European Commission

Presentation of **V**ehicle **E**nergy consumption **C**alculation **TO**ol (VECTO)

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Transport and Ozone

Unit C2

Stakeholder Meeting

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Climate Action

European Commission

VECTO

Vehicle Energy Consumption Calculation Tool

Simulation tool to calculate both, fuel consumption and CO_2 emissions from the **whole** vehicle

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Vecto development

- VECTO has been developed by the Commission (DG CLIMA and JRC) with TUG support over the last two years

- ACEA, OEMs and component manufacturers have been also involved and provided key input and test vehicles

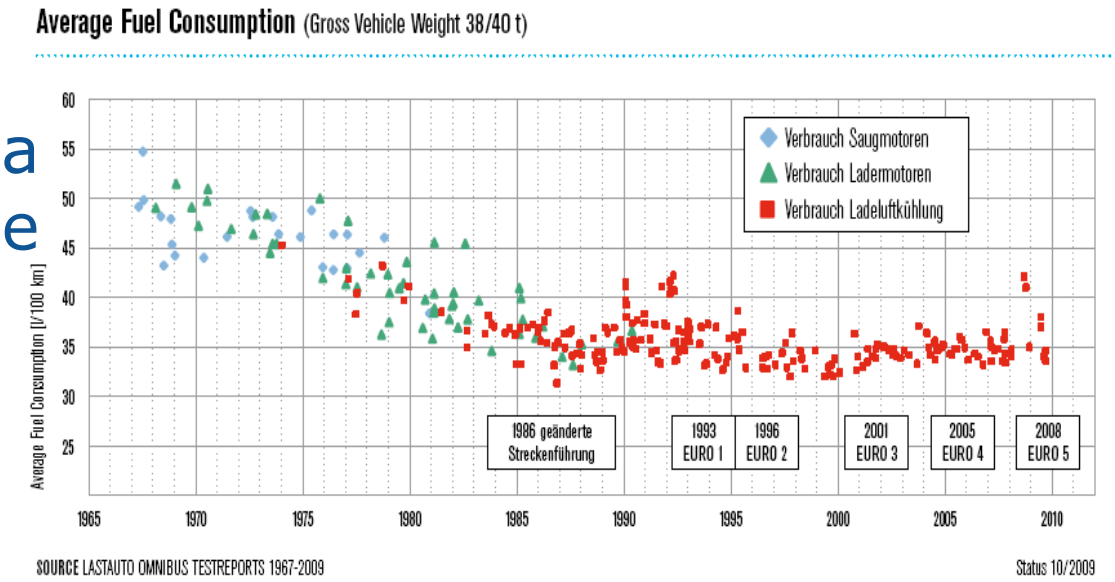
- DG CLIMA is the leader for this project

- Further development will take place in the next years (contract already launched).

Why do we want to measure HDVs

No official/unified measurement or certification scheme for HDVs in EU (unlike for cars and vans)

Some single data exist but indicative in nature



HDVs are more complicated than LDVs

- Low, medium, high, long, short cab etc
- 2,3,4,5,6 axles, 4x2, 4x4, 6x2, 6x4, 6x6 etc
- Different tires for each axle, single/twin tires etc
- Same engine but different gear boxes/axles ect
- Rigid, semi-trailer, tractor, coach, bus, citybus etc
- Any combination mentioned above

Millions of types!!!

HDV CO_2 in the EU Policy context

HDVs account for

- About 6% of total EU GHG emissions
- About 25% of total GHG road transport emissions
- Freight transport (trucks) main source of HDV emissions
- Passenger transport: buses and coaches

Roadmap for low carbon economy in 2050 :

- Reduce GHG emissions from 80% to 95% by 2050 (Base 1990)
- Transport sector foreseen to reduce emissions between 54 and 67% by 2050

White Paper on Transport:

- Target 60% reduction in GHG emissions by 2050 (Base 1990)
- 20% by 2030 (Base 2008)

Regulatory situation in EU

Existing Regulations setting performance standards for:

- **Cars (Reg. 443/2009), and**
- **Vans (Reg. 510/2011)**

Currently no legislation setting performance standards for HDV CO_2 emissions or parts thereof

Current test cycle procedure for HDVs is based on the engine (e.g. for regulation air pollutant emissions), not the whole vehicle

Scope

- Serve for all possible **policy steps** including:
  - Monitoring, reporting **and certification**
  - Improve market forces (e.g. by comparable customer information)
  - Labelling
  - Improve/help foot-printing schemes
- Give a reliable **real world** picture of the fuel consumption/CO_2 emissions – accuracy ~ 95 %
- Fit for the **future** (include new technologies)
- **Minimize burden** on OEMs

History

So far examined and result:

Approaches explored:

- Measurement on a chassis dynamometer
- Measurement with PEMS
- Component measurement and model simulation

Selected option:

Component measurement and model simulation for the **whole vehicle (truck and trailer)**

Methodology ("VECTO") considers:

Engine, driving resistances of whole vehicle (rolling, aerodynamic), gearbox, most relevant auxiliaries

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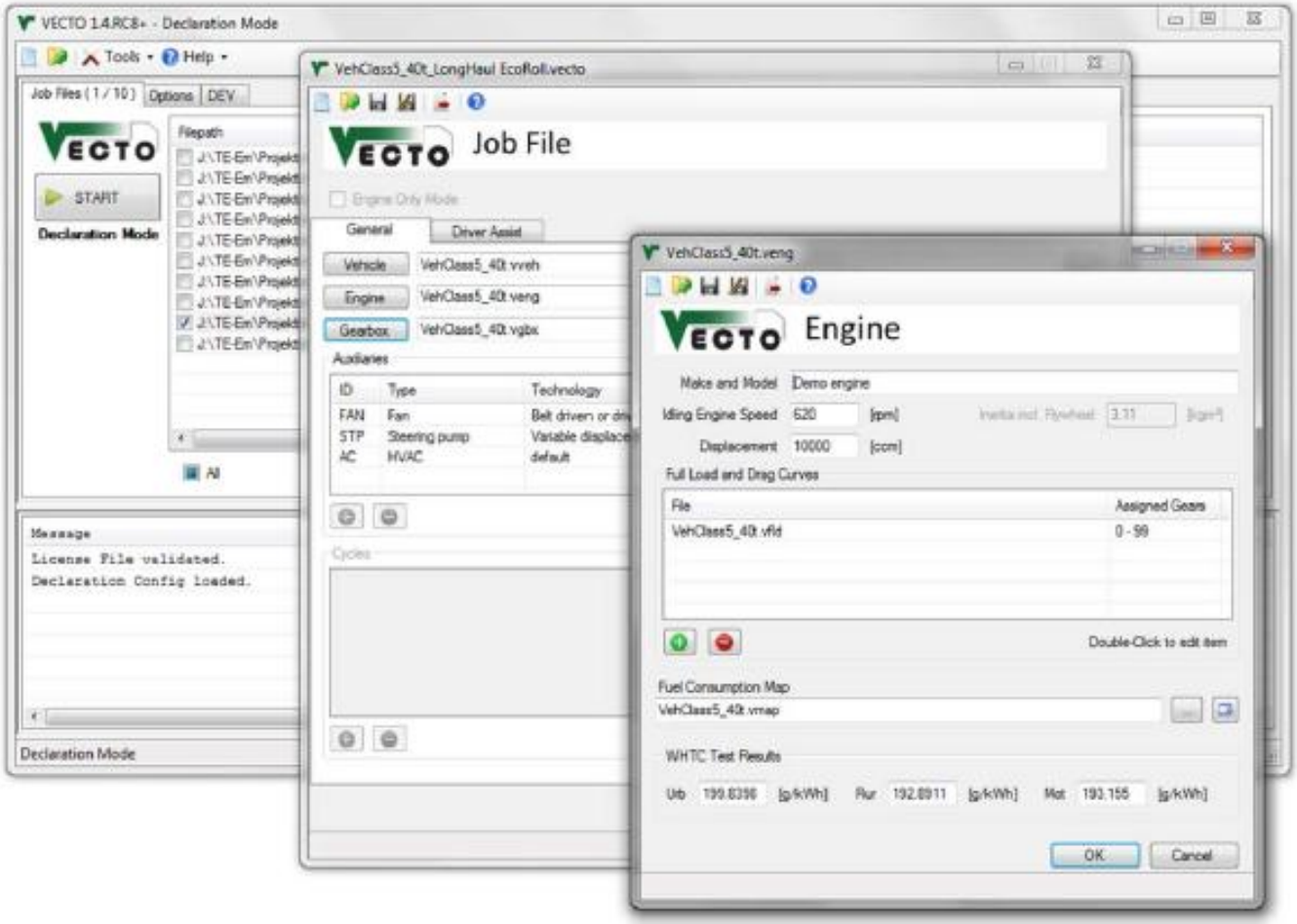
VECTO Graphical User Interface (GUI)



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VECTO's modes

VECTO offers a ***declaration mode***, where all *generic data* and the *test cycle* are allocated automatically as soon as the ***vehicle class*** is defined.

An ***engineering mode*** is also offered, 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*** of VECTO fuel consumption and CO_2 emissions are automatically calculated for all CO_2 test cycles allocated to the vehicle for average payload, full load and empty driving. Results are given in **g/km** and **g/ton-km** or **g/pass-km**.

Which of these values will be used in a final certification process is not decided yet.

Components and input data

For the following components, relevant **input data** for VECTO have to be delivered from standardised test procedures :

-- Vehicle mass

-- Tires (dimensions and rolling resistance coef)

-- Engine (engine fuel flow map)

-- Transmission (transmission ratios, loss maps for gear box and axle, default values optional)

-- Aerodynamic drag (Cd x A, for some vehicle classes generic values can be used)

Components and generic values

For the following components **generic values** are defined, which are allocated by the software VECTO to the vehicle depending on the vehicle class and mission profile. :

- Auxiliaries (alternator, air compressor, alternator, steering pump, cooling fan, Heating Ventilation AC-HVAC)
- Mass of the standard bodies and trailers
- Vehicle payload (truck) or passengers weight (bus)
- Test cycle

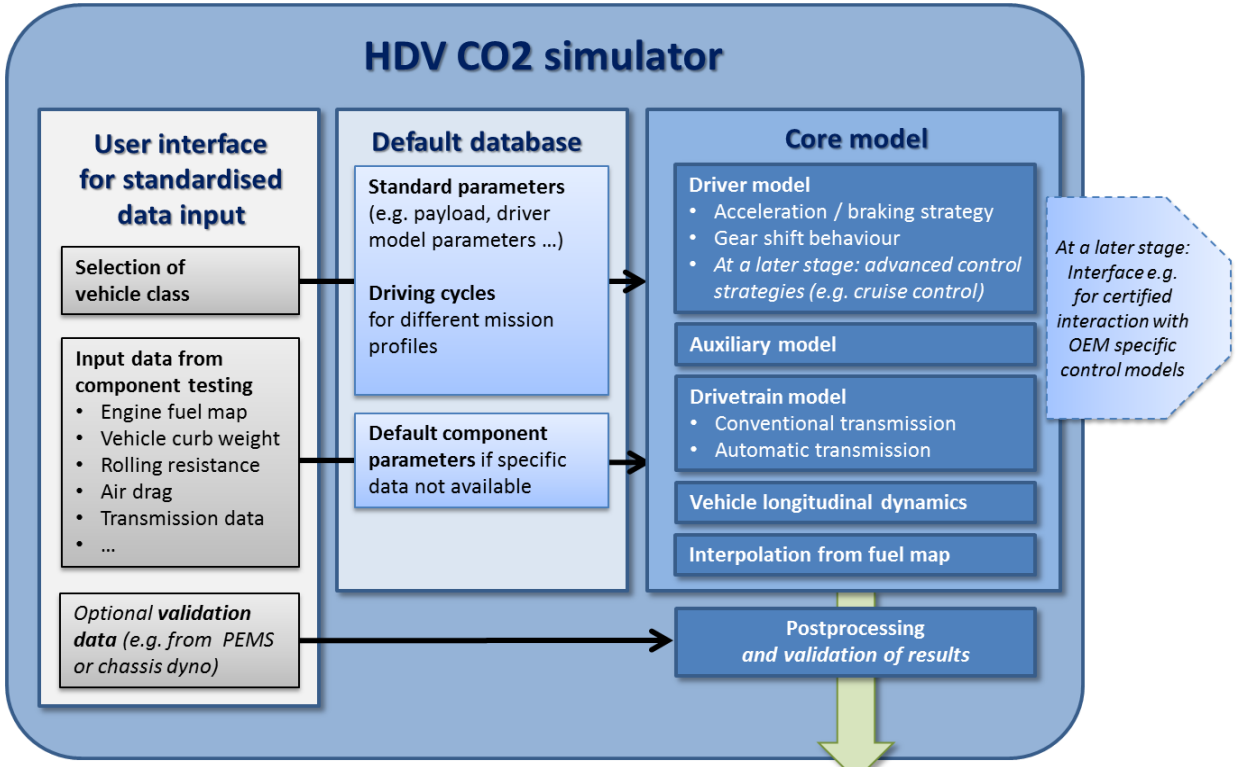
VECTO: Programme structure

Developed initially to cover:

- Delivery trucks (long haul and regional-city)
- Coaches
- Effort to include city buses

Effort to standardize:

- Measurement protocols for input data generation
- Individual component simulation models
- Mission profiles and cycles
- Evaluation / validation approaches



VECTO

Vehicle Energy Consumption Calculation Tool

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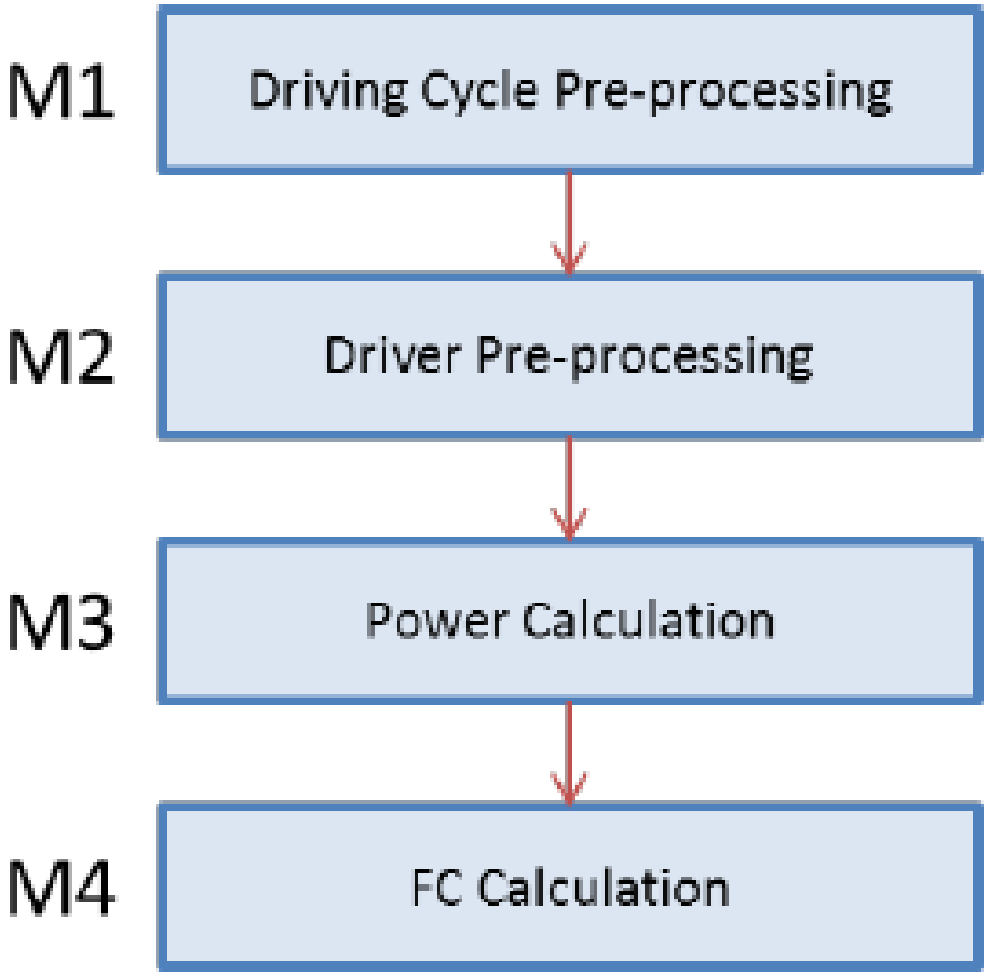
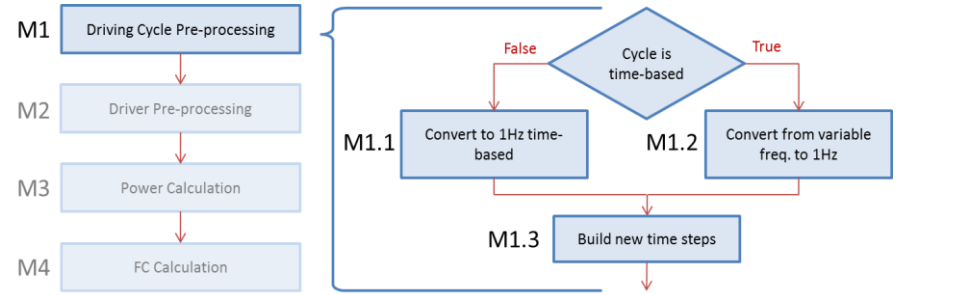
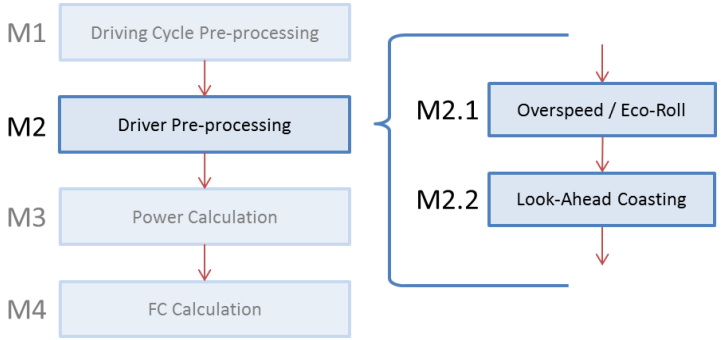
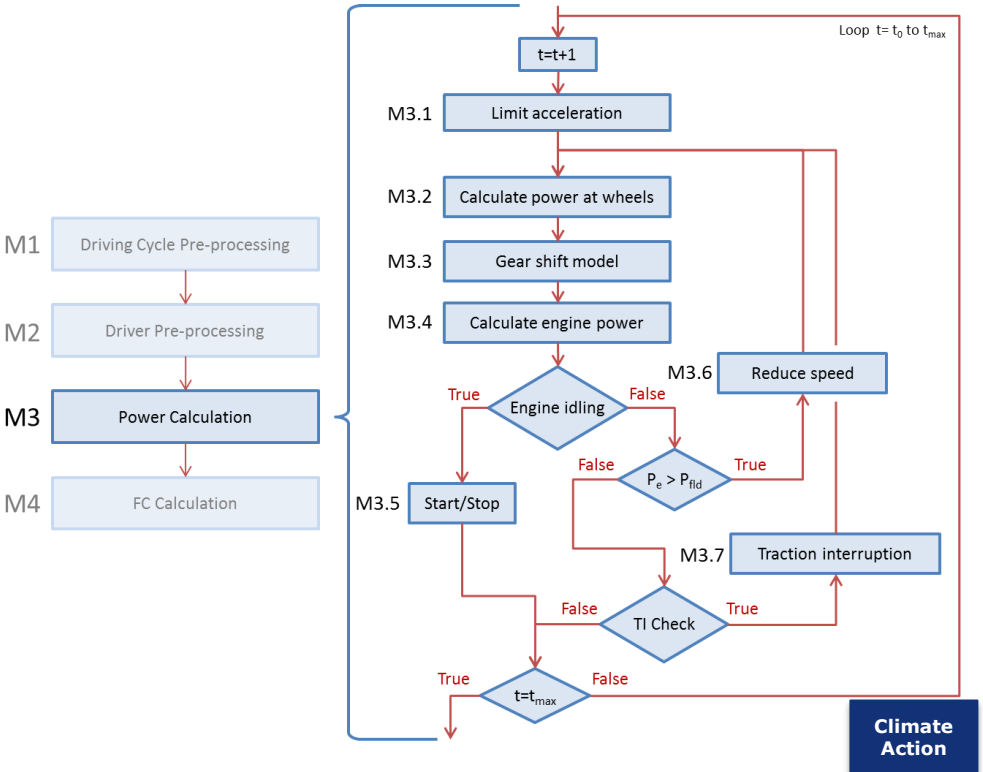
Model structure – Four main modules

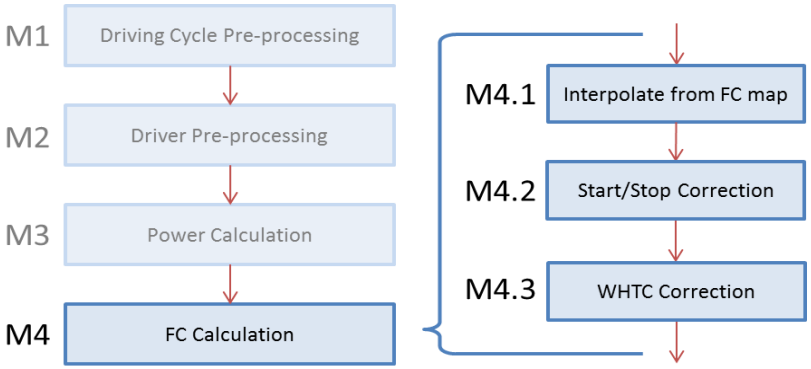


Model structure - Four main modules









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Tasks of single modules (1)

In **Driving Cycle Pre-processing (M1)** the distance-based driving cycle (mission profile) is being converted to 1Hz. Time-based cycles are converted to 1Hz if necessary.

Driver Pre-processing (M2) applies driver functions to the driving cycle which can't be considered later in the backwards power calculation (M3) like Over-speed or Look-Ahead Coasting.

Tasks of single modules (2)

Power Calculation (M3) is the core of the model. Here the engine operation points (engine torque and speed) are calculated for each time step considering driving resistances and powertrain losses and auxiliary power demands.

Finally in **FC Calculation (M4)** the fuel consumption (FC) is being interpolated from the stationary FC map and the WHTC correction is applied.

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

Rigid and tractors classification

The generic values are allocated to the vehicle by VECTO automatically depending on the HDV class in which the vehicle falls.

Classification, mission profile or type of use and identification of standard bodies for each type of HDV

	Identification of vehicle class				Segmentation (vehicle configuration and cycle allocation)					Norm body allocation		
Axles	Axle configuration	Chassis configuration	Maximum GVW [t]	<-- Vehicle class	Long haul	Regional delivery	Urban delivery	Municipal utility	Construction	Standard body	Standard trailer	Standard semitrailer
2	4x2	Rigid	>3.5 - 7.5	0		R	R			B0		
2	4x2	Rigid or Tractor	7.5 - 10	1		R	R			B1		
		Rigid or Tractor	>10 - 12	2	R	R	R			B2		
		Rigid or Tractor	>12 - 16	3		R	R			B3		
		Rigid	>16	4	R+T	R		R		B4	T1	
		Tractor	>16	5	T+S	T+S						S1
	4x4	Rigid	7.5 - 16	6				R	R	B1		
		Rigid	>16	7					R	B5		
		Tractor	>16	8					T+S			W1?
3	6x2/2-4	Rigid	all weights	9	R+T	R		R		B6	T2	
		Tractor	all weights	10	T+S	T+S						S2
	6x4	Rigid	all weights	11					R	B7		
		Tractor	all weights	12					R			S3
	6x6	Rigid	all weights	13					R	W7		
		Tractor	all weights	14					R	W7		
4	8x2	Rigid	all weights	15					R	B8		
	8x4	Rigid	all weights	16					R	B9		
	8x6 & 8x8	Rigid	all weights	17					R	W9		

R = Rigid & Body
R+T = Rigid & Body & Trailer *)
T+S = Tractor & Semitrailer
W =no (Cd*A) measurement, only vehicle weight and frontal area

*) Whether it is sufficient to simulate the truck-trailer combination based on cd*A for Rigid & Body or the full-vehicle test for aerodynamic drag has to be performed additionally with Rigid & Body & Trailer has to be clarified

Busses classification

	Identification of vehicle class					Segmentation and cycle allocation				
Axles	Axle configuration	Chassis configuration	Characteristics	Maximum GVW [t]	<-- Vehice 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

For each class the corresponding test cycles, the standard body or trailer and the payload are defined as well as the data relevant for the simulation of the generic auxiliaries.

Simulation of engine power

Simulation of engine power:

Vehicle specific
C_d*A

Vehicle specific
m*g*sinα

Vehicle specific
transmission:

$P_e = P_{roll.} + P_{air} + P_{acc} + P_{grad} + P_{trans}$

Vehicle + tire specific
$m_{vehicle}$, m_{load},
RRC from drum tests

Vehi

iciency

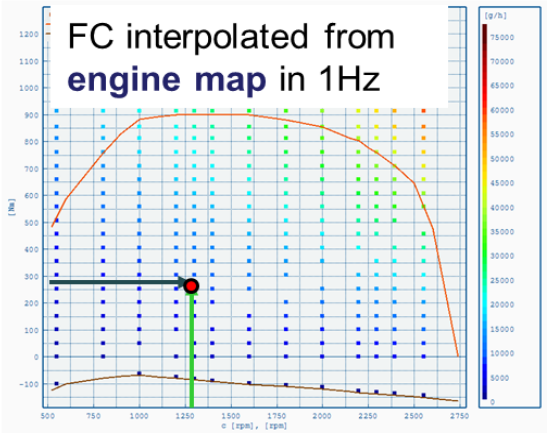
mponent specific loss
ps possible

Simul

$d_{tire} \times \pi$)

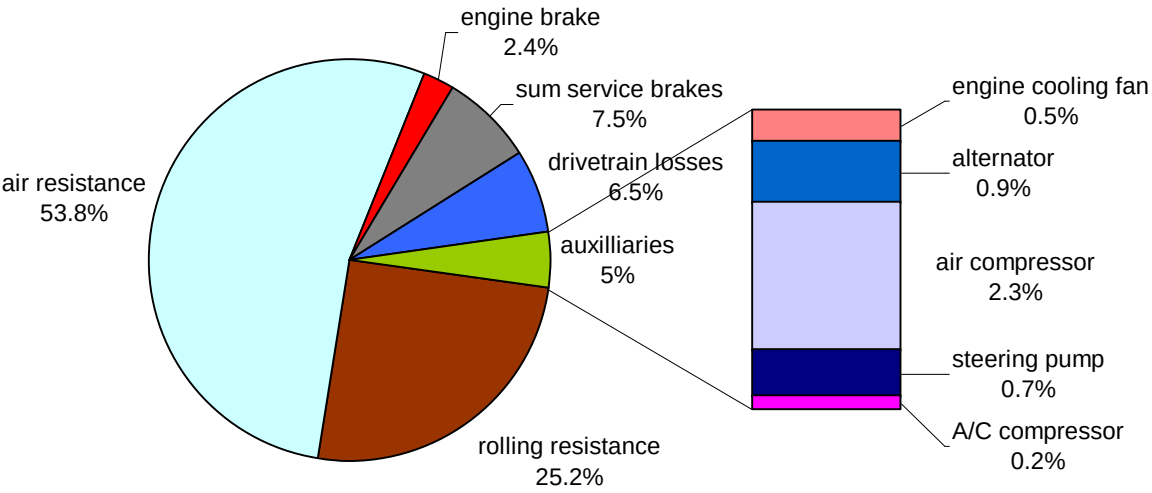
icle transmission ratios
i_{gear}, i_{axle}

DON'T PANIC!

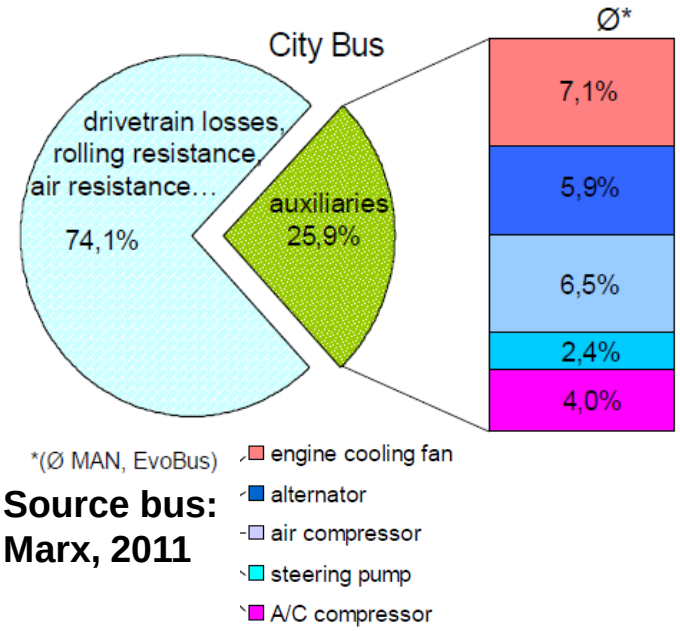


Shares of energy consumption

EURO V semitrailer 28 t



EURO V city bus



Source bus:
Marx, 2011

→ Must be included:
***** Air resistance**
***** Rolling resistance**
***** Engine efficiency**
→ +transmission ratios

Shall be included:
**** Transmission losses**

Should be included
as far as possible:
*** Auxiliaries**
*** Power consumers**

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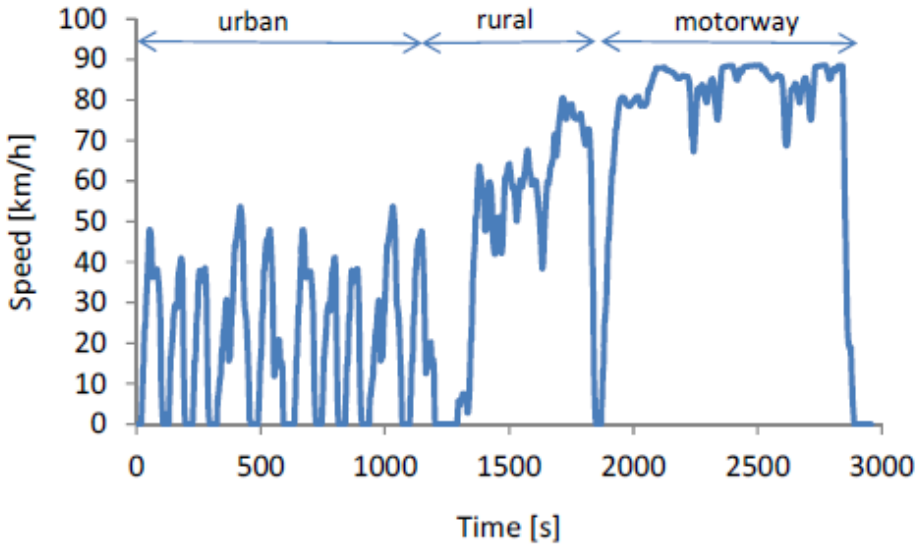
Evaluation of simulation program

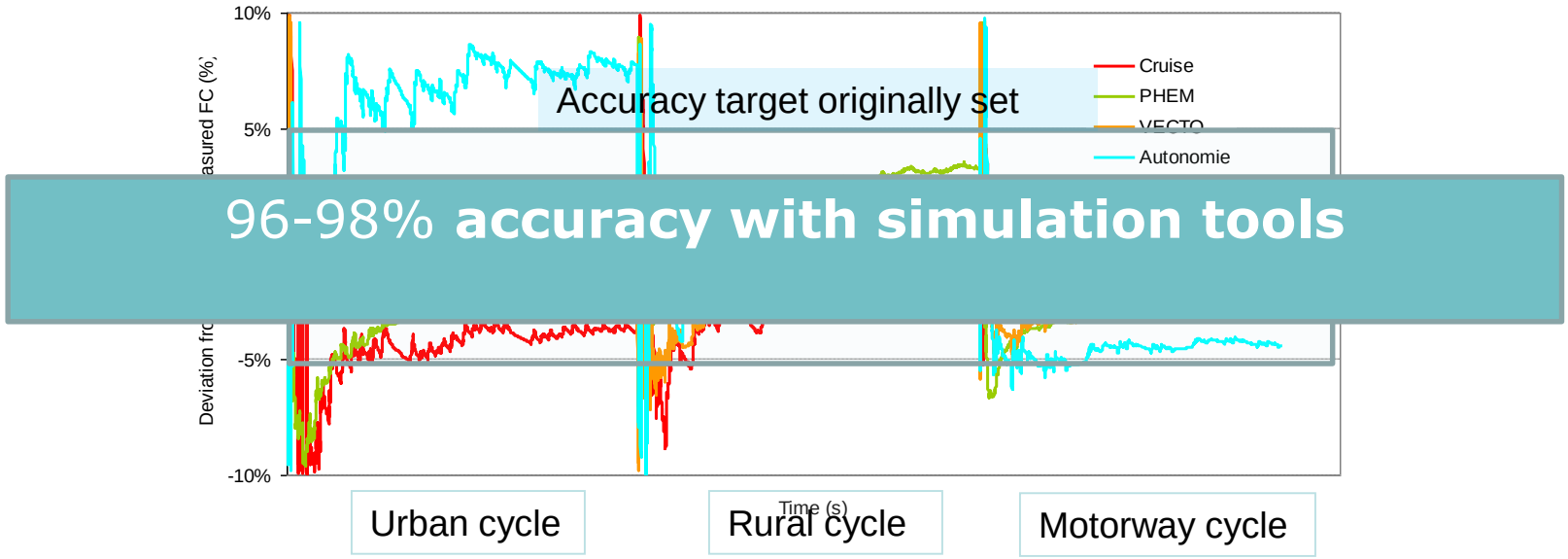
- Selected 12 ton truck, measured over various conditions on chassis dyno
- Performed simulations with VECTO
- Verify good correlation between measured and simulated values
- Compared against 3 commercially available simulators
- First sensitivity analysis – uncertainties quantification



Vehicle Empty Mass [kg]	8862
Rated power [kW]	185
Rated Torque [Nm]	840
Displacement [cm]	6000
Idling speed [rpm]	600
A_cross x Cd [m2]	6.16 (derived from track measurements)
Tyre RRC [-]	0.0077 (derived from track measurements)
Fuel Consumption Map	From steady state RPM vs Torque points as measured by manufacturer
Gearbox & Final Drive characteristics	Ratios and efficiencies as provided by manufacturer
Auxiliary power consumption	power functions as provided by manufacturer
Auxiliary operation	As measured during tests

Fuel consumption over sub-cycle (normalized by measured average 100=measurement)

	VECTO	Cruise	PHEM	Autonomie
Urban part	99	96	101	-
Rural part	98	101	96	98
Motorway part	98	101	98	96



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 February 2013
- Joint Commission-ACEA activity

Included

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

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Vehicles used

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]	220	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	

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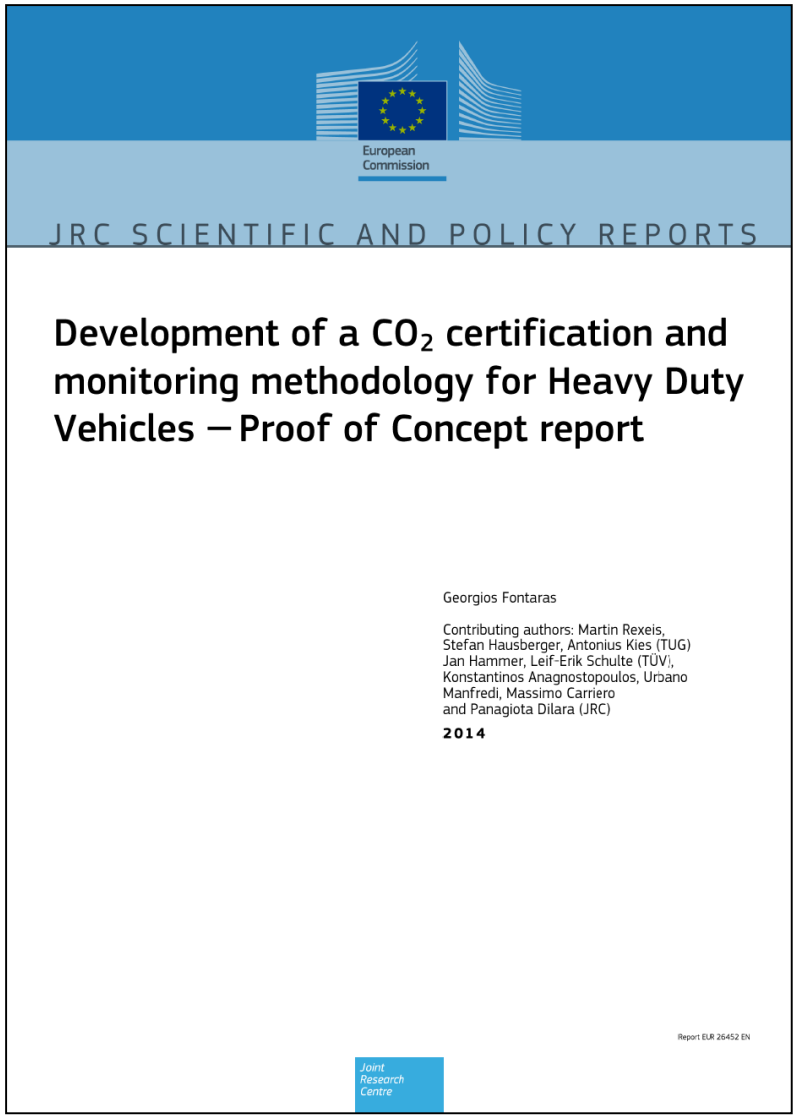

The full report can be found on DG Clima's website

http://ec.europa.eu/clima/policies/transport/vehicles/heavy/docs/hdv_co2_certification_en.pdf

Report conclusions and follow up

- Simulated fuel consumption was calculated with a range of ±3% from the real world measurements or even less.

- Finalize and validate topics remaining open in the methodology such as gearbox and driveline efficiency, auxiliary units power consumption, automatic gear shifting strategies, mobile air-conditioning simulation for city buses.

- Perform a sensitivity analysis in order to more accurately quantify the uncertainty of the method for different vehicle types/categories.

- Investigate the necessary conditions for expanding the methodology to other HDV categories.

Timeline

- VECTO development: on-going

- Dissemination and trials: from 2013 to mid-2016

- Possible legislative proposals: 2015

- Possible first reporting year: 2018

Thank you for your attention

- VECTO demonstration will follow
- 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:

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