



Vehicle Energy Consumption calculation TOol - VECTO

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European Commission

DG Climate Action

Unit C4: Road Transport



Simulation tool to calculate both, fuel consumption and CO₂ emissions from the whole vehicle



Vecto development

- VECTO has been developed by the Commission (DG CLIMA leading, JRC) with TUG support over the last seven years
- ACEA, OEMs and component manufacturers have been also involved and provided key input and test vehicles



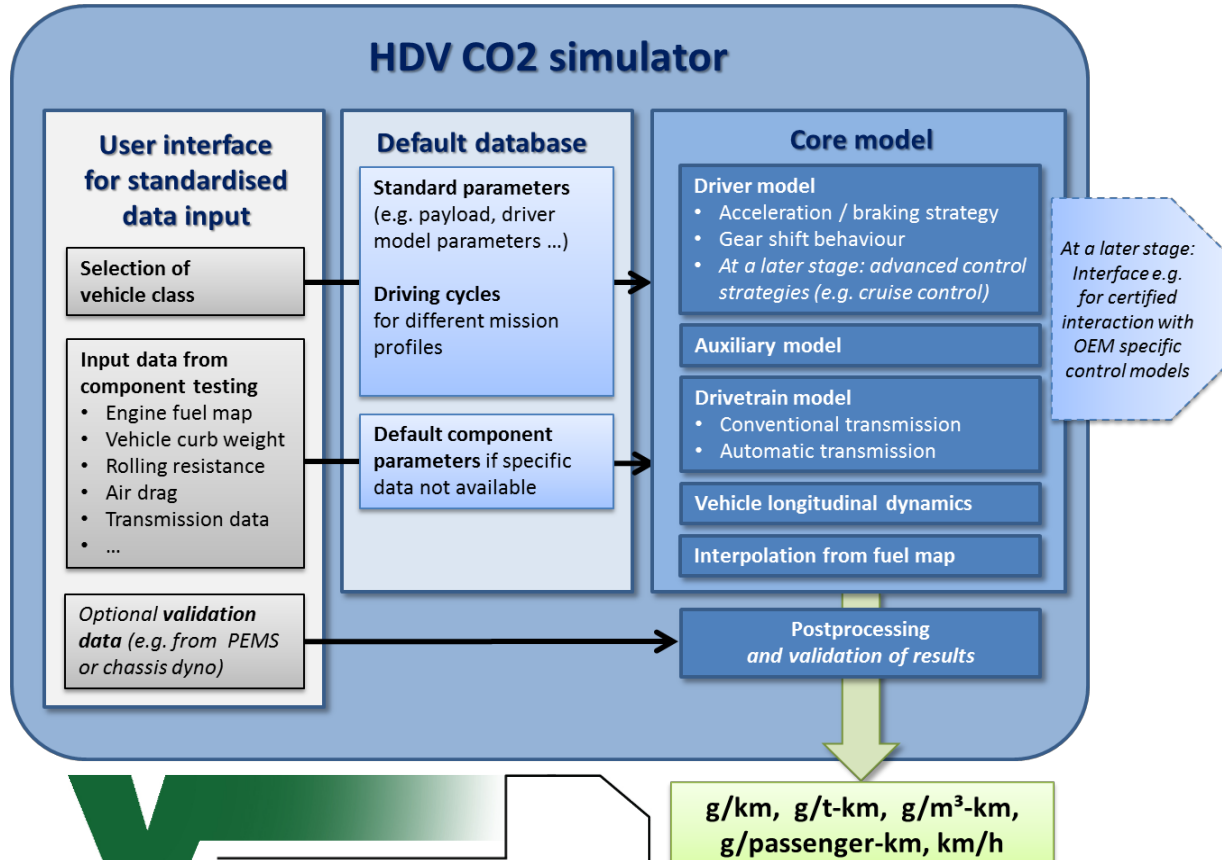
Tests

Tests, on trucks, performed in 2012-2014 demonstrated VECTO's accuracy and reliability.

The software was further tested and improved in 2015 during the "Pilot Phase - PP".

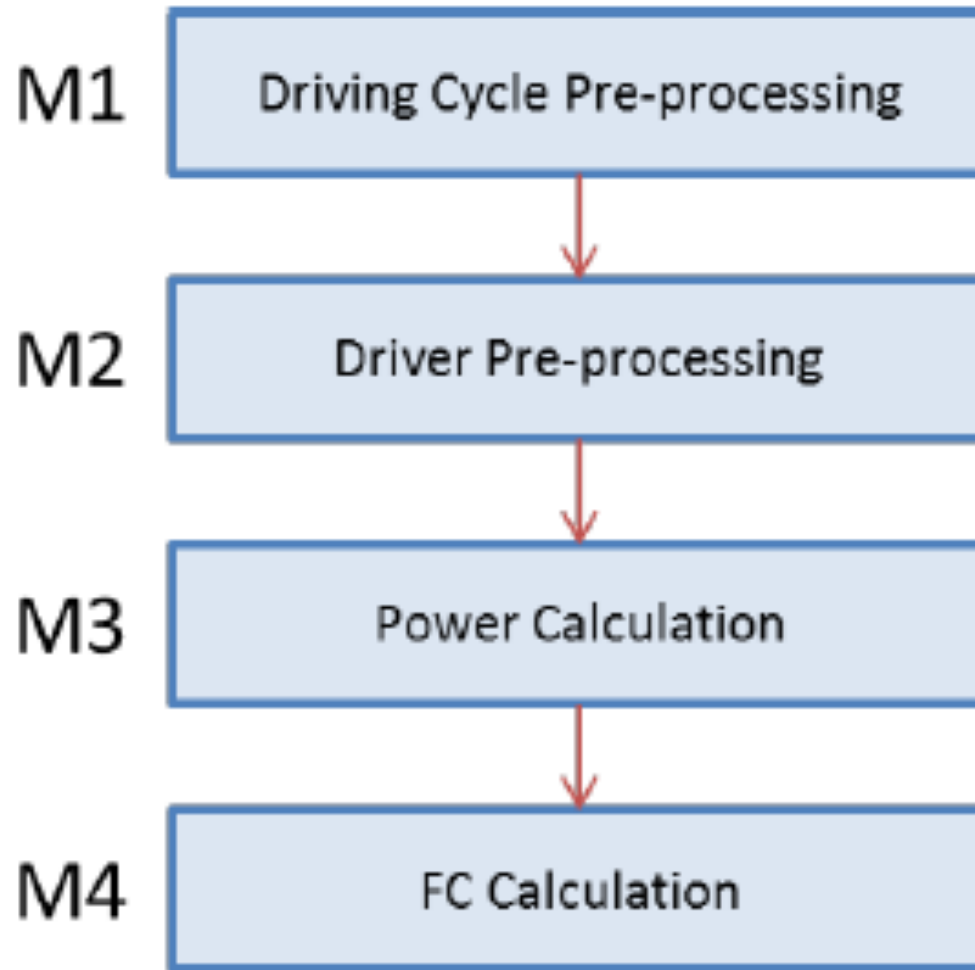
The tool is now broadly ready to be the backbone of certification.

VECTO - Structure

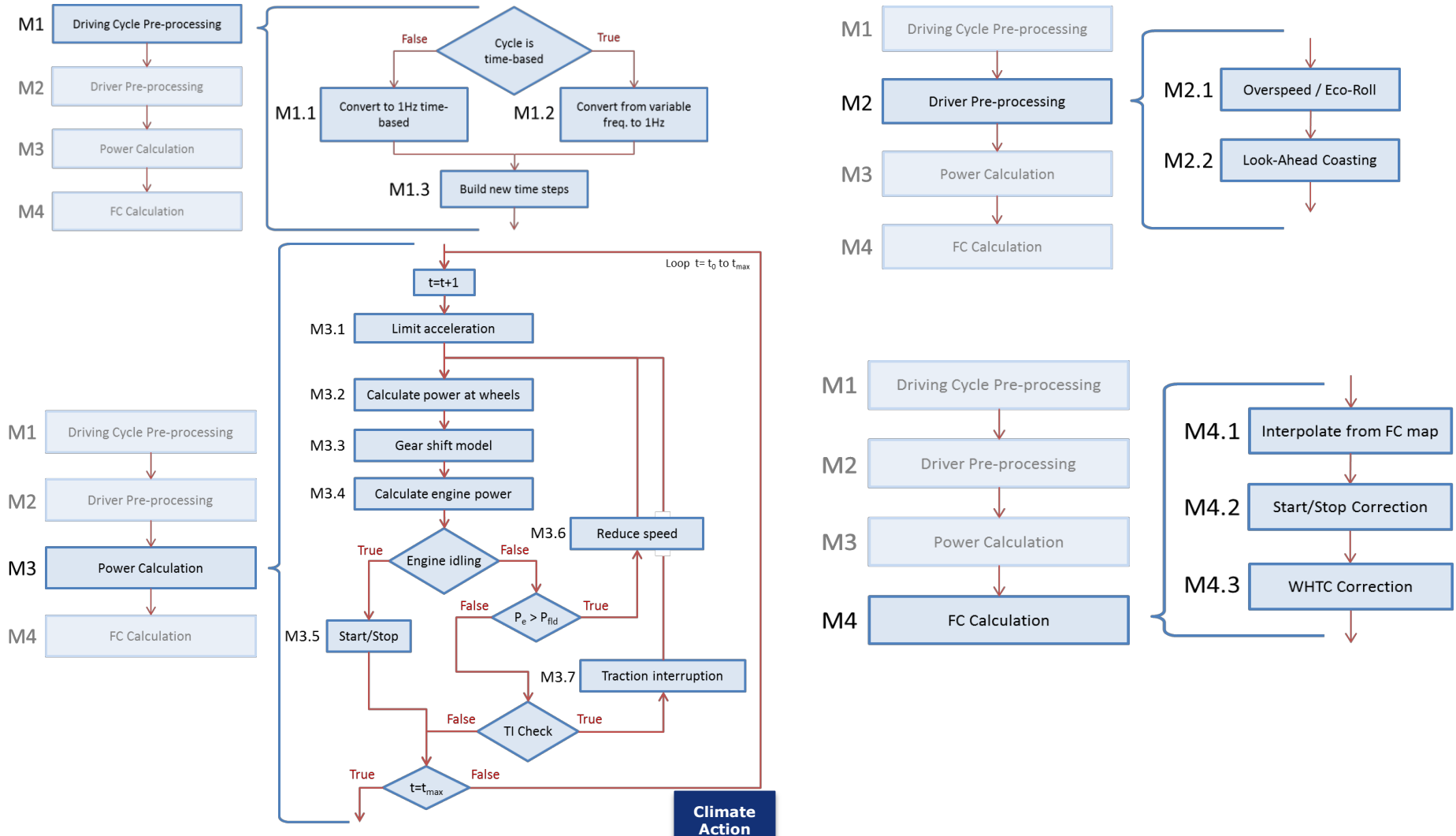


Vehicle Energy Consumption Calculation Tool

Model structure - Four main modules

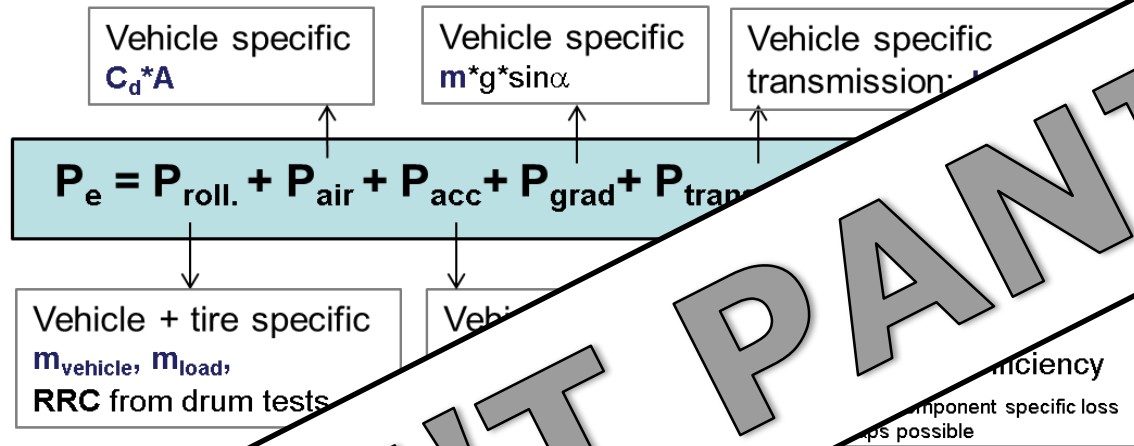


Model structure - Four main modules



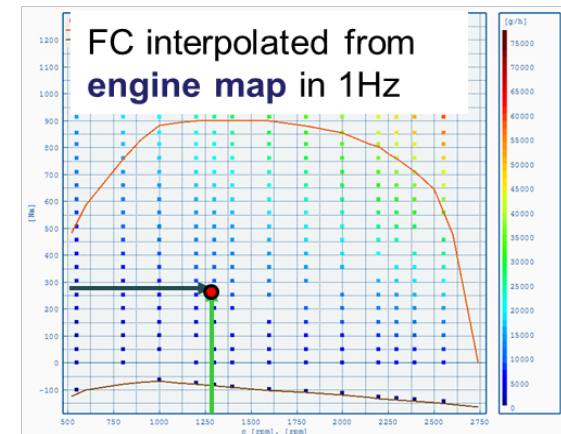
Simulation of engine power

Simulation of engine power:

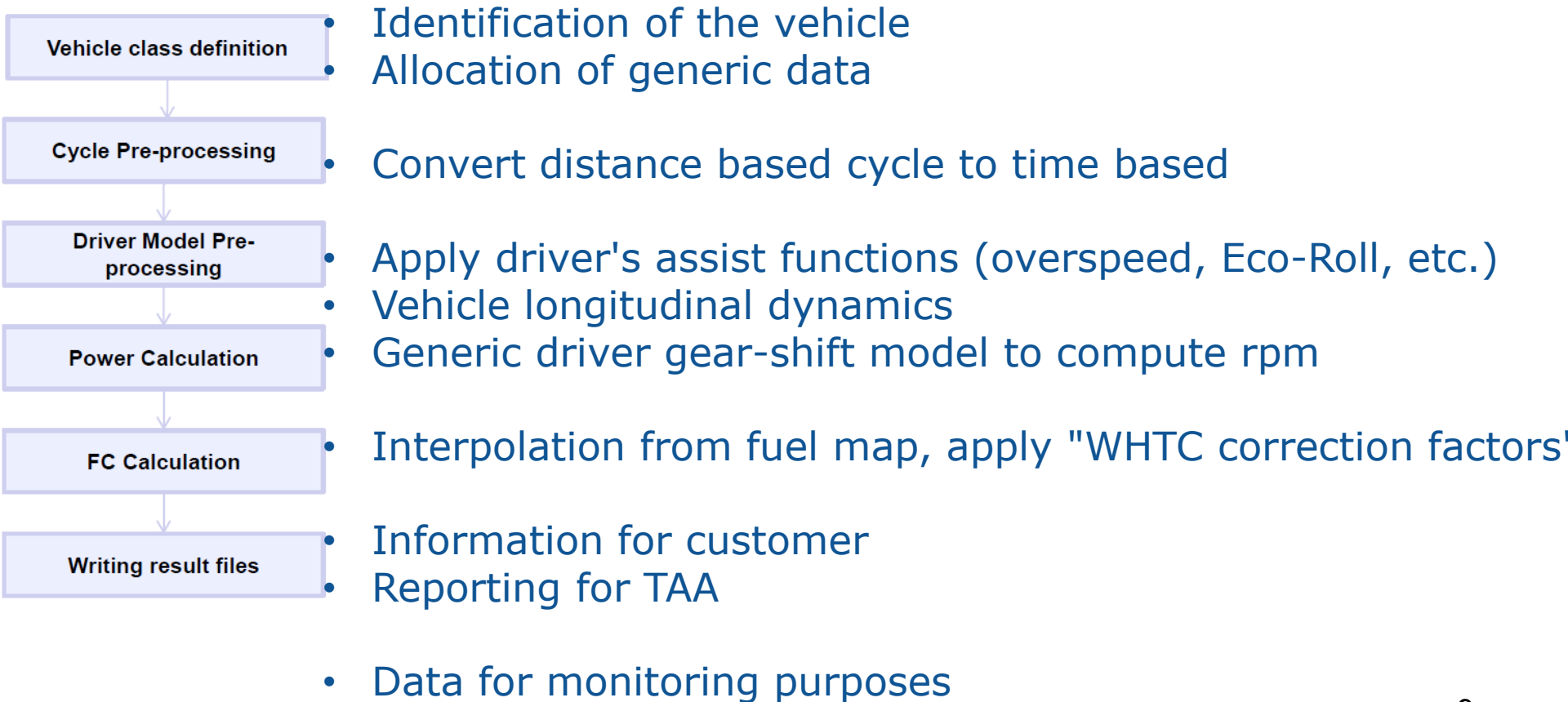


DON'T PANIC!

Simul



Simulation's steps





VECTO's modes

Declaration mode where all *generic data* and the *test cycle* are allocated automatically as soon as the ***vehicle class*** is defined.

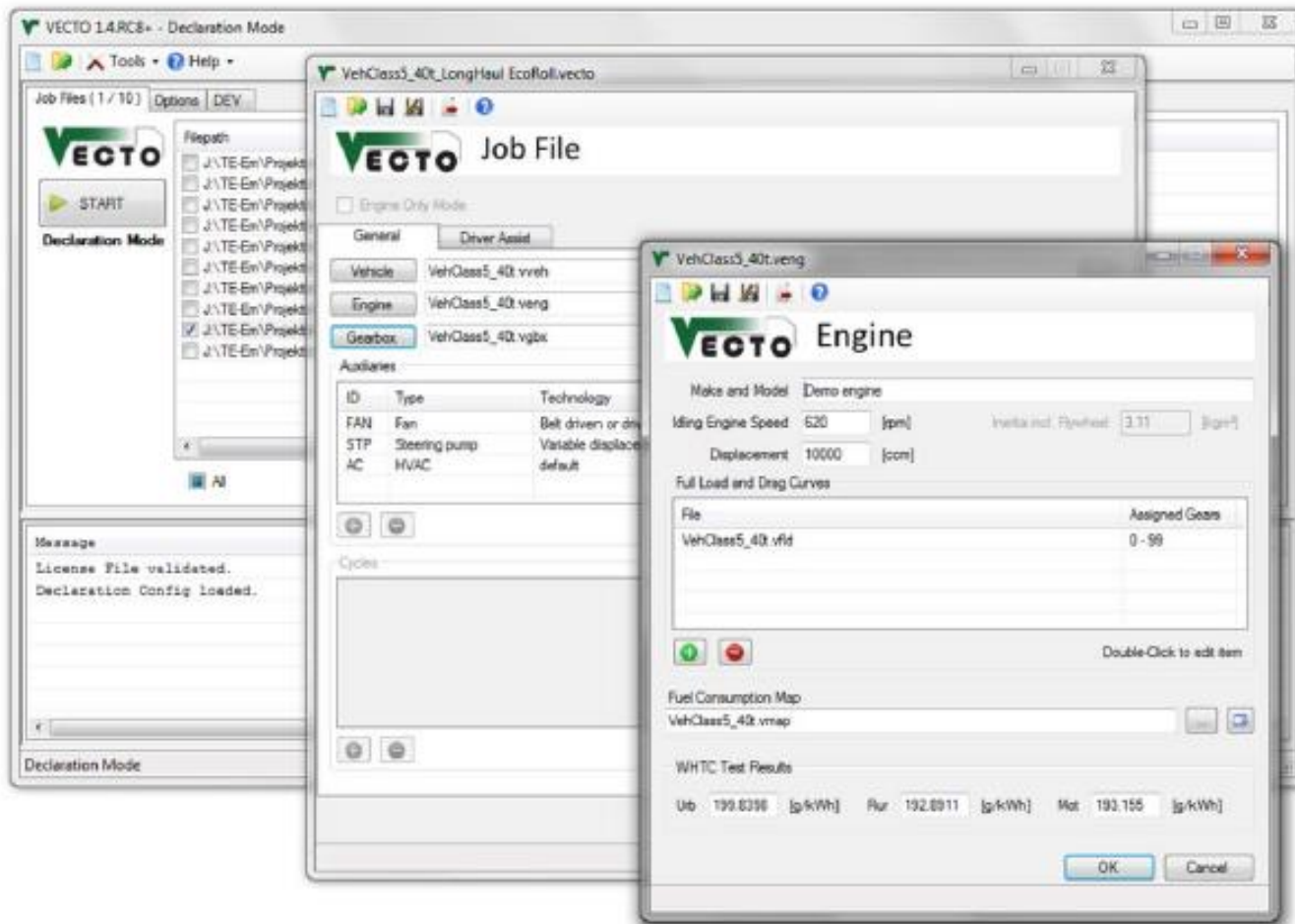
Engineering mode where the user can select and change all input data to allow recalculation of test data e.g. for model validation.

VECTO output

In the ***declaration mode*** FC and CO₂ emissions are automatically calculated for all test cycles allocated to the vehicle for average payload and full load.

Results given in **g/km, g/cm³-km, g/ton-km** or **g/pass-km**. Other metrics can be also considered at a later stage

VECTO Graphical User Interface (GUI)



Job Files (1/1) Options

Mode

Declaration Mode

Engineering Mode

Batch Mode

Cycle Distance Correction

Use gears/rpm's form driving cycle

Write modal results

Shutdown system after last job

Message	Time	Source
License File validated.	4/27/2016 9:09:1...	
Declaration Config loaded.	4/27/2016 9:09:1...	

Declaration Mode

Job Files (1 / 1) Options

VECTO

Filepath

C:\PGM\VECTO\2015_11_12\VECTO-3.0-beta1\Generic Vehicles\Declaration Mode\40 Long Haul Truck\40_Long_Haul_Truck.vecto

START V2.2

START V3

Declaration Mode

All

Message	Time	Source
License File validated.	4/27/2016 9:09:1...	
Declaration Config loaded.	4/27/2016 9:09:1...	

Declaration Mode

Tools Help

Job Files (1/1) Options

Filepath
 C:\PGM\VECTO\2015_11_12-VECTO-3.0beta1\Generic Vehicles\Declaration Mode\40t Long Haul Truck\40_Long_Haul_Truck.vecto

START V2
START V3

Declaration Mode

40t_Long_Haul_Truck.vecto

Job File

Engine Only Mode

General Driver Assist

Vehicle: 40t_Long_Haul_Truck.vveh
 Engine: 40t_Long_Haul_Truck.veng
 Gearbox: 40t_Long_Haul_Truck.vgbox

Auxiliaries

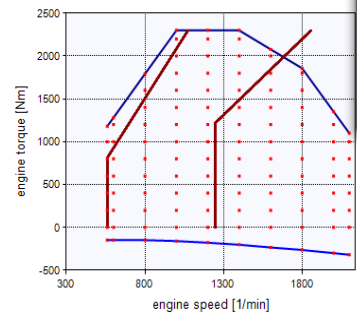
ID	Type	Technology
FAN	Fan	Hydraulic driven - Constant displacement pump
STP	Steering pump	Variable displacement
AC	HVAC	Default
ES	Electric System	Custom Technology List
PS	Pneumatic System	Default

Cycles

- Long Haul
- Regional Delivery

12.71351 kW Generic 40t Long Haul Truck

12-Speed AMT Generic 40t Long Haul Truck



Save Cancel

VECTO Engine

Make and Model: Generic 40t Long Haul Truck

Idling Engine Speed: 560 [rpm] Inertia incl. Flywheel: 5.1471 [kgm²]

Displacement: 12730 [ccm]

Full Load and Drag Curve: 40t_Long_Haul_Truck.vfld

Fuel Consumption Map: 40t_Long_Haul_Truck.vmap

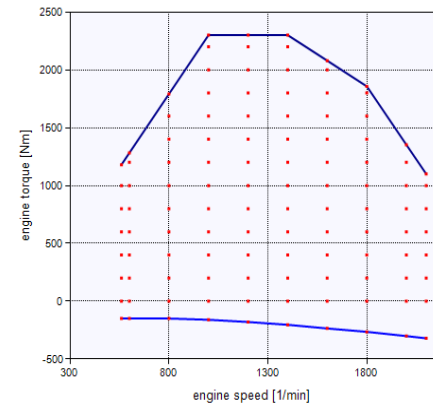
WHTC Correction

Correction Factors calculated with VECTO-Engine

Urban: 0.97 Rural: 0.99 Motorway: 1.02

Import from VECTO-Engine

Save Cancel



Job Files (1 / 1) Options

VECTO Filepath
 C:\PGM\VECTO\2015_11_12\VECTO-3.0\beta\1\Generic Vehicles\Declaration Mode\40t Long Haul Truck\40_Long_Haul_Truck.vecto

START V2.2
 START V3

Declaration Mode

40t_Long_Haul_Truck.vecto

VECTO Job File

Engine Only Mode

General Driver Assist

Vehicle: 40t_Long_Haul_Truck.vveh
 Engine: 40t_Long_Haul_Truck.veng
 Gearbox: 40t_Long_Haul_Truck.vgbox

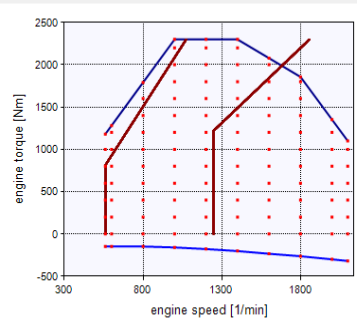
Auxiliaries

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AC	HVAC	Default
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PS	Pneumatic System	Default

Cycles

- Long Haul
- Regional Delivery

12.71 351 kW Generic 40t Long Haul Truck
 12-Speed AMT Generic 40t Long Haul Truck



engine torque [Nm] vs engine speed [1/min]

Save Cancel

40t_Long_Haul_Truck.vgbox

VECTO Gearbox

Make and Model: Generic 40t Long Haul Truck

Transmission Type: Automated Manual Transmission (AMT)

Gears

Gear	TC	Ratio	Loss Map or Efficiency [%]	Shift Polygons	Full Load C
Axle	-	2.59	Axle vtlm	-	-
01	-	14.93	Indirect Gear vtlm	-	-
02	-	11.64	Indirect Gear vtlm	-	-
03	-	9.02	Indirect Gear vtlm	-	-
04	-	7.04	Indirect Gear vtlm	-	-
05	-	5.64	Indirect Gear vtlm	-	-
06	-	4.4	Indirect Gear vtlm	-	-
07	-	3.39	Indirect Gear vtlm	-	-

Double-Click to edit gear

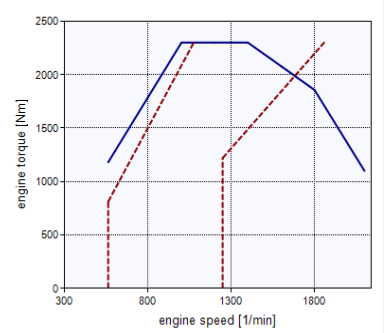
Gear shift parameters

Allow shift-up inside polygons (AMT) Torque reserve: 20 [%]
 Skip Gears (MT, AMT) Minimum shift time: 2 [s]

Start Gear

Torque reserve: 20 [%]
 Reference vehicle speed at clutch-in: 2 [m/s]
 Reference acceleration at clutch-in: 0.6 [m/s²]

Gear 1 shift polygons



engine torque [Nm] vs engine speed [1/min]

Inertia: 0 [kgm²] Traction Interruption: 1 [s]

Torque Converter

Installed (AT)

Torque converter characteristics file

Inertia: 0 [kgm²] Reference rpm: 0 [1/min]

Save Cancel

Declaration Mode

Tools Help

Job Files (1 / 1) Options

VEGTO

START V2.2

START V3

Declaration Mode

Filepath
 C:\PGM\VECTO\2015_11_12-VECTO-3.0\beta1\Generic Vehicles\Declaration Mode\40t Long Haul Truck\40_Long_Haul_Truck.vecto

40t_Long_Haul_Truck.vecto

VEGTO Job File

Engine Only Mode

General Driver Assist

Vehicle 40t_Long_Haul_Truck.vveh

Engine 40t_Long_Haul_Truck.veng

Gearbox 40t_Long_Haul_Truck.vgbx

Auxiliaries

ID	Type	Technology
FAN	Fan	Hydraulic driven - Constant displacement pump
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AC	HVAC	Default
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Double-Click to edit auxiliary

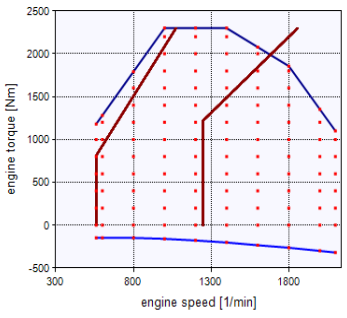
Cycles

Long Haul
Regional Delivery

Double-Click to open file

12.71 351 kW Generic 40t Long Haul Truck

12-Speed AMT Generic 40t Long Haul Truck



Save Cancel

Open

C:\PGM\VECTO\2015_11_12-VECTO-3.0\beta1\Generic Vehicles\Declaration Mode\40t Long Haul Truck\

Directory

Filename
40t_Long_Haul_Truck.vveh

40t_Long_Haul_Truck.vveh

OK Cancel

List Options

Message
 License File val:
 Declaration Conf:



Mission profiles

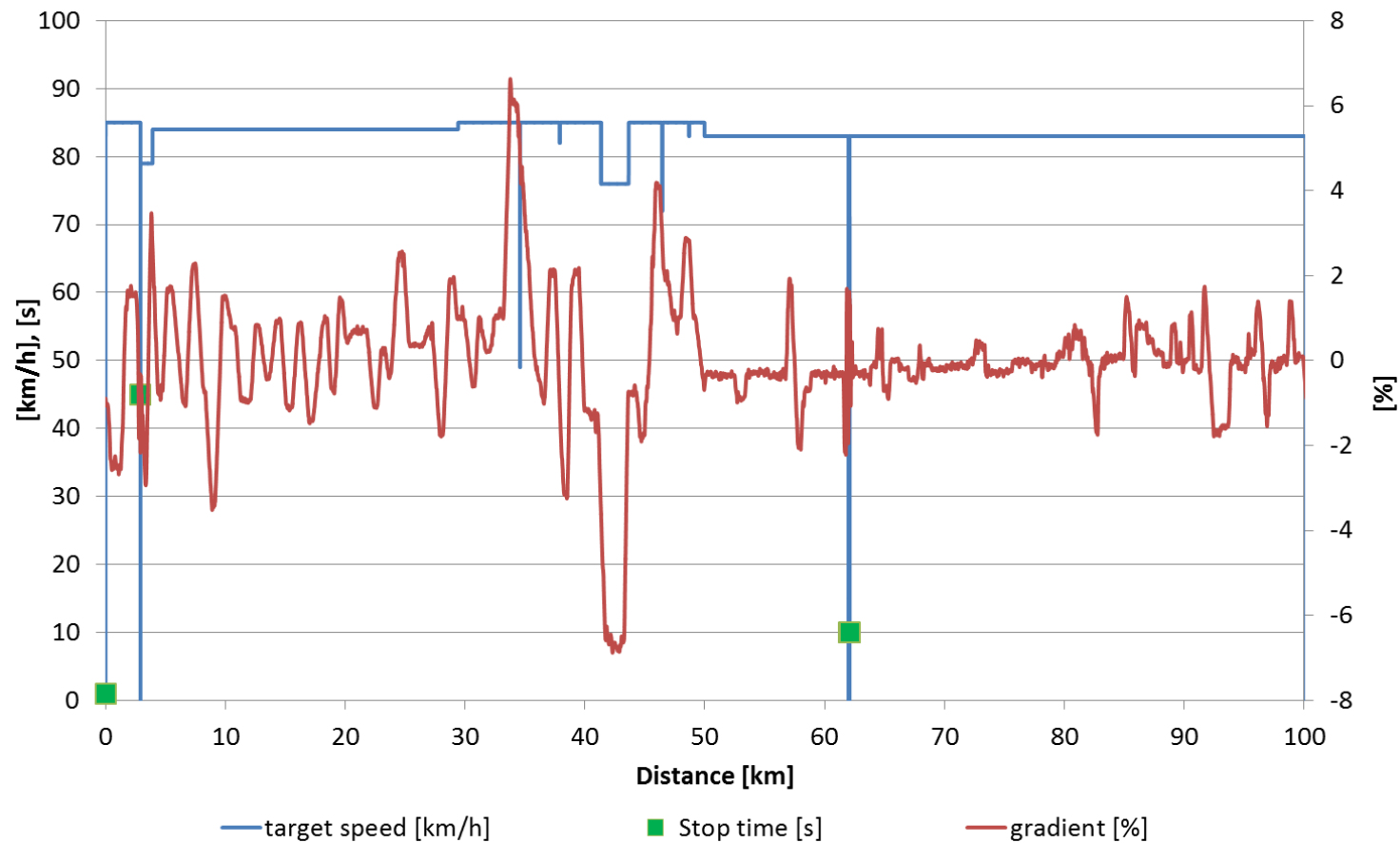
Trucks

- Urban delivery
- Regional delivery
 - Long haul
 - Construction
- Municipal utility

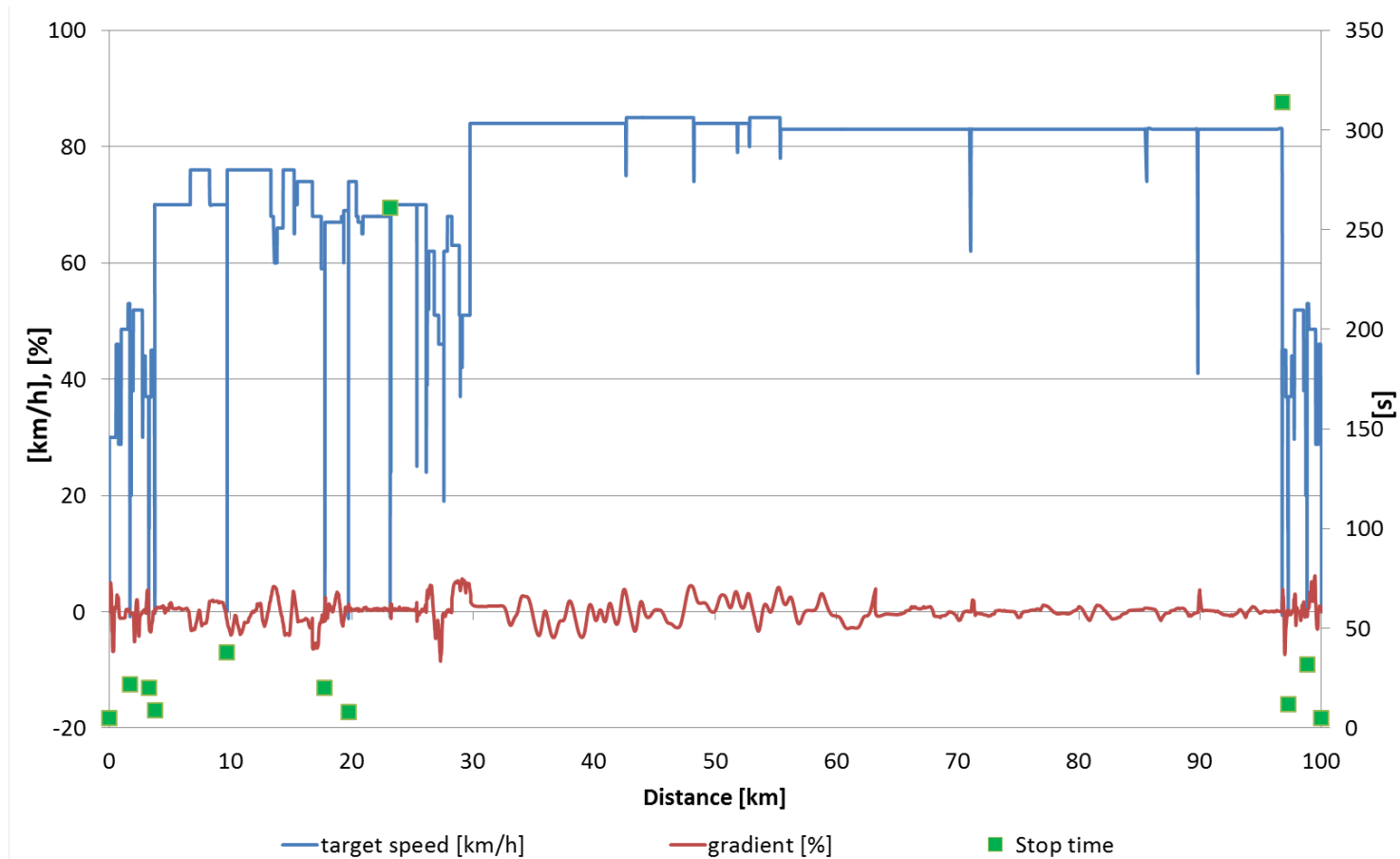
Buses and coaches

- City-bus heavy urban
 - City-bus urban
- City-bus suburban
 - Interurban bus
- Coach

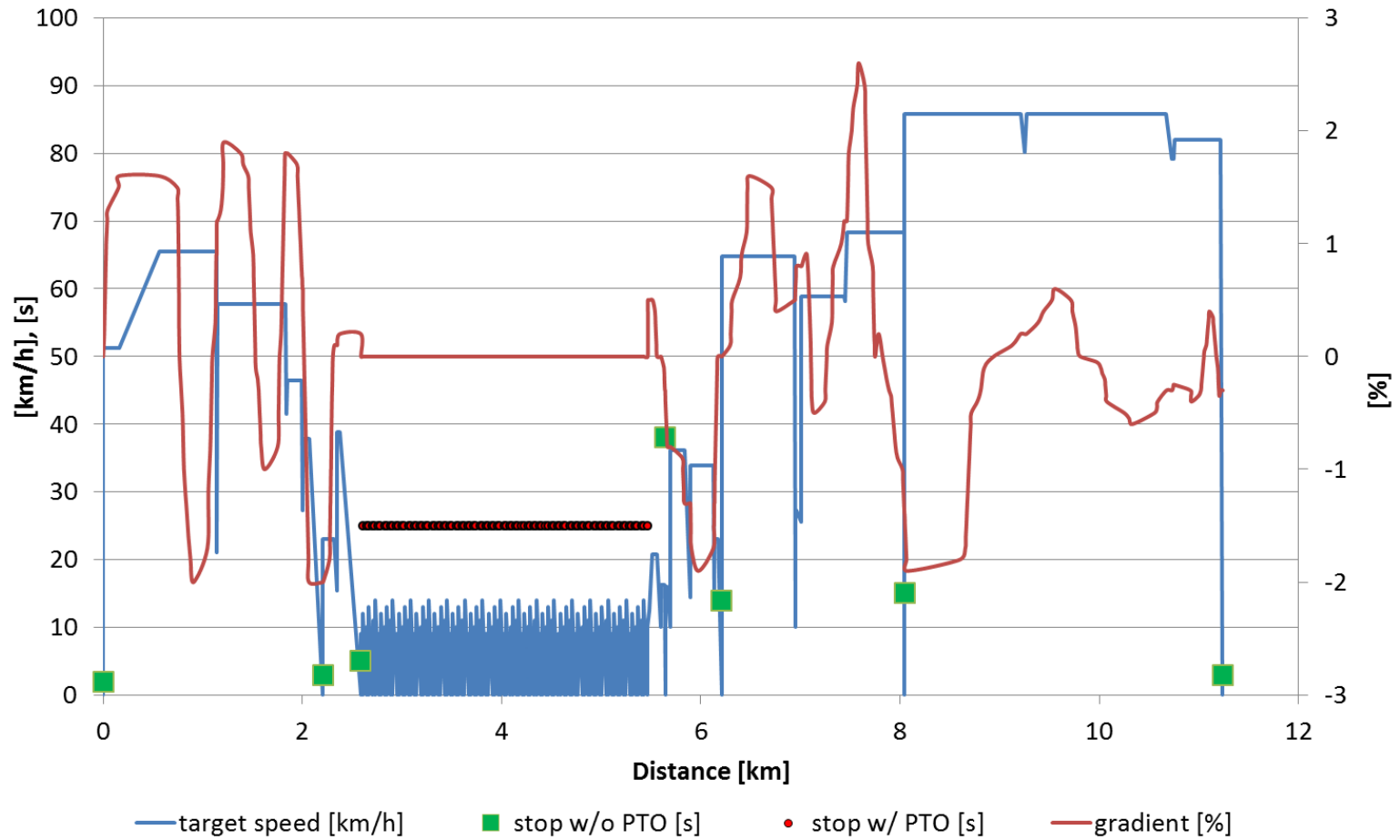
Long Haul (2015 update)



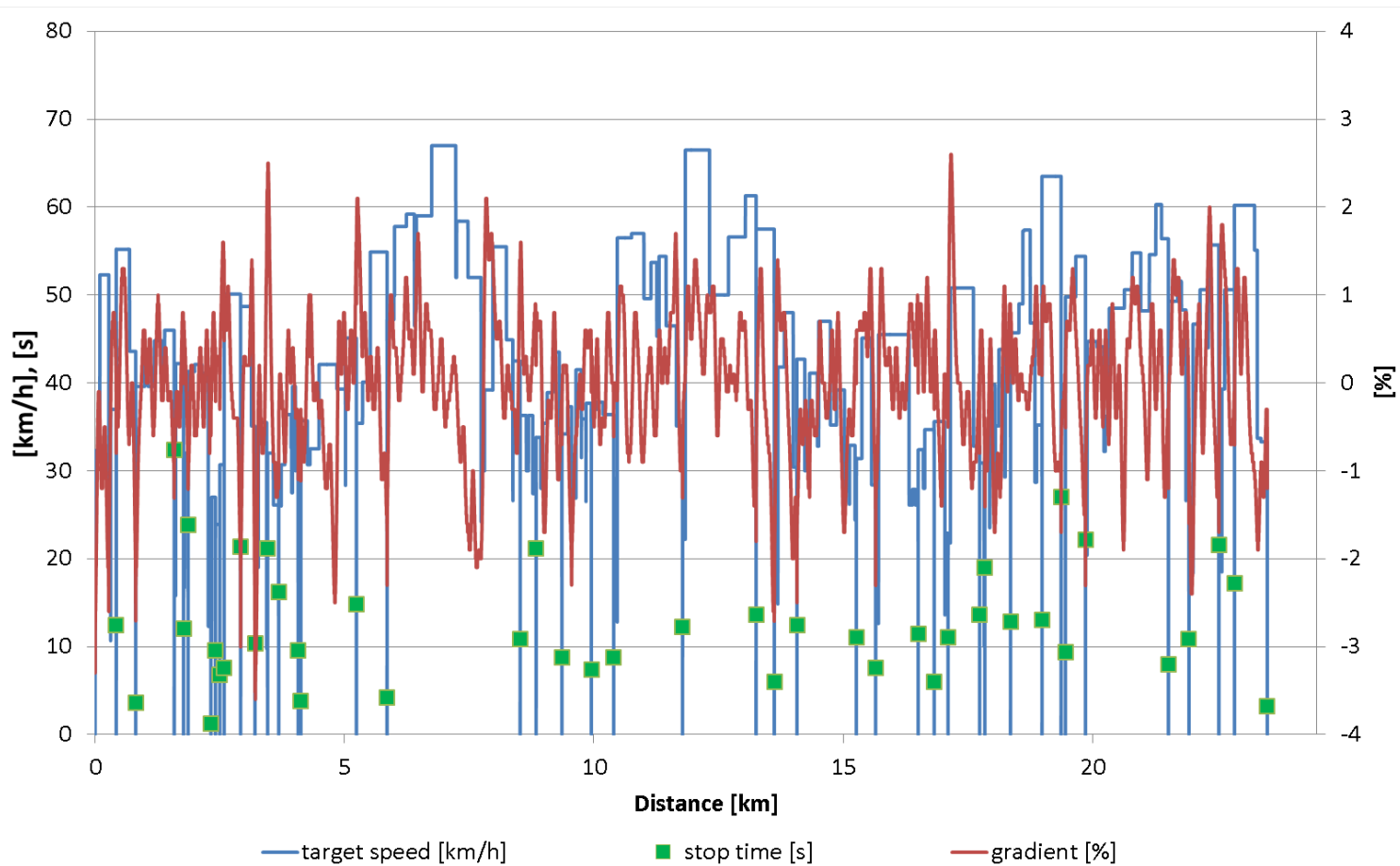
Regional delivery (2016 update)



Municipal cycle (2017 update)



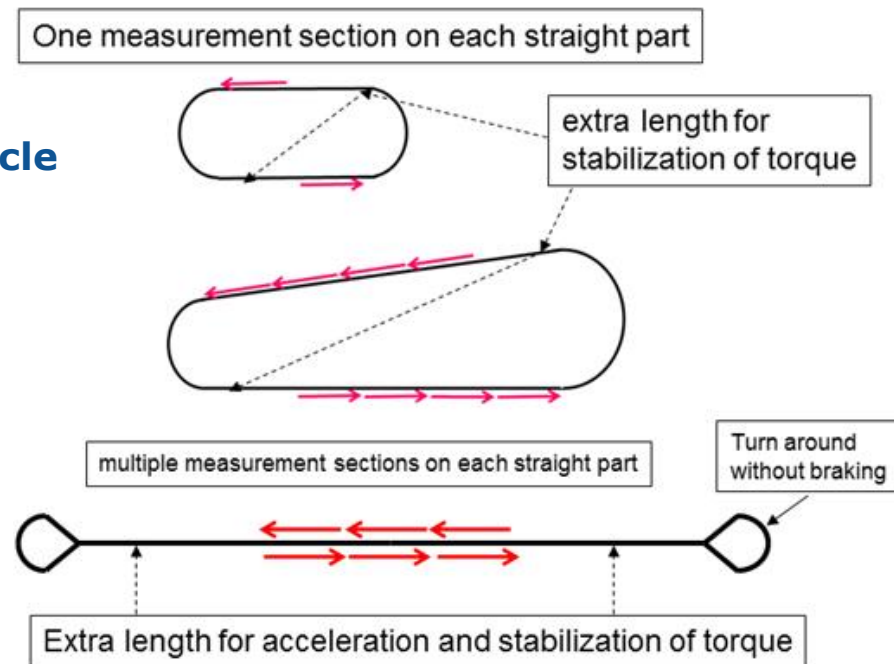
Suburban cycle (2016 update)



Input data: Aerodynamic drag - RRC

Constant speed test (at 2 speeds)

- Rim torque meter
- Anemometer
- Correction for gradient and for vehicle speed variations
- Correction for ambient P and T
- $F = F_0 + C_d * A * v^2 * r/2$



Important tire and vehicle conditioning for accurate $C_d * A$ results.

RRC calculated in these tests not to be used. Official value to be used for monitoring purposes

Vehicle groups for vehicles of category N

Description of 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 maximum 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)								
	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	7.5 – 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)								
	Rigid	>16	(7)								
	Tractor	>16	(8)								
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	
	Tractor	all weights	12	T+ST	T+ST+T2	T+ST	T+ST+T2			R	
6x6	Rigid	all weights	(13)								
	Tractor	all weights	(14)								
8x2	Rigid	all weights	(15)								
8x4	Rigid	all weights	16						R	(generic weight+ CdxA)	
8x6 8x8	Rigid	all weights	(17)								

* EMS - European Modular System

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

- R = Rigid & standard body
- T1, T2 = Standard trailers
- ST = Standard semitrailer
- D = Standard dolly

Busses classification

Identification of vehicle class						Segmentation and cycle allocation				
Axles	Axle configuration	Chassis configuration	Characteristics	Maximum GVW [t]	← Vehicle class	Heavy Urban	Urban	Suburban	Interurban	Coach
2	4x2	City	Class I + low floor or low entry, no luggage compartment	<18	B 1	HU	UR	SU		
		Interurban	Class II + luggage compartment and/or floor height ≤0.9m	<18	B2				IU	
		Coach	Class III + floor height ≥0.9m and/or double decker	<18	B3					CO
3	6x2	City	Class I + Low floor or low entry, no luggage compartment	>18	B4	HU	UR	SU		
		Interurban	luggage compartment and/or floor height ≤0.9m	>18	B5				IU	
		Coach	floor height ≥0.9m and/or double decker	>18	B6					CO

"Proof of concept" activity

Scope:

- Prove that simulation based monitoring can deliver results that accurately reflect fuel consumption and performance of modern HDVs
- Verify the validity and soundness of the approach
- Extensive measurements concluded in February 2013
- Joint EC-ACEA activity

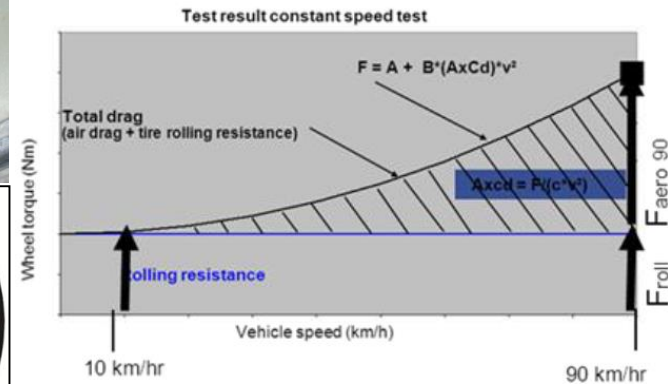
Included

- Two HDVs (DAF and Daimler)
- Proving ground testing (Iveco's circuit)
- Chassis dyno testing (JRC)
- On – road / PEMS testing (JRC)
- Engine test bed testing (JRC)



Torque measurement	Wheel rim (Actros) Axis (CF75)
Zeroing	Daily basis to eliminate drift High precision GPS (Actros)
Positioning / speed	Sensors at fixed points on ground (CF75)
Wind speed and wind angle	Ultrasonic Wind Anemometer (both)
Ambient temperature, humidity, pressure	Weather station installed on board (both)
Fuel consumption	OEM integrated flow meter (both) AVL KMA flowmeter (where possible)
Vehicle mass	JRC's balance

Equipment used



Anemometer installed on vehicle



Torque meter rim or flange between rim and wheel end

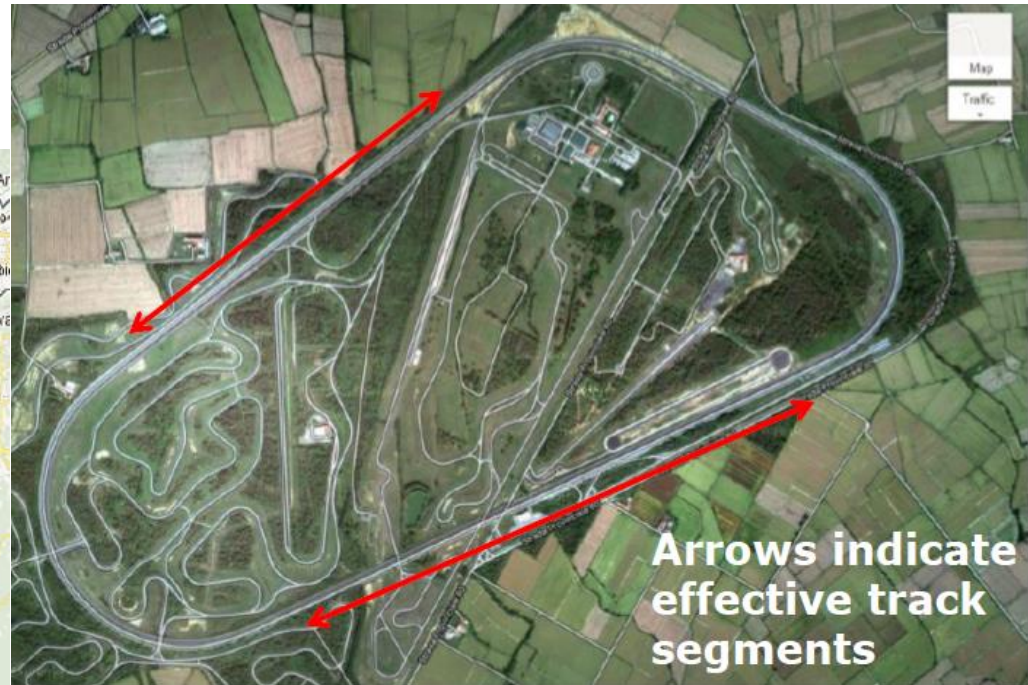
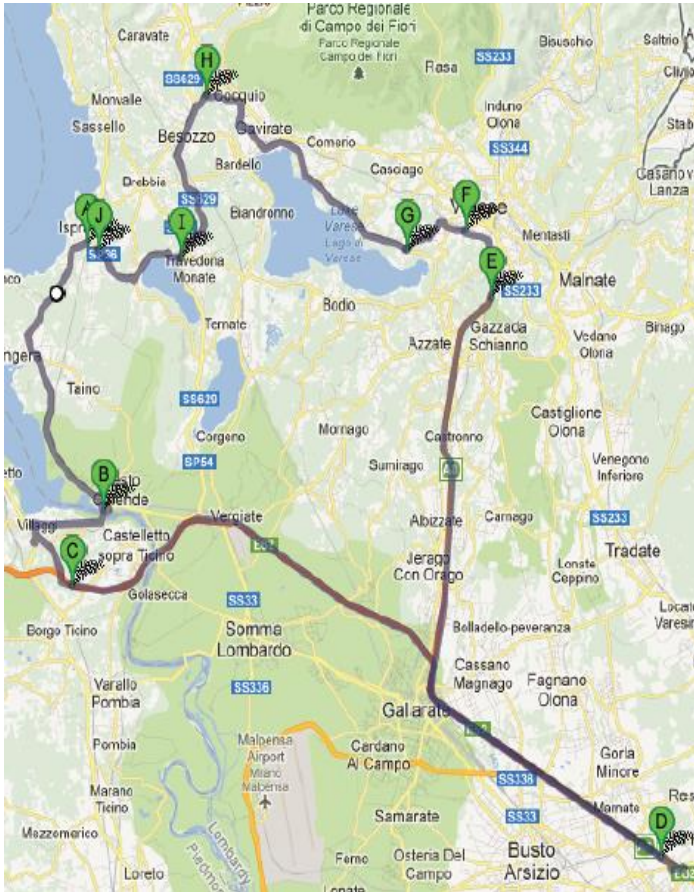


Test vehicles

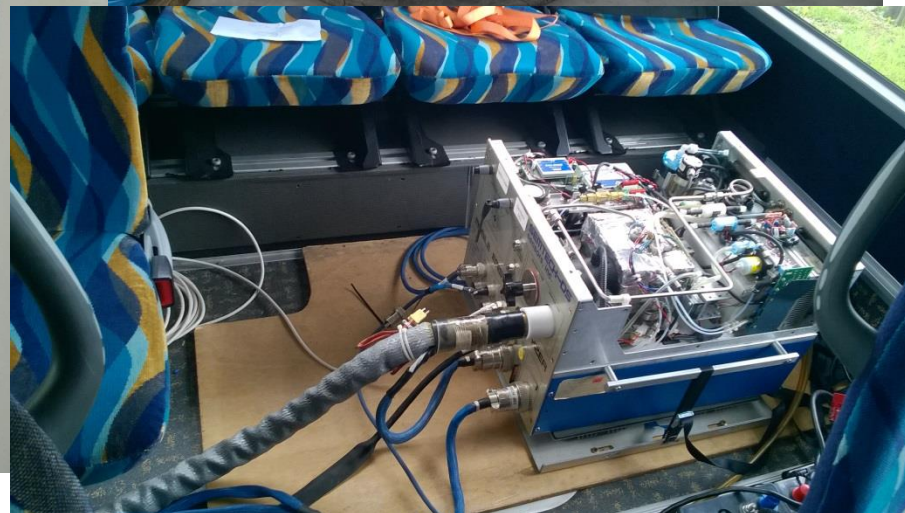


OEM	Daimler	DAF
Model	Actros	CF75
Maximum vehicle weight [kg]	40000	18600
Test mass [kg]	33580	14270
Engine Emission Standard	Euro VI	Euro V
Rated power [kW]	330	265
Rated Torque [Nm]	2200	1050
Displacement [l]	12.8	9.2
Fuel Consumption Map	From steady state RPM vs Torque points as measured by manufacturers	
Gearbox & Final Drive characteristics	As provided by manufacturers	

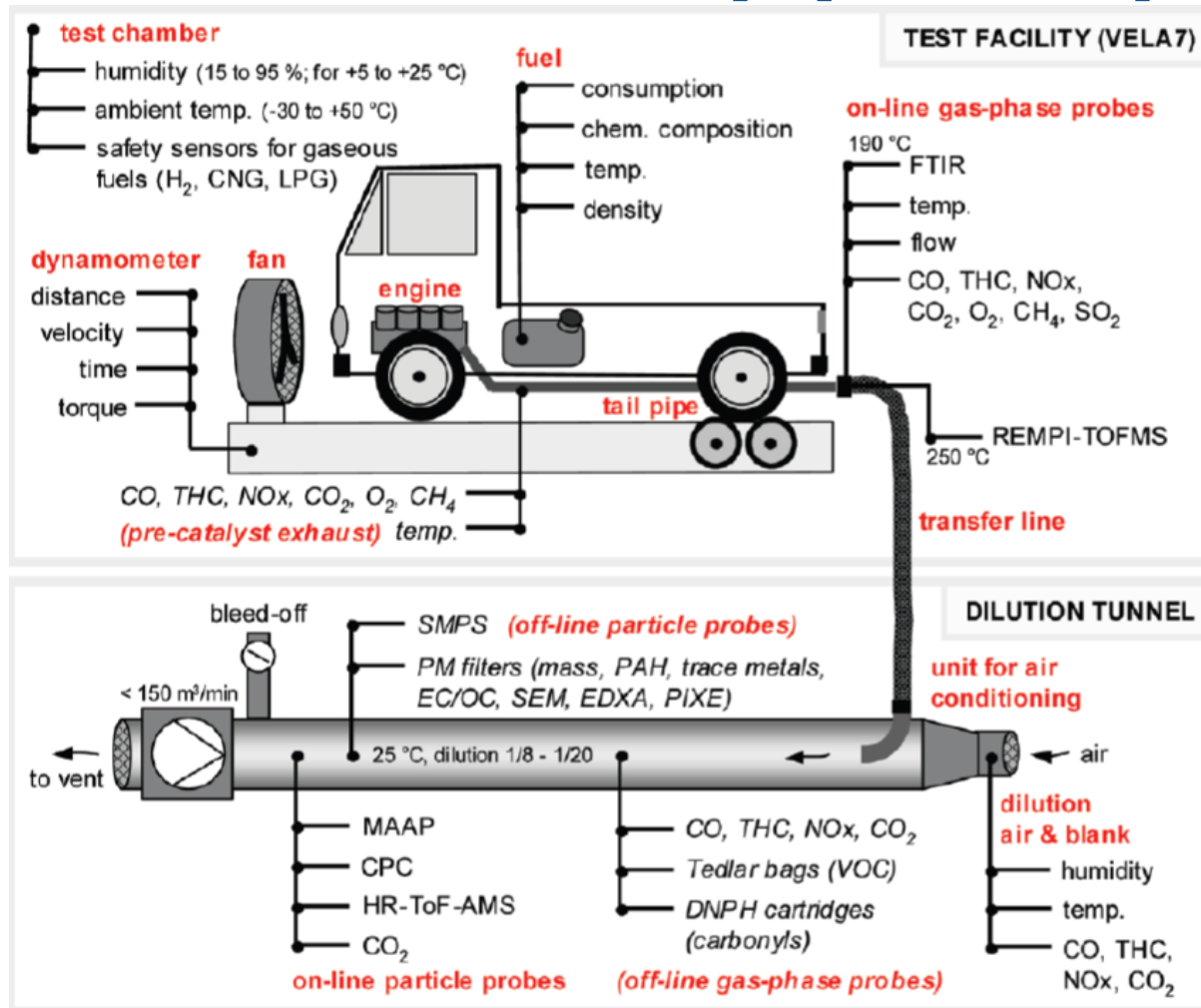
Test Route



Buses & coaches Pre Pilot Phase (PPT)



JRC's test facility (VELA 7)



GUI του VECTO pre-processing tool

VECTO-Engine 1.3


Input

Component data

Manufacturer TUG
 Model Best engine ever
 Certification Number 123456789

Idle speed of CO2-parent engine 600 [1/min] Type of test fuel Diesel / CI
 Engine idle speed 600 [1/min] NCV of test fuel 42.500 [MJ/kg]

Engine displacement 12000 [ccm]
 Engine rated power 130 [kW]
 Engine rated speed 2200 [1/min]



Data files

Fuel consumption map of CO2-parent engine J:\TE-Em\Projekte\2013_08_HDV_CO2_LOT_4_SR7\VECTO-Engine\Releases\VECTO-Engine 1.3\Demo input data\Demo_Map_...
 Full-load curve of CO2-parent engine J:\TE-Em\Projekte\2013_08_HDV_CO2_LOT_4_SR7\VECTO-Engine\Releases\VECTO-Engine 1.3\Demo input data\Demo_FullLo...
 Full-load curve J:\TE-Em\Projekte\2013_08_HDV_CO2_LOT_4_SR7\VECTO-Engine\Releases\VECTO-Engine 1.3\Demo input data\Demo_FullLo...
 Motoring curve curve of CO2-parent engine J:\TE-Em\Projekte\2013_08_HDV_CO2_LOT_4_SR7\VECTO-Engine\Releases\VECTO-Engine 1.3\Demo input data\Demo_Motor...

Specific fuel consumption measured

WHTC coldstart total 200.00 [g/kWh] WHTC-Urban 200.00 [g/kWh]
 WHTC hotstart total 200.00 [g/kWh] WHTC-Rural 200.00 [g/kWh]
 WHTC-Motorway 200.00 [g/kWh]

Correction factors

CF-RegPer 1.00

START FULL DATA EVALUATION Precalculate characteristic engine speeds and grid for fuel map

Output

Output Directory J:\TE-Em\Projekte\2013_08_HDV_CO2_LOT_4_SR7\VECTO-Engine\Releases\VECTO-Engine 1.3\Demo input data

Message

WHTC Simulation Results:
 Urban: 205.09 [g/kWh]
 Rural: 187.13 [g/kWh]
 Motorway: 178.05 [g/kWh]
 Total: 189.18 [g/kWh]
 Writing XML output file
 Completed.
 ATTENTION: 4 Warning(s) occurred: Please check detailed descriptions in 'Message Window'!

Reference fuels for testing

Engine fuel technology	Reference fuel type	Standard used for determination of NCV
Diesel CI	B7	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
Ethanol CI	ED95	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
Petrol PI	E10	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
Ethanol PI	E85	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
LPG	LPG Fuel B	ASTM 3588 or DIN 51612
Natural Gas	G ₂₅	ISO 6976 or ASTM 3588

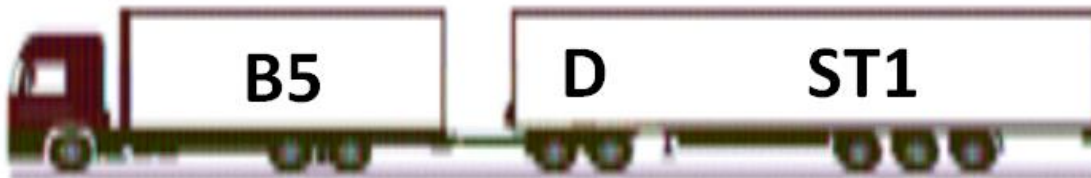
Standard bodies and standard trailers

name	curb mass [kg]	max gross mass [kg]	delta CdxA for trailer operation in long haul [m ²]		axle count [-]	wheels dimension	tyre RRC [N/kN]	cargo volume [m ³]
			as first trailer	as second trailer (EMS)				
B1	1600	-	-	-	-	-	-	36.5
B2	1900	-	-	-	-	-	-	45.2
B3	2000	-	-	-	-	-	-	47.7
B4	2100	-	-	-	-	-	-	49.4
B5	2200	-	-	-	-	-	-	51.9
T1	3400	10500	1.3	-	2	235/75 R17.5	5.5 (mid of energy class "C")	39.8
T2	5400	18000	1.5	1.5	2	385/65 R22.5		49.5
ST1	7500	24000	0	2.1	3	385/65 R22.5		91
Dolly	2500	12000	-	-	2	315/70 R22.5		0

EMS



Group 5



Group 9 & 11



Group 10 & 12



Thank you for your attention!

- I will be happy to address your questions

- More info can be found at:

<http://ec.europa.eu/clima/policies/transport/vehicles/heavy>

- Contact details:

Dimitrios SAVVIDIS: dimitrios.savvidis@ec.europa.eu