop  
Ispra, November, 2018



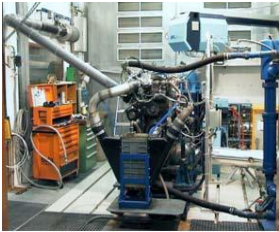
# Content

- Background
- Overview “VECTO method”
  - Simulation tool
  - Component testing
  - Validation
  - Open issues
- VECTO application in Commission Regulation (EU) 2017/2400 as regards the determination of the CO<sub>2</sub> emissions and fuel consumption of heavy-duty vehicles
  - Main principles
  - Vehicle Segmentation
  - Generic data
  - Verification testing procedure (VTP)
- What are the VECTO CO<sub>2</sub> figures used for?

# Background

# Background:

## Possible options for HDV CO<sub>2</sub> certification



### Engine test:

CO<sub>2</sub> emissions of the engine in [g/kWh] in a standard cycle (WHTC)

- + Test procedure already defined
- No assessment on vehicle efficiency



### Road load test + chassis dynamometer test:

- + Fuel consumption of entire vehicle [g/km]
- o Needs separate testing of air drag and rolling resistance as input
- Costly due to manifold combinations of engines, gearboxes, axle, tires..
- Vehicles might be optimised for chassis dynamometer testing

# Background:

## Possible options for HDV CO<sub>2</sub> certification



### On-road test:

- + Fuel consumption of entire vehicle [g/km]
- Costly due to manifold combinations of engines, gearboxes, axle, tires..
- Poor reproducibility

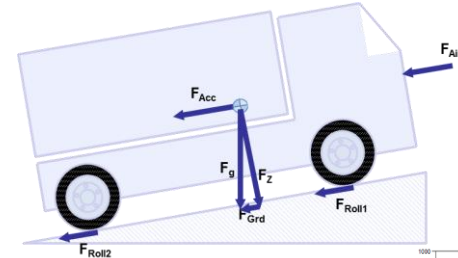
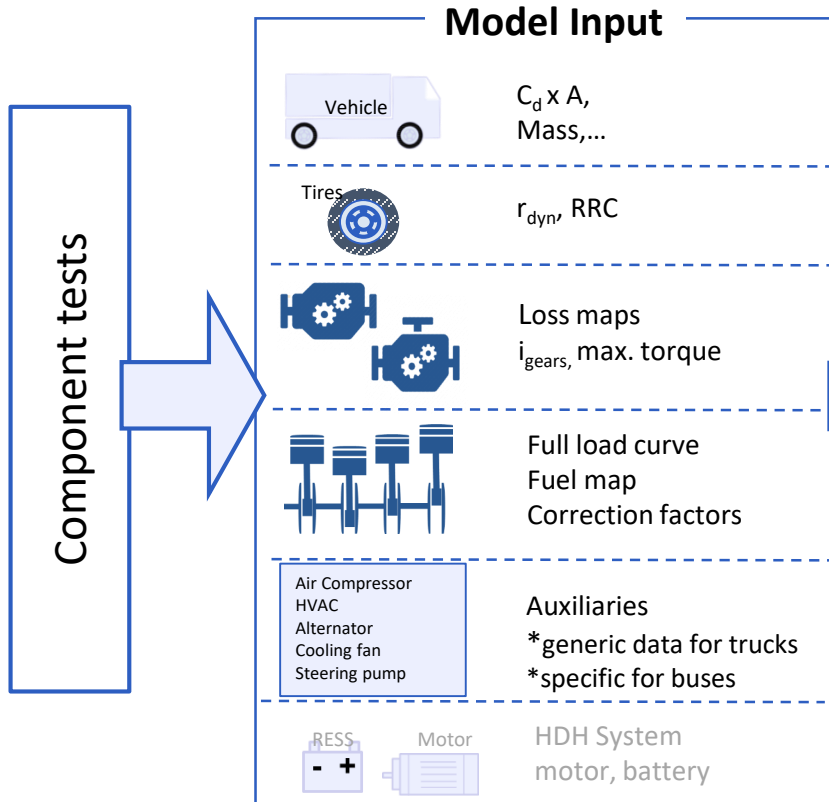


### Component tests plus vehicle simulation:

- + Fuel consumption of the entire vehicle [g/km]
- + Cost efficient since measured component data can be applied in all vehicles
- + High reproducibility and flexibility
- Regular updates of simulation tool necessary to cover relevant technologies

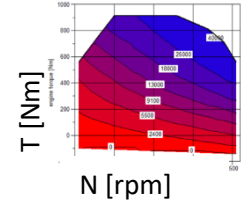
# Overview VECTO method

# Overview “VECTO method”



$$P_e = P_{Air} + P_{Roll} + P_{Acc} + P_{Grd} + P_{Loss} + P_{Aux}$$

$$n = v \times 60 \times i_{axle} \times i_{gear} \times \frac{1}{D_{wheel} \times \pi}$$



# VECTO simulation tool

- VECTO (“Vehicle Energy Consumption calculation TOol)

***is a simulation tool for energy demand, fuel consumption and CO<sub>2</sub> emissions***

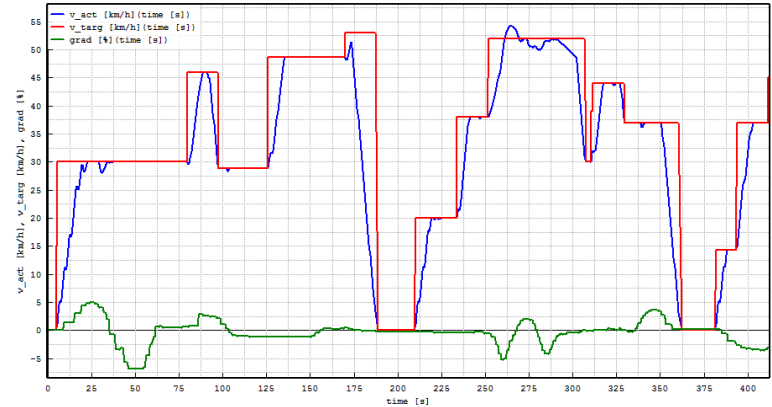
with the main features:

- longitudinal dynamics modelling
- “backward” calculation approach (predominantly)
- “Look ahead” functionalities
- approx. 0.5 s simulation time steps



# Mission profiles and driver model

- Mission profiles are **target-speed** cycles **over distance**
- **Generic driver model**
  - Acceleration/deceleration behaviour
  - Coasting
  - Overspeed
  - Gearshift strategy (MT, AMT, AT)
  - ...



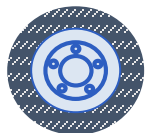
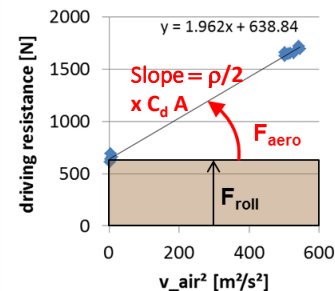
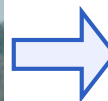
⇒ Individual vehicle specific **realistic vehicle specific speed profiles**

⇒ **Fully comparable results** between different vehicles  
(no oscillations like in forward models)

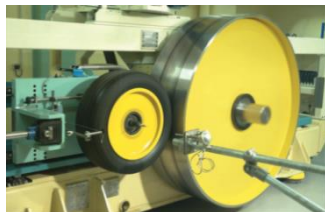
# Component testing



Constant speed test with „standard body“ and/or trailer. Measure torque at wheels and air speed.

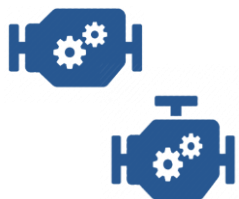


Drum test according to Regulation (EC) No 1222/2009



Specific tire label value e.g. 4.51 kg/ton

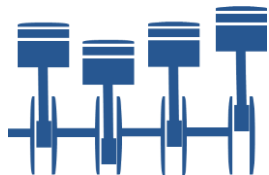
# Component testing



- Loss map options:
- 1) default values
  - 2) measured idle losses  
+ calc. torque dependency
  - 3) Complete measurement



Map for losses  
for each gear



Engine test bed  
according to UN/ECE  
Regulation 49: WHTC, full  
load curve, motoring  
curve and steady state  
fuel map



Fuel map,  
Full load, motoring curve  
WHTC correction factors

# Standard values for component data

Vehicle Component	VECTO Input		Generic “standard values”
	Component Test		
Engine	Engine dyno		Not applicable
Air drag	Constant speed test (test track)		Available
Rolling resistance	Tire drum		Available
Transmission	Test rig	Test rig + generic	Generic only
Retarder	Test rig		Available
Axle	Test rig		Available
Angle drive	Test rig		Available
Auxiliaries	Lorries: not applicable		Technology dependent

Plus “Family concepts” to reduce number of component tests



# General approach for auxiliaries (Lorries)

- Considered auxiliary units:
  - Engine cooling fan
  - Steering pump
  - Electric system
  - Pneumatic system
  - HVAC system
  - Power take off (PTO)
- Technology dependent generic tables or functions for constant average power demand in VECTO simulations
- Auxiliary technology has to be defined in VECTO input data
- Auxiliary power demand depends on technology and driving cycle

# Example: Engine cooling fan

Fan drive	Fan control	Fan power consumption [W]				
		Long haul	Regional delivery	Urban delivery	Municipal utility	Construction
Crankshaft mounted	Electronic controlled visco clutch	618	671	516	566	1037
	Bimetallic controlled visco clutch	818	871	676	766	1277
	Discrete step clutch	668	721	616	616	1157
	On/off clutch	718	771	666	666	1237
Belt driven or driven via transmission	Electronic controlled visco clutch	989	1044	833	933	1478
	Bimetallic controlled visco clutch	1189	1244	993	1133	1718
	Discrete step clutch	1039	1094	983	983	1598
	On/off clutch	1089	1144	1033	1033	1678
Hydraulically driven	Variable displacement pump	938	1155	832	917	1872
	Constant displacement pump	1200	1400	1000	1100	2300
Electrically driven	Electronically	700	800	600	600	1400

# Model validation (“Proof of concept”)

Measurements conducted by OEMs (component tests) and JRC (on-road full vehicle tests)

Test Equipment:

- FC on-board measurement
- GPS and ECU data
- Torque-measurement rims
- On-board anemometer
- ...

→ Comparison of measured and simulated fuel consumption in on-road full vehicle tests

## Mercedes-Benz Actros

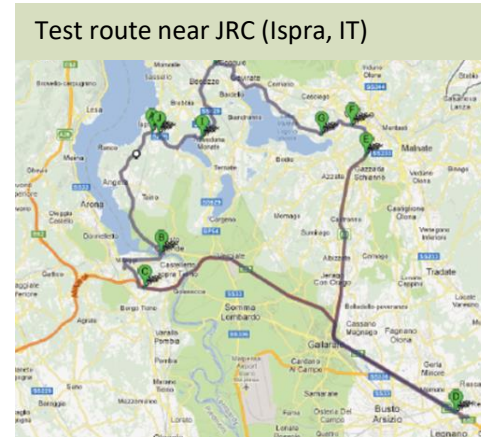
40t (33.6t test weight), EURO VI, 330kW

Application	Deviation
Target speed cycle with VECTO driver model	+ 1.15 %
Measured vehicle speed as input	- 3.08 %

## DAF CF75

18.6t (14.3t test weight), EURO V, 265kW

Application	Deviation
Target speed cycle with VECTO driver model	-0.5%
Measured vehicle speed as input	+1.8%



# VECTO: Main Open Issues and Future Challenges

- Update generic gear shift strategies (AMT, AT) *in progress*
- Advanced Driver Assistance Systems (“ADAS”) Engine stop-start, Eco-roll, predictive cruise control *in progress*
- Advanced engine technologies e.g. dual fuel engines, waste heat recovery *in progress*
- Methods for buses and coaches *in progress*
- Vehicles not exceeding 7.5 tons *under preparation*
- Hybrid electric vehicles (He-HDV) *in progress*
- Incorporation of specific designs of bodies, trailers and semitrailers into the CO2 certification *in progress*
- Incorporation of OEM specific control strategies *long term challenge*

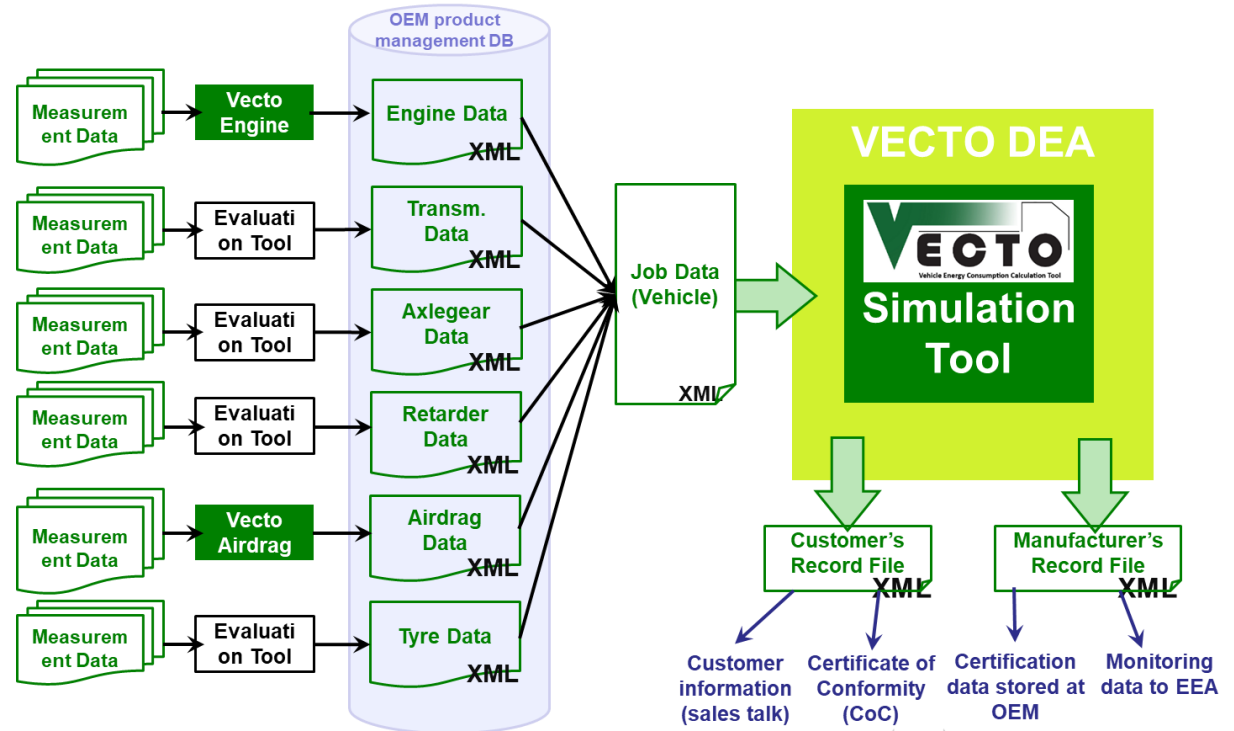


# Application of VECTO according to Commission Regulation (EU) 2017/2400

# The “VECTO process”

## Main principles:

- Every vehicle gets an individual VECTO result
- All data shall be handled in electronic form
- Data integrity measures installed “hashing”



# Vehicle segmentation (lorries)

- All generic model data is defined based on the “**vehicle group**”
  - Driving cycles (“mission profiles”)
  - Standard body and/or trailer
  - Payload and load distribution
  - Auxiliary power demand
- Vehicle group is defined by
  - Axle configuration (e.g. 4x2)
  - Chassis configuration (rigid, tractor)
  - Technically permissible maximum laden mass (TPMLM)

# Lorry Segmentation (Table 1 of Annex I to Commission Regulation (EU) 2017/2400)

Elements relevant to the classification in vehicle groups			Vehicle group	Allocation of mission profile and vehicle configuration							Standard body allocation
Axle configuration	Chassis configuration	Technically permissible max. laden mass (tons)		Long haul	Long haul (EMS*)	Regional delivery	Regional delivery (EMS*)	Urban delivery	Municipal utility	Construction	
4x2	Rigid	>3.5 – <7.5	(0)	<i>not covered yet</i>							
	Rigid (or tractor)**	7.5 – 10	1			R		R			B1
	Rigid (or tractor)**	>10 – 12	2	R+T1		R		R			B2
	Rigid (or tractor)**	>12 – 16	3			R		R			B3
	Rigid	>16	4	R+T2		R			R		B4
Tractor	>16	5	T+ST	T+ST+T2	T+ST	T+ST+T2					
4x4	Rigid	7.5 – 16	(6)	<i>not covered yet</i>							
	Rigid	>16	(7)	<i>not covered yet</i>							
	Tractor	>16	(8)	<i>not covered yet</i>							
6x2	Rigid	all weights	9	R+T2	R+D+ST	R	R+D+ST		R		B5
	Tractor	all weights	10	T+ST	T+ST+T2	T+ST	T+ST+T2				
6x4	Rigid	all weights	11	R+T2	R+D+ST	R	R+D+ST		R	R	B5
	Tractor	all weights	12	T+ST	T+ST+T2	T+ST	T+ST+T2			R	
6x6	Rigid	all weights	(13)	<i>not covered yet</i>							
	Tractor	all weights	(14)	<i>not covered yet</i>							
8x2	Rigid	all weights	(15)	<i>not covered yet</i>							
8x4	Rigid	all weights	16							R	(generic weight+ CdxA)
8x6 8x8	Rigid	all weights	(17)	<i>not covered yet</i>							

\* EMS - European Modular System

\*\* in these vehicle classes tractors are treated as rigids but with specific curb weight of tractor

T...Tractor

R... Rigid & standard body

T1,T2... Standard trailers

ST...Standard semitrailer

D... Standard dolly

# Lorry Segmentation (Table 1 of Annex I to draft Commission Regulation (EU) amending Regulation (EU) 2017/2400) and Directive 2007/46/EC, as voted by TCMV on 30 October 2018)

Description of elements relevant to the classification in vehicle groups			Vehicle group	Allocation of mission profile and vehicle configuration						
Axle configuration n	Chassis configuration n	Technically permissible maximum laden mass (tons)		Long haul	Long haul (EMS)	Regional delivery	Regional delivery (EMS)	Urban delivery	Municipal utility	Construction
4x2	Rigid lorry	> 3,5 – 7,5	(0)							
	Rigid lorry (or tractor)**	> 7,5 – 10	1			R		R		
	Rigid lorry (or tractor)**	> 10 – 12	2	R+T1		R		R		
	Rigid lorry (or tractor)**	> 12 – 16	3			R		R		
	Rigid lorry	> 16	4	R+T2		R		R	R	
	Tractor	> 16	5	T+ST		T+ST	T+ST+T2	T+ST		
	Rigid lorry	> 16	4v***						R	R
4x4	Tractor	> 16	5v***							T+ST
	Rigid lorry	> 7,5 – 16	(6)							
	Rigid lorry	> 16	(7)							
6x2	Tractor	> 16	(8)							
	Rigid lorry	all weights	9	R+T2	R+D+ST	R	R+D+ST		R	
	Tractor	all weights	10	T+ST	T+ST+T2	T+ST	T+ST+T2			
	Rigid lorry	all weights	9v***						R	R
6x4	Tractor	all weights	10v***							T+ST
	Rigid lorry	all weights	11	R+T2	R+D+ST	R	R+D+ST		R	R
6x6	Tractor	all weights	12	T+ST	T+ST+T2	T+ST	T+ST+T2			T+ST
	Rigid lorry	all weights	(13)							
8x2	Tractor	all weights	(14)							
8x4	Rigid lorry	all weights	(15)							
8x4	Rigid lorry	all weights	16							R
8x6 8x8	Rigid lorry	all weights	(17)							

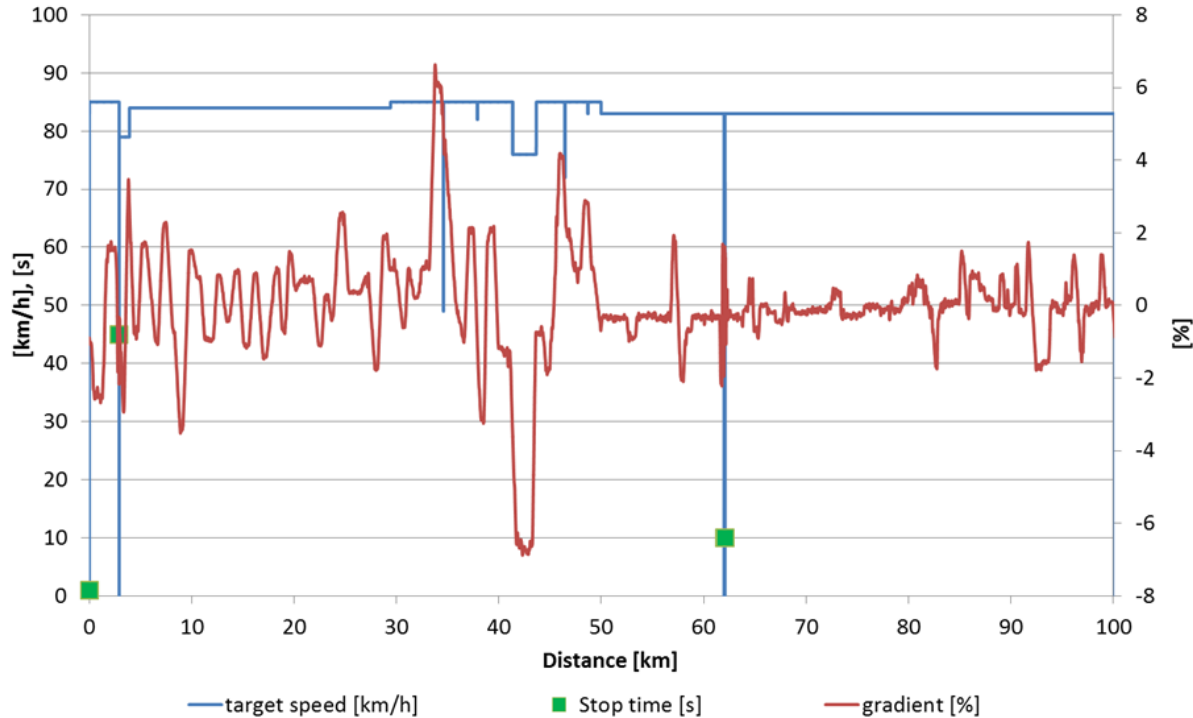
\* EMS - European Modular System

\*\* in these vehicle classes tractors are treated as rigid lorries but with specific curb weight of tractor

\*\*\* sub-group "v" of vehicle groups 4, 5, 9 and 10: these mission profiles are exclusively applicable to vocational vehicles

	T	=	Tractor
	R	=	Rigid lorry & standard body
	T1, T2	=	Standard trailers
	ST	=	Standard semitrailer
	D	=	Standard dolly

# VECTO mission profiles: Long haul

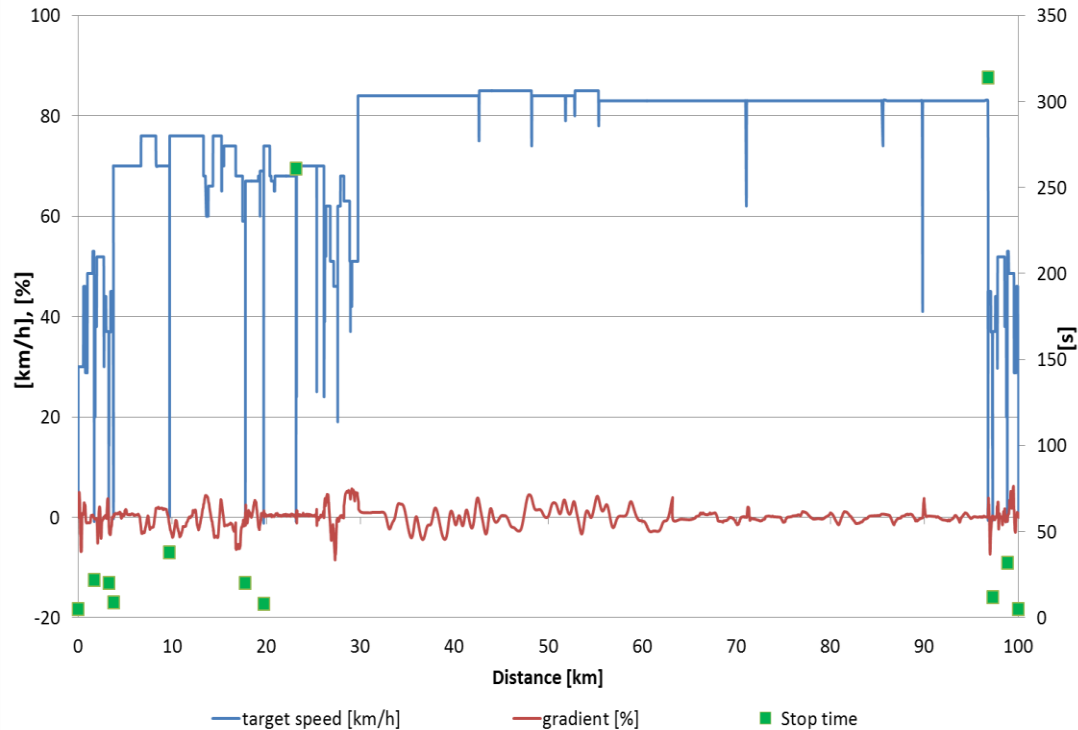


Trip length: 100 km

Average speed: approx. 80km/h

Stop time: 67 s

# VECTO mission profiles: Regional delivery

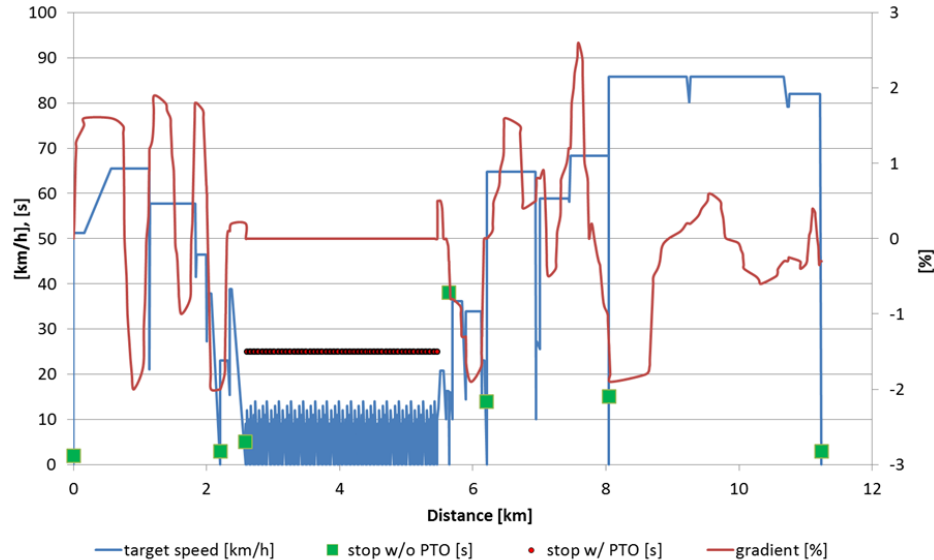


Trip length: 100 km

Average speed: approx. 60km/h

Stop time: 746 s

# VECTO mission profiles: Municipal utility



Shall reflect typical operation of a refuse truck of type “rear loader”. The cycle consists of three parts:

1. Approach to the area of garbage collection
2. Collection part
3. Drive from the area of garbage collection to the waste processing side

Vehicle is simulated with a generic refuse body incl. PTO

## Collection part:

Trip length: 2.9 km      Average speed: approx. 3 km/h

## Total cycle:

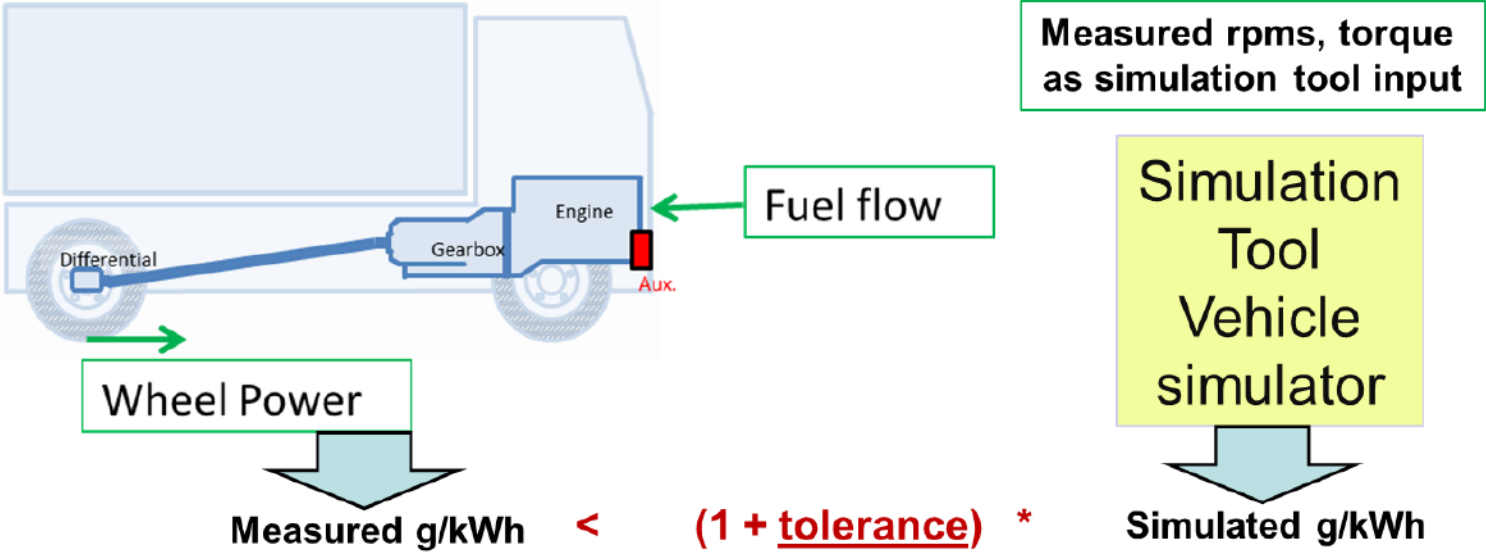
Trip length: 11.2 km      Average speed: approx. 9 km/h



# Verification Testing Procedure (VTP)

- On-road test to verify the CO<sub>2</sub> emissions of new vehicles after production
- To be carried out by the vehicle manufacturer, verified by the approval authority
- Main measurement signals:
  1. Torque and speed at the driven wheels
  2. Engine speed
  3. Fuel consumption
- Signals for 1. and 2. are provided as “cycle” input to VECTO „VTP mode“ together with the vehicle related input data from the CO2 certification
- Pass/Fail check: Wheel work specific fuel consumption (g/kWh) from VTP measurement has to be lower than VECTO simulation result plus tolerance (7.5%)
- Additionally correctness of vehicle input data shall be checked (hashes, components, technology selection for auxiliaries etc.)

# Verification Testing Procedure (VTP)



# VECTO VTP Mode

- Vehicle verification implemented as separate simulation mode
  - Input: measured cycle
  - Output: comparison of (corrected) measured cycle with declared CO2 value
  - Separate XML report

What are the VECTO CO<sub>2</sub> figures used for?

# What are the VECTO CO<sub>2</sub> figures used for?

## 1. CO<sub>2</sub> certification

a) Customer information (sales talk + vehicle documents at purchase) with information according to Part II of Annex IV to Commission Regulation (EU) 2017/2400

1. Vehicle, component, separate technical unit and systems data
  - 1.1. Vehicle data
    - 1.1.1. Vehicle identification number (VIN).....
    - 1.1.2. Vehicle category (N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub>, M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub>).....
    - 1.1.3. Axle configuration.....
    - 1.1.4. Max. gross vehicle weight (t).....
    - 1.1.5. Vehicle's group.....
    - 1.1.6. Name and address of manufacturer.....
    - 1.1.7. Make (trade name of manufacturer).....
    - 1.1.8. Corrected actual curb mass (kg).....
  - 1.2. Component, separate technical unit and systems data
    - 1.2.1. Engine rated power (kW).....
    - 1.2.2. Engine capacity (ltr).....
    - 1.2.3. Engine reference fuel type (diesel/LPG/CNG...).....
    - 1.2.4. Transmission values (measured/standard).....
    - 1.2.5. Transmission type (SMT, AMT, AT-S, AT-S).....
    - 1.2.6. Nr. of gears.....
    - 1.2.7. Retarder (yes/no).....
    - 1.2.8. Axle ratio.....
    - 1.2.9. Average rolling resistance coefficient (RRC) of all tyres:

Payload low [kg]							
	Average vehicle speed	CO <sub>2</sub> emissions			Fuel consumption		
Long haul	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Long haul (EMS)	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Regional delivery	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Regional delivery (EMS)	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Urban delivery	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Municipal utility	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Construction	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km

Payload representative [kg]							
	Average vehicle speed	CO <sub>2</sub> emissions			Fuel consumption		
Long haul	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Long haul (EMS)	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Regional delivery	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Regional delivery (EMS)	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Urban delivery	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Municipal utility	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km
Construction	..... km/h	..... g/km	..... g/t-km	..... g/m <sup>3</sup> -km	..... l/100km	..... l/t-km	..... l/m <sup>3</sup> -km

# What are the VECTO CO<sub>2</sub> figures used for?

## 1. CO<sub>2</sub> certification (continued)

b) Mission profile and payload weighted CO<sub>2</sub> value inserted into Certificate of Conformity (CoC)

→ future use e.g. for road toll (proposal COM(2017) 275 final)  
public procurement etc.

## 2. Monitoring and reporting (Regulation (EU) 2018/956)

Starting with 2020: Data collection at European Environment Agency (EEA):

- Registration data delivered by national authorities
- CO<sub>2</sub>, fuel consumption and related data for simulated vehicles by OEMs

Annual analysis of CO<sub>2</sub> data of entire fleet and per OEM

# What are the VECTO CO<sub>2</sub> figures used for?

## 3. CO<sub>2</sub> emission standards (proposal COM(2018) 284 final)

- CO<sub>2</sub> reduction targets for vehicles of groups 4, 5, 9 and 10 using monitoring data for year 2019 as baseline
- Proposed reduction targets:
  - -15% until 2025,
  - -30% until 2030 (to be reviewed)
- Certain set of vehicles (“vocational”) excluded from standards regulation (vehicles with limited cost-effective CO<sub>2</sub> emission reduction potential)
- Incentives for Zero- and Low emission vehicles
- Mechanisms for “Banking & Borrowing” of CO<sub>2</sub> emissions over certain period of years