

Use of COPERT 4 for the compilation & submission of road transport GHG inventories



Leonidas Ntziachristos
ETC/ACC

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European Environment Agency

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Background: EU Institutional Framework

- EU MSs and EU as a whole are parties to UNFCCC
- EU MSs are responsible for own inventories
 - Reporting
 - Methods
- EC (DG CLIMA) is responsible for complete EU inventory, based on individual MSs' inventories
 - EEA – ETC/ACC responsible for compilation & QA/QC implementation programme of EU inventory
 - Further QA/QC by DGs Eurostat and JRC



Background: COPERT Info

- Name stands for **C**omputer **P**rogramme to calculate **E**missions from **R**oad **T**ransport
- COPERT 4 since 2006 (4th major update of original COPERT 85) – annually revised
- Methods & EFs based on results from several research / policy assessment projects
- Incorporates the Tier 3 method of the EMEP/EEA Emission Inventory Guidebook
- Referenced in IPCC2006GL and used to deliver European EFs for CH₄ and N₂O

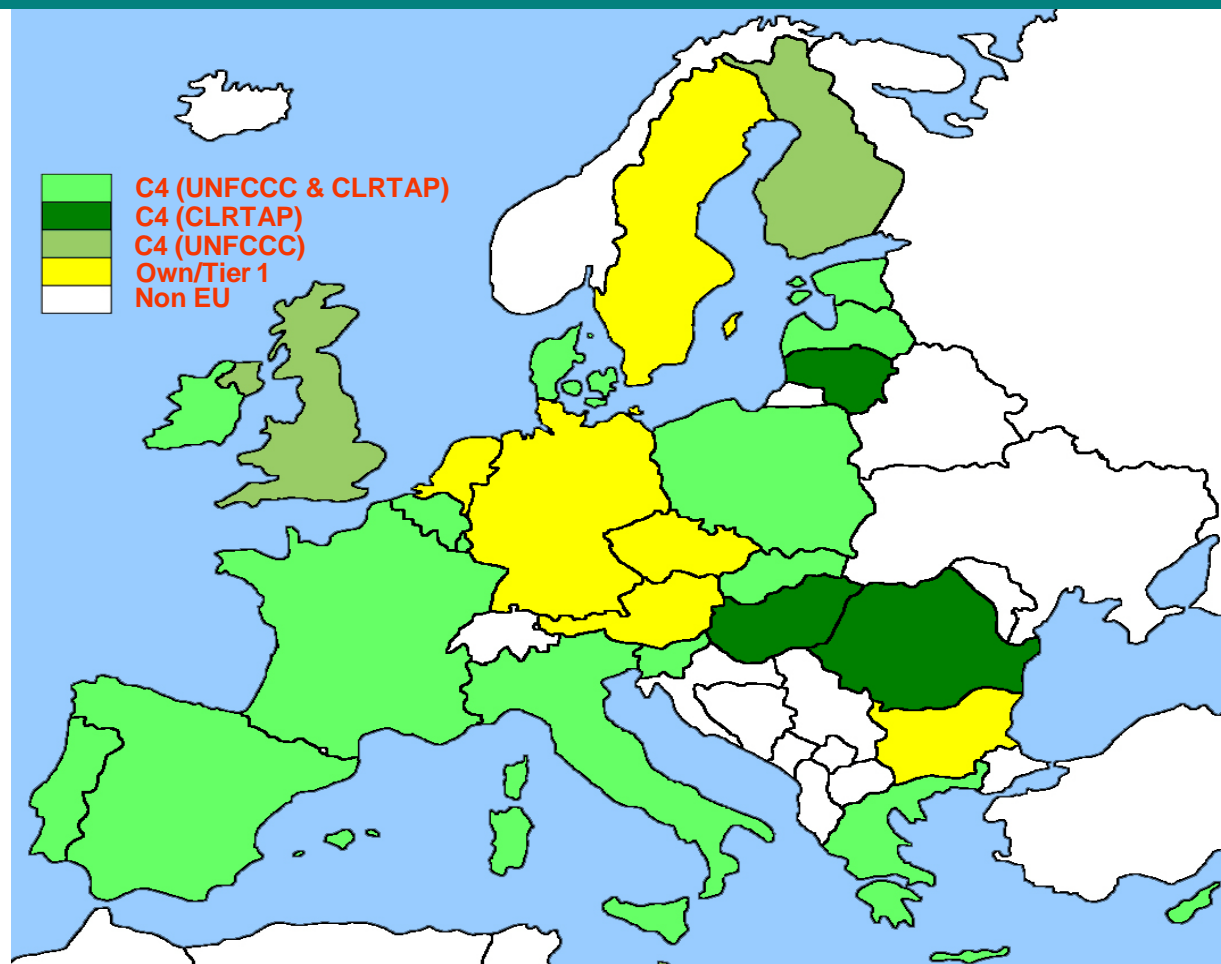


Background: COPERT Admin

- Support for official use (CLRTAP, UNFCCC):
 - **EEA, ETC/ACC**
- Methods and emission factors:
 - **ERMES** (European Research on Mobile Emission Sources) consortium, hosted by **DG JRC/IES**
 - **TFEIP** (Task Force on Emission Inventories and Projections)
- Technical support and development:
 - **AUTH** Lab of Applied Thermodynamics
 - **EMISIA SA**



Background: COPERT Actual Use



Note: BG, RO intend to move to COPERT 4 according to 2010 NIRs



Methodology: Tier Coverage

	CO ₂	CH ₄ , N ₂ O	Urea
Tier 1	FC × EF _{Default}	FC _f × EF _f	Urea Consumption × 'Purity'
Tier 2	FC × EF _{Count.Spec.}	FC _{veh.cat} × EF _{veh.cat}	NA
Tier 3	NA	VKT _{veh.cat} × EF _{veh.cat} + Cold	NA

Legend:

NA Not Available



IPCC Method Coverage by COPERT 4



Methodology: CO₂ Calculation

$$E_{\text{CO}_2}^{\text{CALC}} = 44.011 \times \frac{FC^{\text{CALC}}}{12.011 + 1.008R_{\text{H:C}} + 16.000R_{\text{O:C}}}$$

- Calculation of *ultimate* CO₂ , i.e. all carbon in fuel oxidized to CO₂
- Operates on the basis of g/km emission factors for consistency with other pollutants
- R_{H:C}, R_{O:C} are the ratios of H to C and O to C atoms, respectively in the average fuel molecule



Methodology: Energy Statistics

Provide Fuel Consumption in TJ

Fuel	Annual Consumption (TJ)
Gasoline Leaded	0
Gasoline Unleaded	5569
Diesel	3167
LPG	132
CNG	32,8
Biodiesel	124,5

TJ to t conversion factors

Fuel	COPERT	IPCC default	User Values
Gasoline Leaded	0,043774	0,0443	0
Gasoline Unleaded	0,043774	0,0443	0
Diesel	0,042695	0,043	0
LPG	0,046564	0,0473	0
CNG	0,048	0,048	0
Biodiesel	0,0373	0,027	0

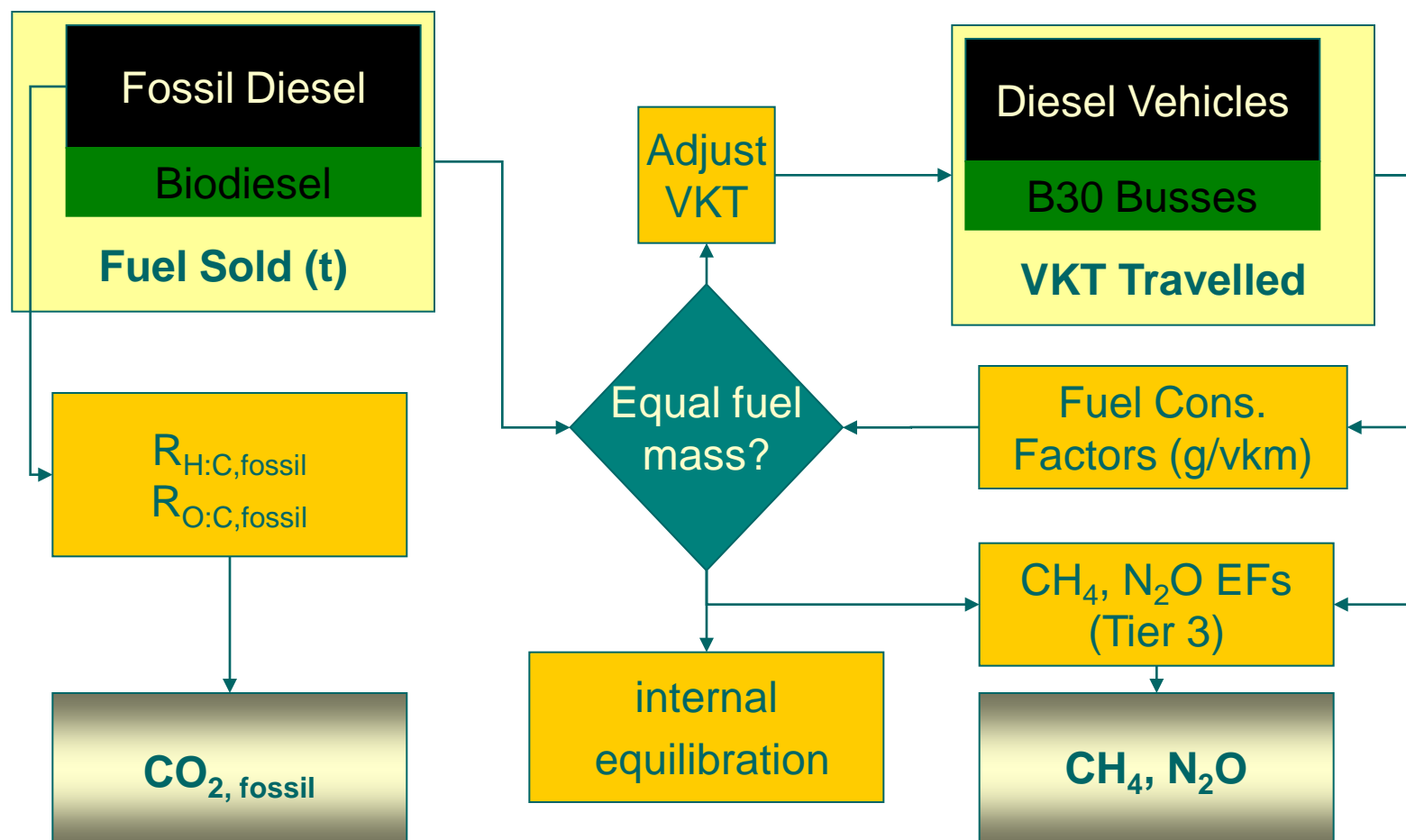
Conversion factor to be used: ☐ COPERT ☒ IPCC default ☐ User Values

? OK Cancel

- Total activity can be introduced in TJ
- Conversion factors (TJ→t) are proposed



Methodology: Algorithm



Emission Factors: CO₂

Fuel	Chemical formula	COPERT					IPCC (kg/TJ)		
		R _{H:C}	R _{O:C}	EF _{CO2} (kg/kg _f)	LHV (MJ/kg _f)	EF _{CO2} (kg/TJ)	Default	Lower	Upper
Petrol	[CH _{1.8}] _x	1.80	0	3.18	43.8	72722	69300	67500	73000
Diesel	[CH ₂] _x	2.00	0	3.14	42.7	73489	74100	72600	74800
E100	C ₂ H ₅ OH	3.00	0.5	1.91	28.9	66191			
NG	0.95 CH ₄ +0.05 C ₂ H ₆	3.90	0	2.76	49.9	55326	56100	54300	58300
	0.85 CH ₄ +0.15 C ₂ H ₆	3.74	0	2.79	49.7	56140			
LPG_A	0.50 C ₃ H ₈ +0.50 C ₄ H ₁₀	2.57	0	3.01	46.1	65447	63100	61600	65600
LPG_B	0.85 C ₃ H ₈ +0.15 C ₄ H ₁₀	2.63	0	3.00	46.3	64879			



Emission Factors: CH₄

- Four values (mg/km) are provided: Cold Urban, Hot Urban, Rural, Highway
- Data mostly based on ARTEMIS project (2000-2006), values differentiated per vehicle category, Euro standard
- Cold/Hot urban part estimated on the basis of cold-start distance
- Emission factors for new technologies based on extrapolation. Low CO₂ equivalent too weak to justify new measurements.



Emission Factors: N₂O

- $EF_{N_2O} = (a \times \text{Cum.Mileage} + b) \times EF_{\text{BASE}}$
 - a, b, EF_{BASE} depend on technology level for gasoline PCs & LCVs
 - a, b depend on fuel sulfur content
 - Different factors for cold urban, hot urban, rural, highway
- Much simpler approach for Diesel cars, HDVs and gasoline motorcycles



Emission Factors: Lube Oil

Category	% of Fuel Consumption
Passenger Cars	0.1
Heavy Duty Vehicles	0.3
2-stroke Mopeds	5...50

- Total contribution 0.2-0.3% for developed countries
- Contribution potentially more important for developing countries



Emission Factors: SCR Urea

		Consumption (Mt)	CO ₂ (Mt)
2010	Gasoline (toe)	107	298
	Diesel (toe)	190	556
	Urea	1	0.238
	Total Road Transport		854
	Urea/Total		0.03%
2020	Gasoline (toe)	104	281
	Diesel (toe)	204	578
	Urea	12.24	2.92
	Total Road Transport		862
	Urea/Total		0.3%

Notes:

- All diesel vehicles assumed Euro 6/VI in 2020, require SCR agent ~ 6% of FC
- CO₂ and consumption taken from PRIMES 2009 baseline



Benefits: GUI

COPERT 4 version 7.0 - C:\Documents and Settings\Leon\Desktop\test701.mdb (Changed)

File Country Fleet Configuration Activity Data Calculation Factors Emissions Advanced Help

Input Fleet Data

Sector: Passenger Cars

Subsector	Legislation Standard	Population	Mileage (km/year)	Mean fleet mileage (km)
Gasoline <1,4l	PRE ECE	0	1245,152708	0
Gasoline <1,4l	ECE 15/00-01	0	1245,152708	0
Gasoline <1,4l	ECE 15/02	48,169185	10006,16915	334039,8391
Gasoline <1,4l	ECE 15/03	0	1245,152708	0
Gasoline <1,4l	ECE 15/04	0	1245,152708	0
Gasoline <1,4l	Improved Conventional	0	1245,152708	0
Gasoline <1,4l	Open Loop	0	1245,152708	0
Gasoline <1,4l	PC Euro 1 - 91/441/EEC	0	1245,152708	0
Gasoline <1,4l	PC Euro 2 - 94/12/EEC	1902,0186	9627,807251	356809,6837
Gasoline <1,4l	PC Euro 3 - 98/69/EC Stage20	10051,332	9797,613415	346521,5866
Gasoline <1,4l	PC Euro 4 - 98/69/EC Stage20	31072,074	10453,43967	307740,1693
Gasoline <1,4l	PC Euro 5 - EC 715/2007	99606,105	11345,54058	257486,8441
Gasoline <1,4l	PC Euro 6 - EC 715/2007	530021,80	14009,20014	125594,9533
Gasoline 1,4 - 2,0l	PRE ECE	0	1245,152708	0
Gasoline 1,4 - 2,0l	ECE 15/00-01	0	1245,152708	0
Gasoline 1,4 - 2,0l	ECE 15/02	0	1245,152708	0
Gasoline 1,4 - 2,0l	ECE 15/03	0	1245,152708	0

? OK Cancel

Hide Run Details

Country:	Denmark
Year:	2030
Beta:	Not Calculated
Apply Statistical Fuel Correction:	No
Mileage Degradation:	No
Mileage Degrad. Factors:	Not Calculated
Fuel Effect Year:	1996
Fuel Effect Factors:	Not Calculated
Hot Emission Factors:	Not Calculated
Cold Emission Factors:	Not Calculated
Evaporation Factors:	Not Calculated
Hot Emissions:	Not Calculated
Cold Emissions:	Not Calculated
Evaporation Emissions:	Not Calculated
Advanced	
Load / Slope Effect:	No



Benefits: Data handling

One file, all years

Single button import/export Excel

Select / Add Country and Year

Select Country and Year

Country	Year
Greece	2005
France	2006
	2007
	2008
	2009
	2010
	2011
	2012

or add a new Country, or a new Year

Country:

Year:

Ltrip (km):

t_trip (h):

Export Data (Excel File)

Years as columns

☒ 2007
☒ 2008
☒ 2009
☒ 2010
☒ 2011
☒ 2012

Sheets to be created

Input Data


☒ Population
☒ Mileage-km per year
☒ Mean Fleet Mileage-km
☒ U Speed-km per h
☒ R Speed-km per h
☒ H Speed-km per h
☒ U Share-perc
☒ R Share-perc
☒ H Share-perc

☒ Fuel Tank Size-It
☒ Canister Size
☒ Fuel Injection-perc
☒ Evap Control-perc
☒ Evap U Share-perc
☒ Evap R Share-perc
☒ Evap H Share-perc
☒ Temperatures
☒ RVP and beta

Select	Sector	Subsector	Technology	2007
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PRE ECE	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	ECE 15/02	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	ECE 15/03	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	ECE 15/04	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	Improved Conventional	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	Open Loop	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PC Euro 1 - 91/441/EEC	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC St	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC St	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PC Euro 5 - EC 715/200	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline <1,4 l	PC Euro 6 - EC 715/200	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	<input checked="" type="checkbox"/>
<input type="checkbox"/>	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	<input checked="" type="checkbox"/>

☐ Show all vehicle categories, independent of the selected years-columns

Changes in methodology / EFs, recalculated with single button click

 Calculate All Emissions for all years (including all factors)



Benefits: Direct export CRF (XML)

Select / Add Country and Year

Select Country and Year

Country	Year
Greece	2005
France	2006
	2007
	2008
	2009
	2010
	2011
	2012

or add a new Country, or a new Year

Country:

Year:

Ltrip (km):

t_trip (h):

Export CRF (XML File)

Select Years to be exported:

<input checked="" type="checkbox"/> 2007
<input checked="" type="checkbox"/> 2008
<input checked="" type="checkbox"/> 2009
<input checked="" type="checkbox"/> 2010
<input checked="" type="checkbox"/> 2011
<input checked="" type="checkbox"/> 2012

Important Info

IPCC requires that reporting is based on the Statistical Fuel Consumption.

If some years appear in the table below this means that calculations for the particular years were based on the calculated Fuel Consumption.

Please check any of the years that you would like to apply Statistical Fuel Correction and the recalculations of the Emissions will be done automatically before exporting.

Year	Convert Calculated to Statistical
2008	<input type="checkbox"/>
2009	<input type="checkbox"/>
2010	<input type="checkbox"/>
2011	<input type="checkbox"/>
2012	<input type="checkbox"/>



Benefits: Software summary

- Pollutants and GHGs within the same calculation set: consistency between UNFCCC and CLRTAP
- Time series held in single file: recalculations made easy (single button)
- Backward compatibility: minimum effort when methods/EFs have to change
- Direct export to CRF (XML)
- Direct import/export to MS Excel for pre and post analysis (if needed)



Benefits: Use of the model

- Model provides the recipe, user has to add the ingredients
- It can assist developing a reasonable 'basic' inventory
 - using default/generic parameters
 - using equivalencies from similar countries
 - It can improve in time
- Mitigation can be estimated, emission factors span from 1970 to 2020
- Models have an educative nature, i.e. users 'learn by doing'



QA/QC: IPCC Criteria - 1(2)

- Transparency

- Methodology and emission factors reviewed and approved by TFEIP, before inclusion in COPERT/AEIG
- Documented in EMEP/EEA AEIG
- Calculations checked by thousand of users

- Completeness

- Major sources covered (>99.7%)
- Urea derived CO₂ will be introduced in 2011
- CO₂ from lube oils possibly important for developing countries (old engines, poor maintenance, high 2S proportion). Tier 3 method based on VKT, vehicle type, vehicle age may be introduced.



QA/QC: IPCC Criteria - 2

- Consistency

- Emission factors reflecting 50-years technology evolution (1970-2020)
- The same method can be used for all years (recalculations for all years with single button click)

- Comparability

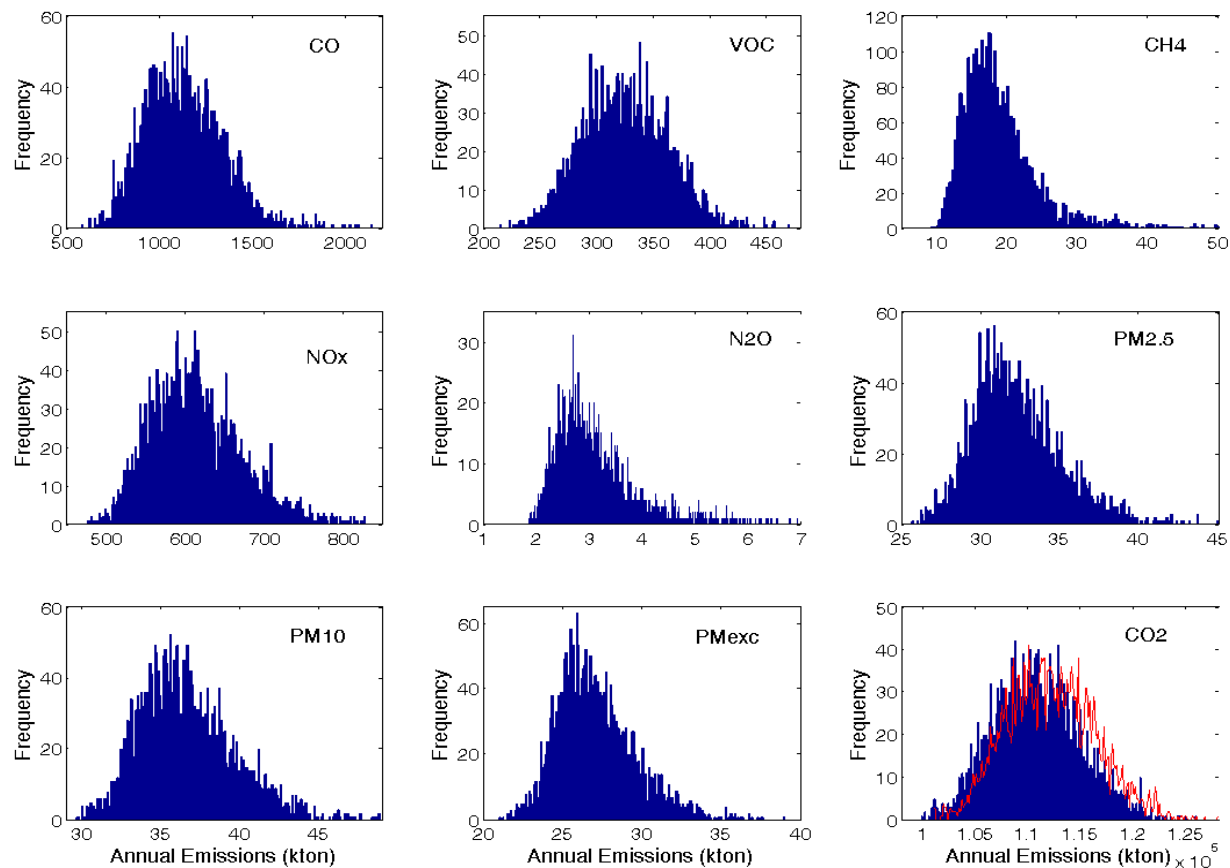
- Inventory structured the same way for all countries. Data cross-check is straightforward

- Accuracy

- Use of a well recognized method, validated in the peer-reviewed literature (~250 *Scopus* citations)
- Check of bottom-up fuel consumption (Tier 3) against statistical one (Tier 1)



QA/QC: Uncertainty Estimates



Note:

- Results refer to Italy 2005. Corrected for uncertainty in statistical fuel consumption



QA/QC: Descriptive Statistics

	CO	VOC	CH ₄	NO _x	N ₂ O	PM _{2.5}	PM ₁₀	PM _{exh}	FC	CO ₂	CO _{2e}
Mean	1,134	325	19	614	3.1	32	37	27	36,945	110,735	112,094
Median	1,118	324	18	608	2.9	32	36	27	36,901	110,622	111,941
St. Dev.	218	38	7	59	0.8	3	3	3	1,241	4,079	4,203
COV (%)	19	12	34	10	26	9	8	9	3	4	4

Note:

- COPERT *Monte-Carlo* Version available to estimate uncertainty ranges in any country



QA/QC: Sensitivity Analysis

CO	S _I	S _{TI}	N ₂ O	S _I	S _{TI}	CH ₄	S _I	S _{TI}	CO ₂	S _I	S _{TI}	FC	S _I	S _{TI}
eEF	0.44	0.56	eEFratio	0.59	0.76	eEFratio	0.61	0.76	eEF	0.40	0.51	eEF	0.43	0.54
eEFratio	0.19	0.29	ltrip	0.06	0.37	eEF	0.13	0.29	eEFratio	0.10	0.22	eEFratio	0.11	0.24
ltrip	0.05	0.21	VUPC	0.06	0.23	ltrip	0.03	0.26	milHDV	0.09	0.2	milHDV	0.09	0.21
O2C	0.03	0.16	eEF	0.04	0.16	VUPC	0.01	0.19	milPC	0.05	0.17	milPC	0.05	0.17
VUPC	0.03	0.17	milHDV	0.01	0.14	HDV	0	0.16	ltrip	0.04	0.21	ltrip	0.04	0.21
milMO	0.01	0.13	milPC	0.01	0.13	milMO	0	0.13	O2C	0.04	0.16	HDV	0.02	0.13
HDV	0.01	0.15	HDV	0	0.13	LDV	0	0.16	HDV	0.02	0.13	VUPC	0.01	0.11
LDV	0	0.12	MOP	0	0.18	MOP	0	0.18	VUPC	0.01	0.11	PC	0.01	0.12
VHPC	0	0.15	LDV	0	0.13	VHPC	0	0.21	PC	0.01	0.12	LDV	0.01	0.13
VRPC	0	0.17	milLDV	0	0.11	milHDV	0	0.16	LDV	0.01	0.12	UPC	0.01	0.14
MOP	0	0.17	milMO	0	0.11	VRPC	0	0.2	UPC	0.01	0.14	MOP	0.00	0.12
UPC	0	0.15	VRPC	0.00	0.18	UPC	0	0.16	MOP	0.00	0.12	milLDV	0.00	0.12
PC	0	0.14	UPC	0	0.13	PC	0	0.2	milLDV	0	0.12	VHPC	0	0.12
milHDV	0	0.12	VHPC	0	0.25	milLDV	0	0.13	VHPC	0	0.11	O2C	0	0.12
milPC	0	0.15	O2C	0	0.24	milPC	0	0.16	milMO	0	0.14	milMO	0	0.14
milLDV	0	0.1	PC	0	0.17	O2C	0	0.21	VRPC	0	0.12	VRPC	0	0.12
ΣS_I	0.79	2.94		0.79	3.44		0.80	3.58		0.78	2.68		0.79	2.72



Documentation

- Methodology:
 - Tier 3 method of the EMEP/EEA AEIG:
<http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009>
- QA/QC:
 - Uncertainty estimates: <http://transportpanel.jrc.ec.europa.eu/projects.html>
- Emission Factors
 - PCs: ARTEMIS Del.3 Emission factor modelling and database
 - HDVs: COST346 http://www.transport-research.info/Upload/Documents/200906/20090619_171904_26922_II_CO-ST346_WGA_FinalReport.pdf
 - PTWs: Artemis WP500 final report, available from LAT/AUTh
 - Biodiesel & Bioethanol: http://air-climate.eionet.europa.eu/reports/ETCACC_TP_2008_5_biofuels_emissions



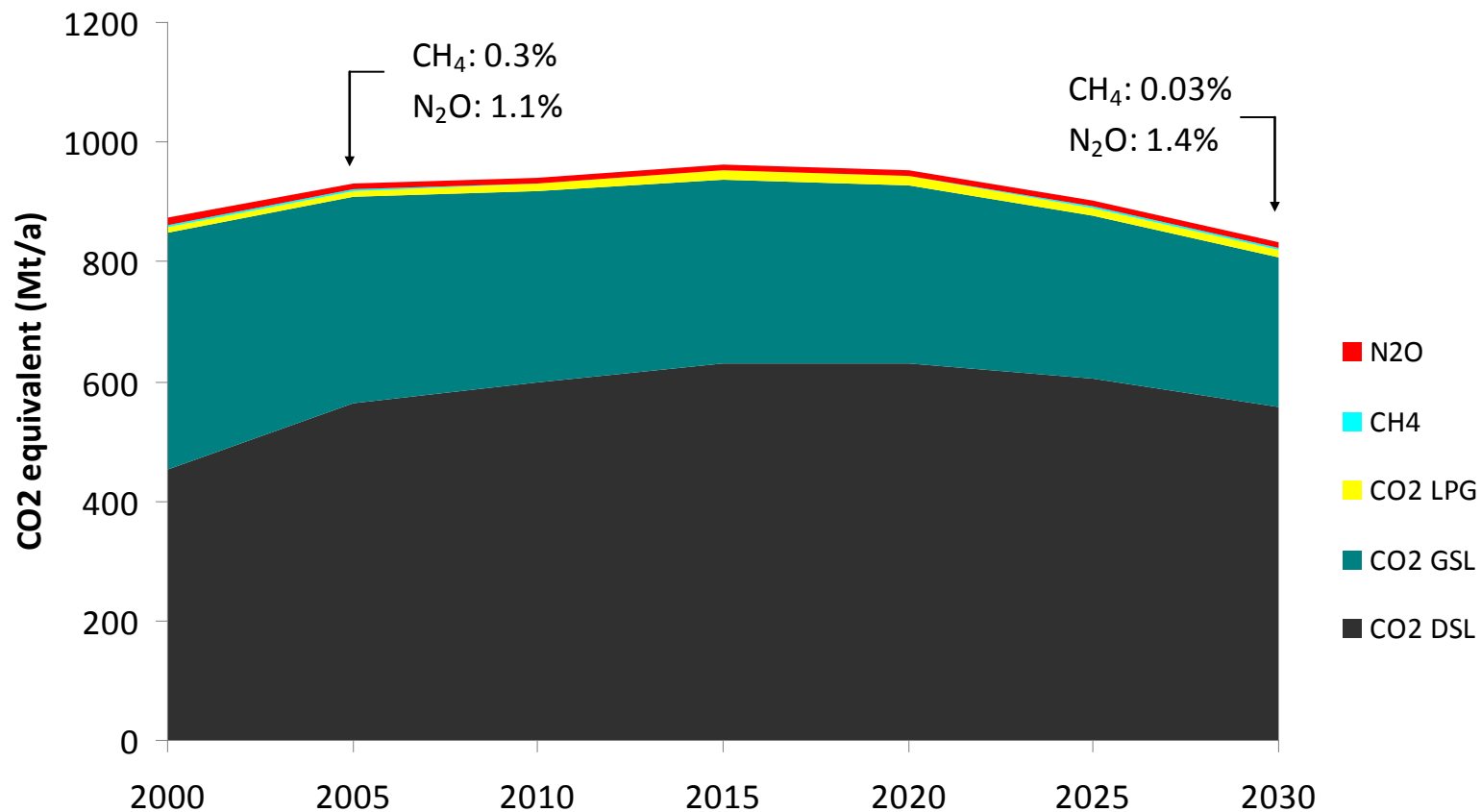
Other Issues: Recalculations

- EU Climate Change Committee (2008):
 - recommended use of COPERT 4 instead of COPERT 3
 - technology specific emission factors in C4 (reduced over C3)
 - ERT in their latest review of EU inventory (2009):

“The ERT also recommends that the European Community provide some discussion in the NIR on the MS methodologies (COPERT III/IV model or other models) and facilitate the harmonization of MS methodologies without compromising the accuracy of MS inventories”
- Use of C4 may decrease total GHG for inventories compiled with C3



Outlook: EU27 Road GHGs



Note:

- Projection based on LIFE EC4MACS Baseline scenario



Outlook: COPERT Updates

- CNG/LNG cars
(only busses currently available)
- Bio-(EtOH, MTBE)
- Lube-oil consumption estimation
(based on VKT, vehicle age)
- Urea CO₂



Outlook: IPCC GLs

- Development of tiers for urea CO₂
- Improve guidance for CO₂ emission factors (biofuels, oxygen content, etc.)
- Guidance and/or reconciliation AQ needs/ fuel sold requirements
- Guidance on new technologies (hybrids, plug-in hybrids, electric + range extender, ...)
- Impact of model / methodology updates on recalculations (how to predict, account for?)
- *PM black carbon effects?* – not a gas...



Acknowledgments

- Martin Adams and Ricardo Fernandez (EEA) for delivering useful input and reviewing this presentation
- EEA/ETC for providing financial support for this trip



More Info: Literature

- About 250 journal papers (SCOPUS) refer to COPERT
- Key articles on validation:
 - Smit et al. (2010) Atmos Environ 44, 2943-2953
 - Beddows & Harrison (2008) Atmos Environ 42 7954-7966
 - Murena et al. (2007) Atmos Environ 41, 2620-2629
 - Mellios et al. (2006) Atmos Environ 40, 7362-7377
 - Winther (1998) Sci Tot Environ 224 149-160



More Info: Tier 3 Activity Data

- FLEETS Data
 - Basis for EU27 + (CH, HR, NO, TR)
 - Available at <http://lat.eng.auth.gr/copert>
- VKT split
 - Vehicle category/technology
 - Urban, rural, highway driving
 - Mean speed per driving mode
- Age functions
 - Mileage as a function of vehicle age

