Use of COPERT 4 for the compilation & sub-mission of road transport GHG inventories

Leonidas Ntziachristos

ETC/ACC

IPCC Expert Meeting on Use of Models and Measurements in GHG Inventories
Sydney, Australia, 9-11 August 2010

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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 **CO**mputer **P**rogramme to calculate **E**missions from **R**oad **T**ransport
- COPERT **4** since 2006 (4^{th} 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 CH_4 and N_2O

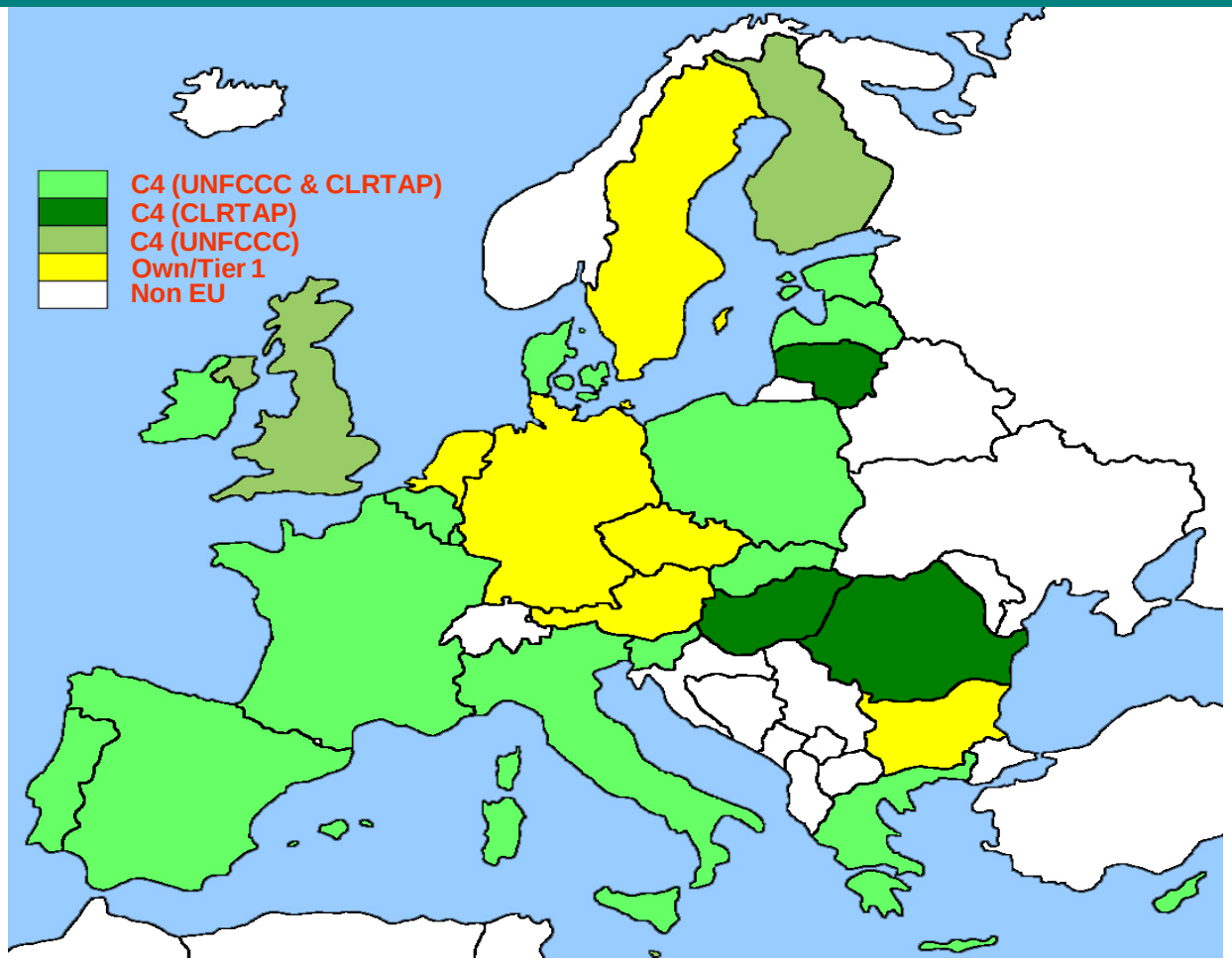
Background: COPERT Admin

- 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_2O	Urea
Tier 1	$FC \times EF_{Default}$	$FC_f \times EF_f$	Urea Consumption × 'Purity'
Tier 2	$FC \times EF_{Count.Spec.}$	$FC_{veh.cat} \times EF_{veh.cat}$	NA
Tier 3	NA	$VKT_{veh.cat} \times EF_{veh.cat}$ + Cold	NA

Legend:

NA Not Available

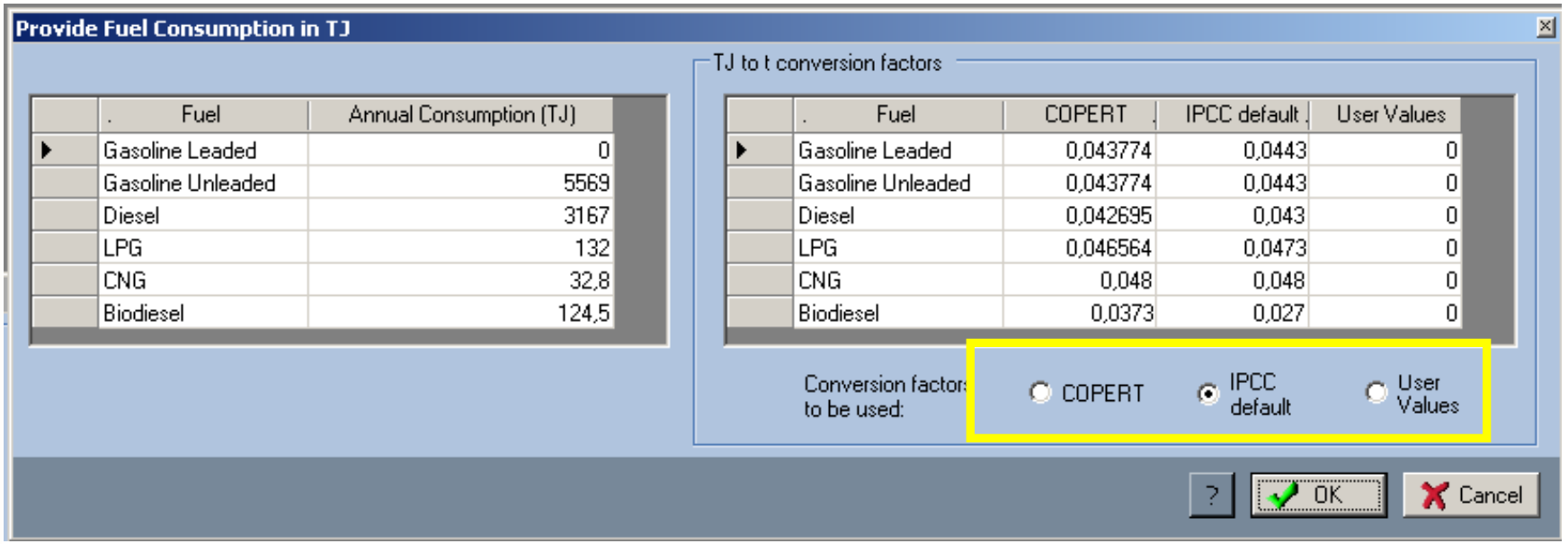
IPCC Method Coverage by COPERT 4

Methodology: CO_2 Calculation

$$E_{CO_2}^{CALC} = 44.011 \times \frac{FC^{CALC}}{12.011 + 1.008R_{H:C} + 16.000R_{O:C}}$$

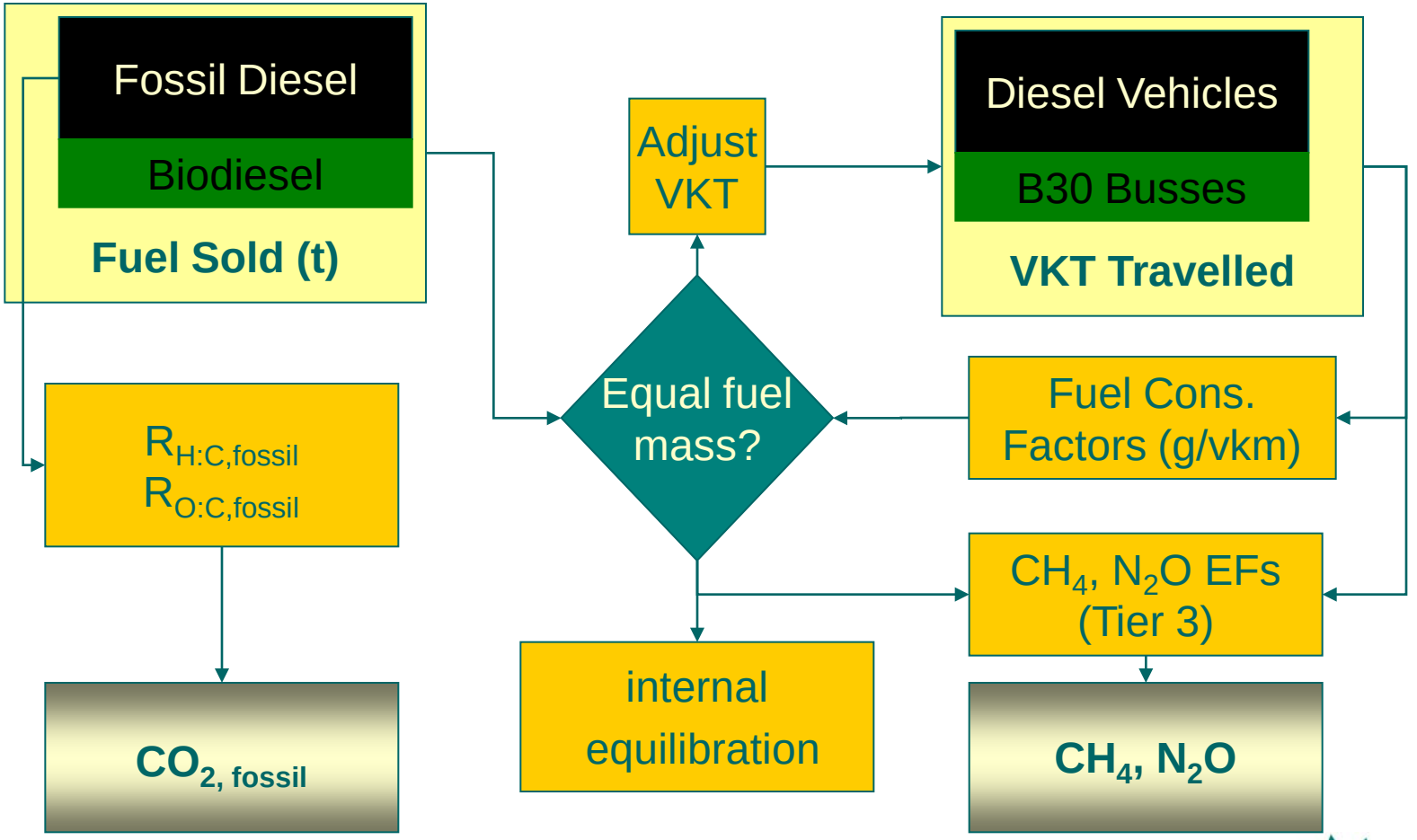
- Calculation of *ultimate* CO_2 , i.e. all carbon in fuel oxidized to CO_2
- Operates on the basis of g/km emission factors for consistency with other pollutants
- $R_{H:C}$, $R_{O:C}$ are the ratios of H to C and O to C atoms, respectively in the average fuel molecule

Methodology: Energy Statistics



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

Methodology: Algorithm



Emission Factors: CO_2

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_2H_5OH	3.00	0.5	1.91	28.9	**66191**			
NG	0.95 CH_4+0.05 C_2H_6	3.90	0	2.76	49.9	**55326**	**56100**	54300	58300
	0.85 CH_4+0.15 C_2H_6	3.74	0	2.79	49.7	**56140**			
LPG_A	0.50 C_3H_8+0.50 C_4H_{10}	2.57	0	3.01	46.1	**65447**	**63100**	61600	65600
LPG_B	0.85 C_3H_8+0.15 C_4H_{10}	2.63	0	3.00	46.3	**64879**			

Emission Factors: CH_4

- 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 CO_2 equivalent too weak to justify new measurements.

Emission Factors: N_2O

- $EF_{N2O} = (a \times Cum.Mileage + b) \times EF_{BASE}$
  - 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

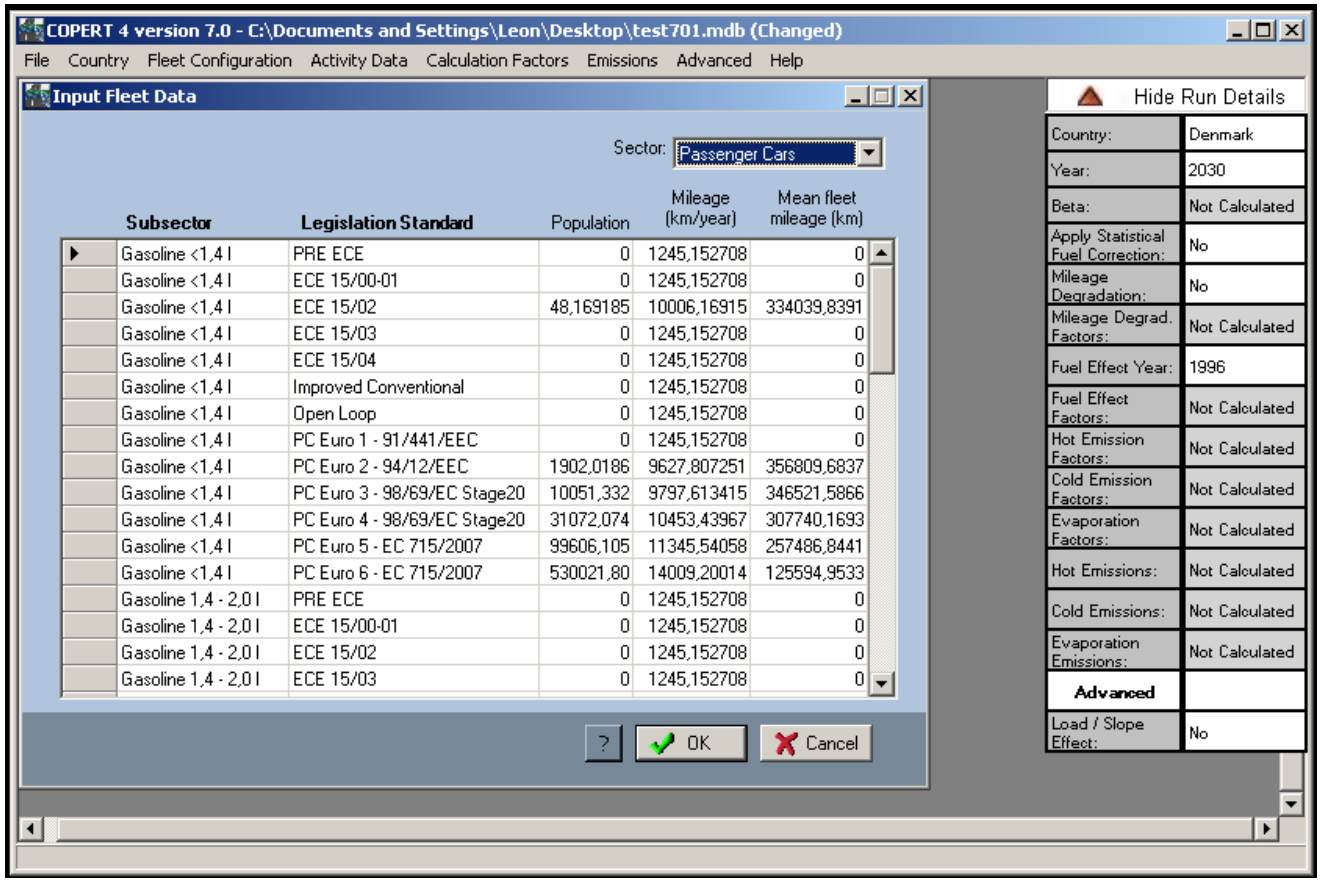
Emission Factors: SCR Urea

		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:

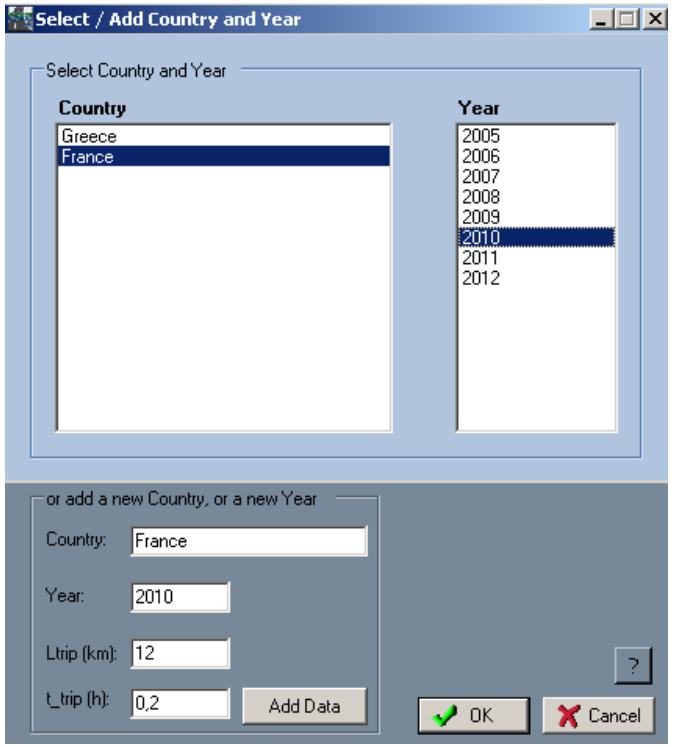
- All diesel vehicles assumed Euro 6/VI in 2020, require SCR agent ~ 6% of FC
- CO_2 and consumption taken from PRIMES 2009 baseline

Benefits: GUI

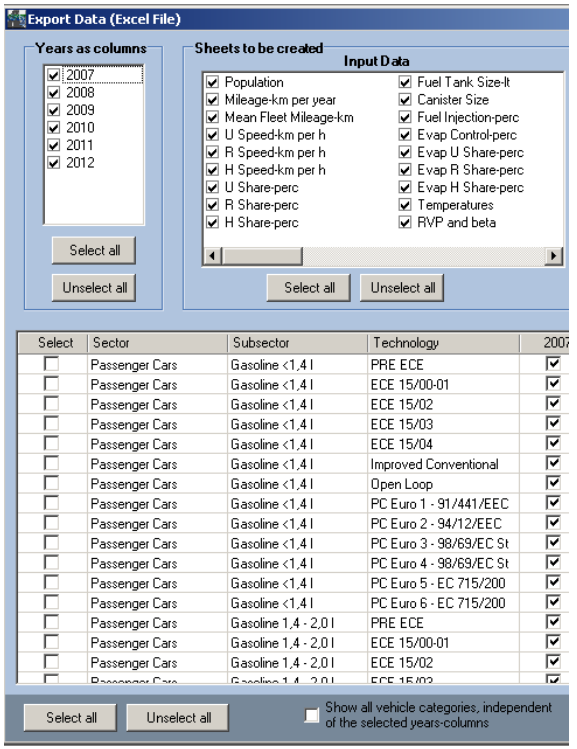


Benefits: Data handling

One file, all years

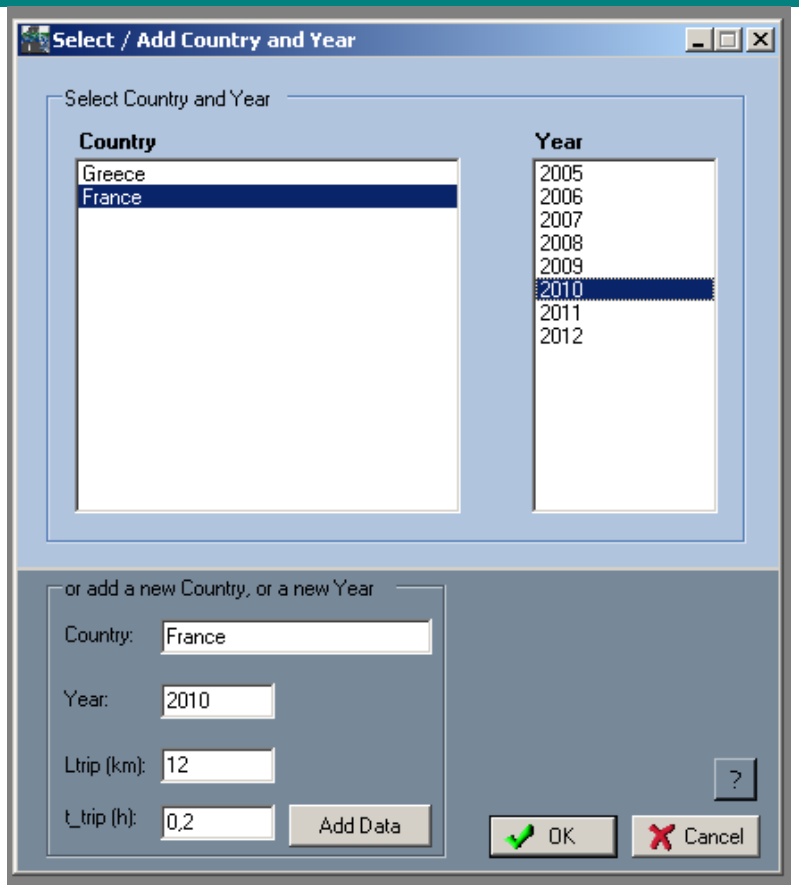


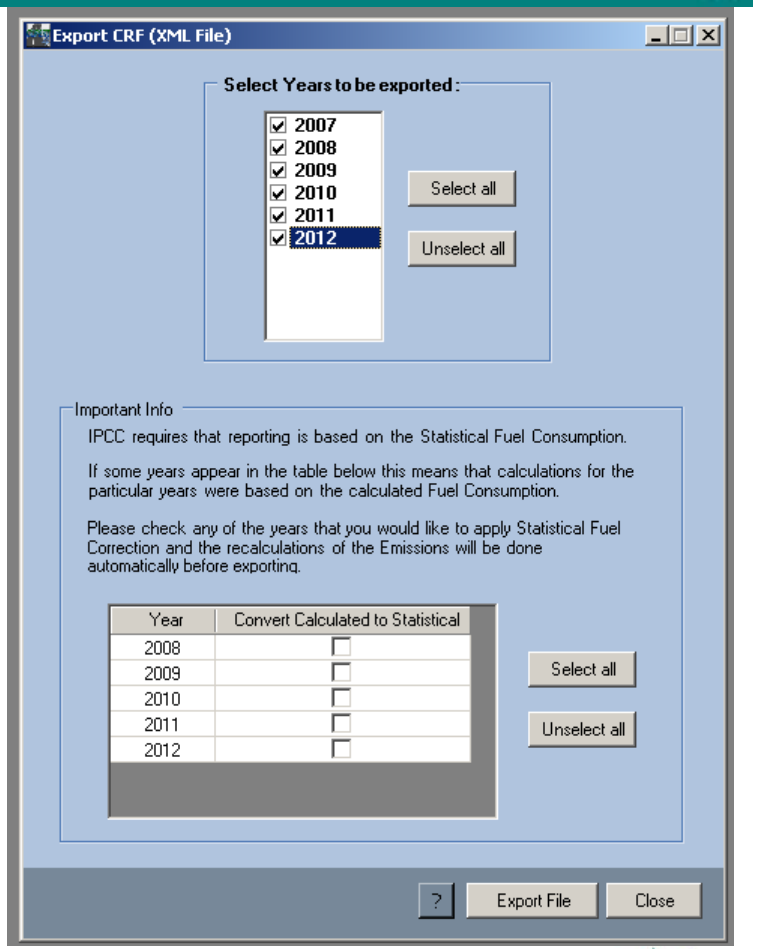
Single button import/export Excel



Changes in methodology / EFs, recalculated with single button click

Benefits: Direct export CRF (XML)





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’

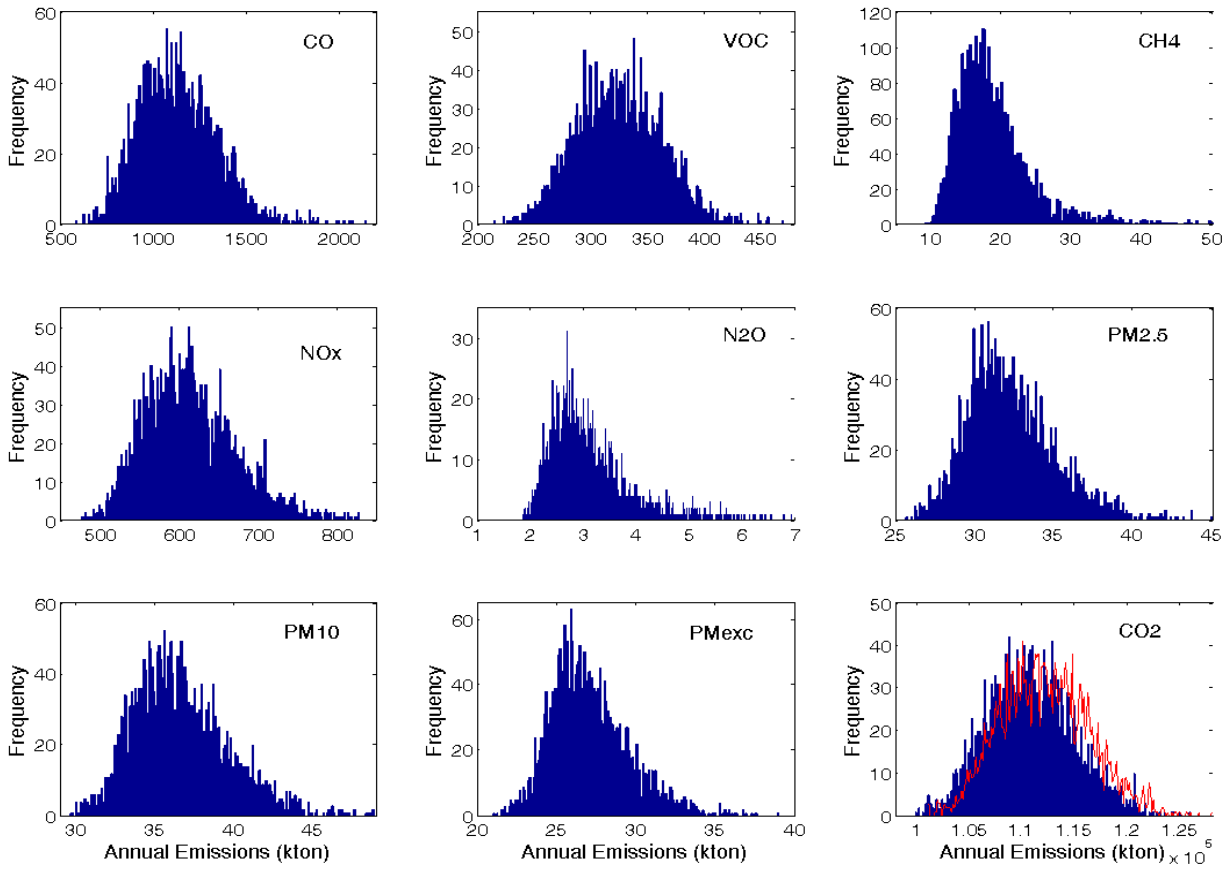
QA/QC: IPCC Criteria - 1(2)

- 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 CO_2 will be introduced in 2011
  - CO_2 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_2O	$PM_{2.5}$	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_2O	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_COST346_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

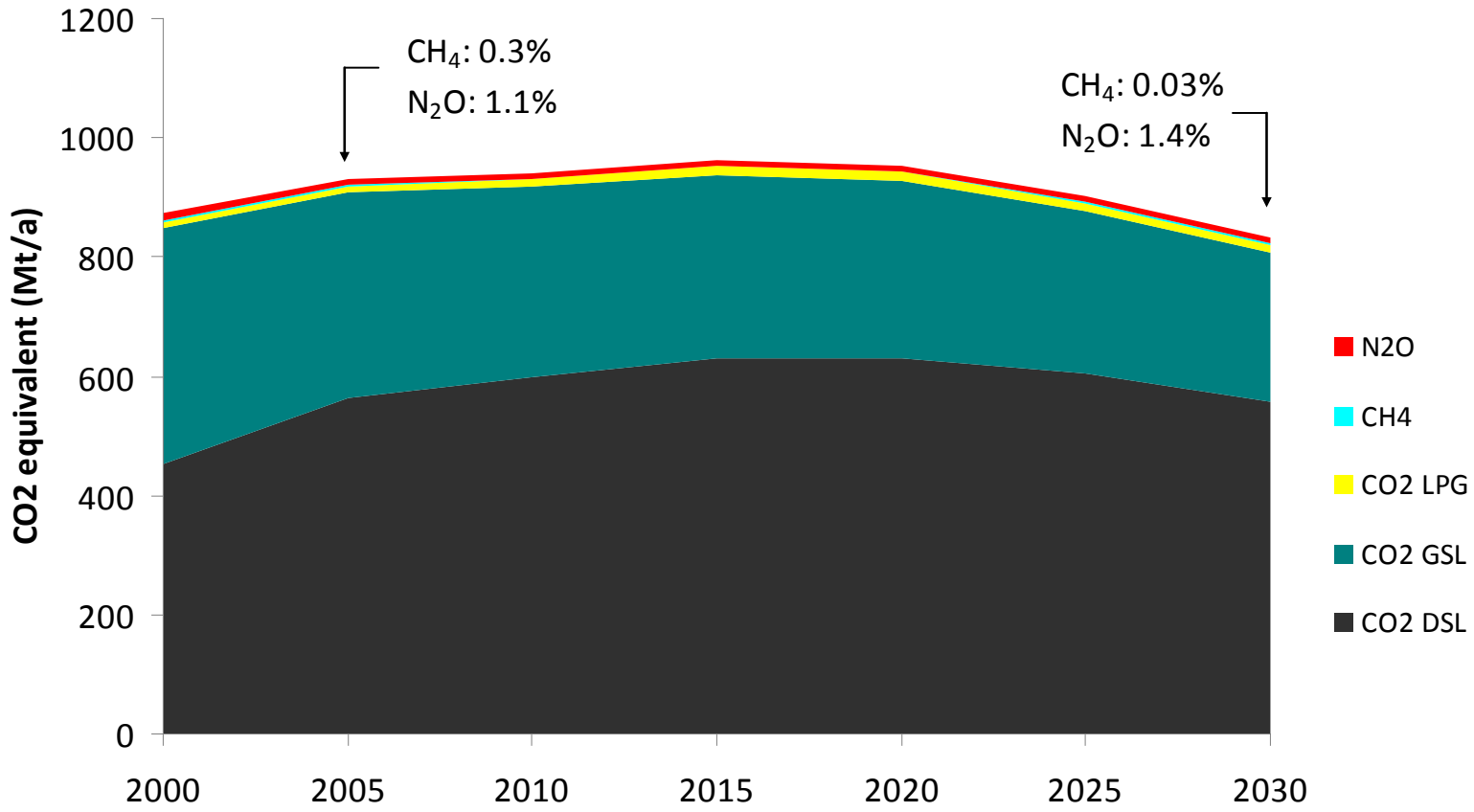
Other Issues: Recalculations

- 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 CO_2

Outlook: IPCC GLs

- Development of tiers for urea CO_2
- Improve guidance for CO_2 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