



LABORATORY OF APPLIED THERMODYNAMICS

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# **Key uncertainty factors in projecting road transport emissions**



IIASA, Laxenburg, 2011-3-21

# Contents

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- TREMOVE projections
- Model versions
- Outlook



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# TREMOVE projections



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# Uncertainty of TREMOVE (v.3.3.1) baseline

Output Variable	Units	Median <sup>2010</sup>	Median <sup>2020</sup>	Median <sup>2030</sup>	cov <sup>2010</sup>	cov <sup>2020</sup>	cov <sup>2030</sup>
CO	Ton	252,000	119,402	119,439	69%	51%	51%
PM	Ton	10,750	3,400	3,421	25%	27%	27%
VOC	Ton	46,927	30,279	31,559	37%	26%	24%
TAXrest	M€	-8,454	-8,768	-9,365	21%	22%	22%
NOx	Ton	331,319	170,500	158,458	19%	17%	17%
COSTinsurance	M€	24,922	38,291	44,671	6%	13%	14%
TAXinsurance	M€	1,260	1,934	2,255	6%	13%	14%
VATfuel	M€	8,041	9,418	11,412	13%	13%	13%
TAXfuel	M€	33,301	41,490	48,064	12%	12%	12%
COSTfuel	M€	30,727	32,106	40,202	11%	11%	12%
TAXownership	M€	6,166	10,810	12,070	8%	11%	12%
FC	Ton	46,618,917	55,591,702	60,043,602	11%	11%	11%
COSTrepair	M€	59,798	73,706	86,483	3%	10%	10%
VATrepair	M€	7,293	9,090	10,691	3%	10%	10%
COSTlabour	M€	10,869	14,896	16,607	9%	9%	9%
COSTlabourtax	M€	11,634	15,944	17,773	9%	9%	9%
VATpurchase	M€	10,841	11,566	13,107	5%	9%	9%
COSTpurchase	M€	84,178	99,323	114,467	4%	8%	9%
TAXregistration	M€	22.5	24.2	27.4	7%	8%	8%
VATrest	M€	1,252	1,293	1,377	5%	5%	5%
Costs	M€	323,333	396,036	458,228	2%	4%	4%
Vehicles	#	33,652,081	37,918,723	40,997,888	2%	3%	3%
Vehkms	×10 <sup>6</sup> km	585,653	665,914	720,553	2%	3%	3%
COSTrest	M€	41,193	44,395	47,695	2%	2%	2%

# Uncertainty of TREMOVE output (Scenario intro of Euro VI)

- ◆ New technology (EURO VI) introduced in 2013 for HDVs and Buses
- ◆ Additional purchase cost (Euro/veh)

Vehicle class	Min	Max
<7,5 t	2.855,0	3.553,0
7,5 - 16 t	3.287,0	4.084,0
16 - 32 t	4.185,0	5.198,0
>32 t	4.651,0	5.780,0
Diesel busses	4.185,0	5.198,0

- ◆ Additional maintenance cost (urea cost-Euro/km)

AdBlue cost	HTD1	HTD2	HTD3	HTD4	BUS
euro /litre	0,009	0,0075	0,00675	0,006	0,006

- ◆ Emission limits [g/km] (HC, NOx, PM)

Limit values	CO	HC	NOx	PM
Euro V	1,5	0,46	2	0,02
Euro VI	1,5	0,13	0,4	0,01
% Reduction	0	72	80	50

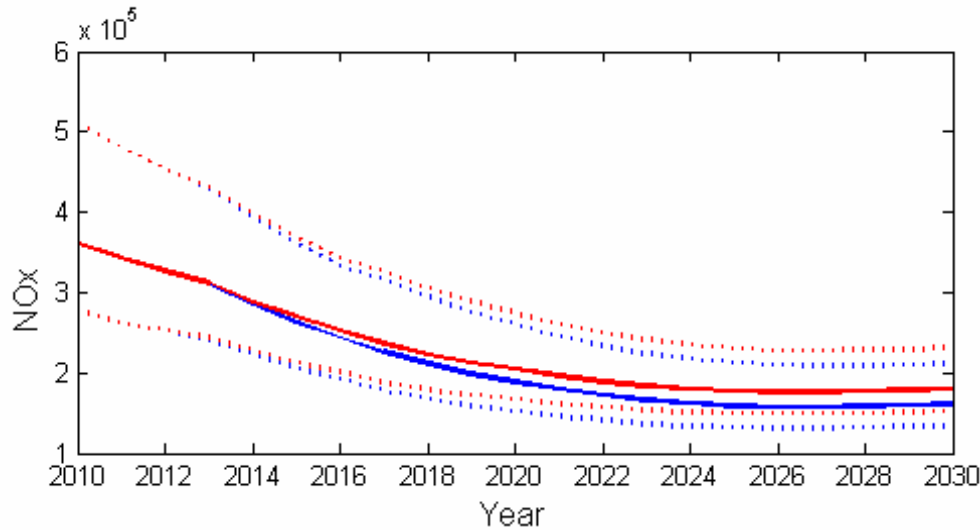
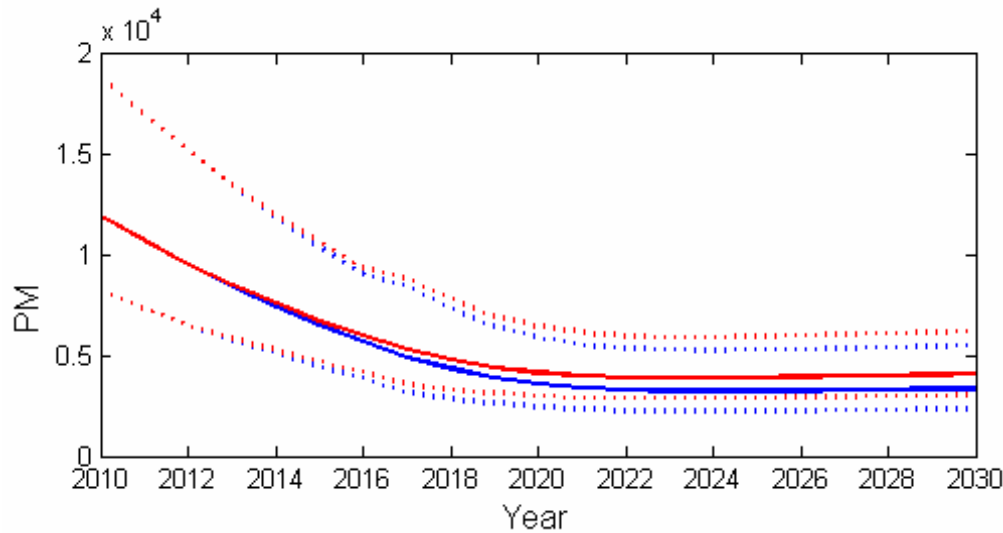
- ◆ Small increase in fuel consumption (0.5-2% relative to EURO V)

# Uncertainty of TREMOVE output (Scenario intro of Euro VI)

COSTpurchase [M€]	2020	2030
Baseline	105,591	121,983
Scenario 3	105,722	122,287
% diff	0.1	0.2
COSTrepair [M€]	2020	2030
Baseline	77,360	90,137
Scenario 3	77,449	90,317
% diff	0.1	0.2
Costs [milEuro]	2020	2030
Baseline	375,041	434,465
Scenario 3	375,216	434,914
% diff	0.0	0.1
PM [Ton]	2020	2030
Baseline	4,128	4,068
Scenario 3	3,594	3,364
% diff	-12.9	-17.3
NOx [Ton]	2020	2030
Baseline	204,280	179,722
Scenario 3	189,119	160,714
% diff	-7.4	-10.6

VOC [Ton]	2020	2030
Baseline	29,874	31,501
Scenario 3	29,821	31,508
% diff	-0.2	0.0
Fuel cons. [Ton]	2020	2030
Baseline	52,179	56,217
Scenario 3	52,221	56,229
% diff	0.1	0.0
Vehicles [#]	2020	2030
Baseline	37,434,661	40,543,655
Scenario 3	37,433,657	40,541,438
% diff	0.0	0.0
Vehicle km [×10 <sup>6</sup> km]	2020	2030
Baseline	657,732.0	712,663
Scenario 3	657,673.0	712,541
% diff	0.0	0.0

# Uncertainty of TREMOVE output (Scenario intro of Euro VI)



Red: baseline  
Blue: scenario





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# Model Versions



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# Projected emission factors

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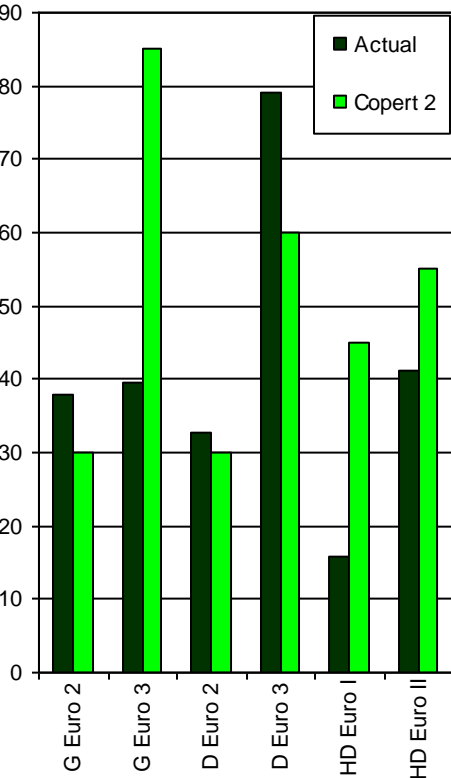
- Emission reductions for future vehicle technologies generally follow the rule:

$$\frac{EF_{\text{Future}}}{EF_{\text{Current}}} = \frac{ES_{\text{Future}}}{ES_{\text{Current}}}$$

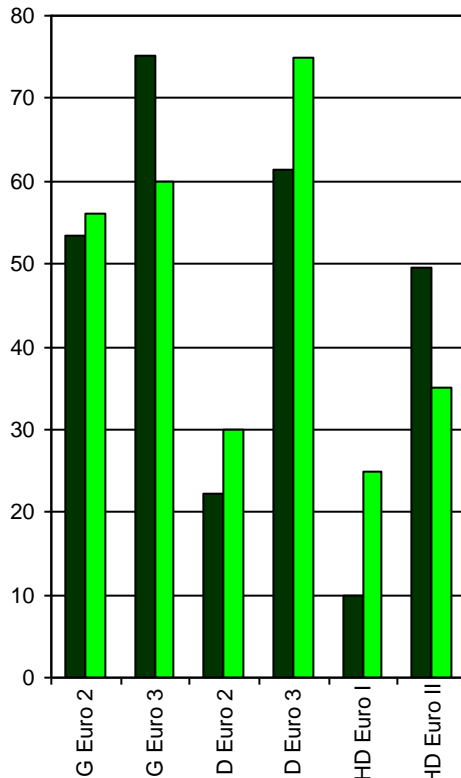
- Limitation:
  - ◆ Real-world behaviour does not (always) follow emission standards

# Learning from our past...

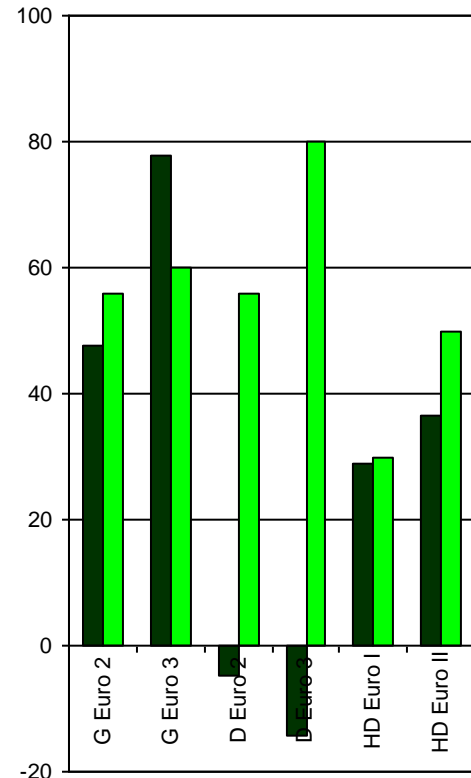
Removal efficiency (%) **CO**



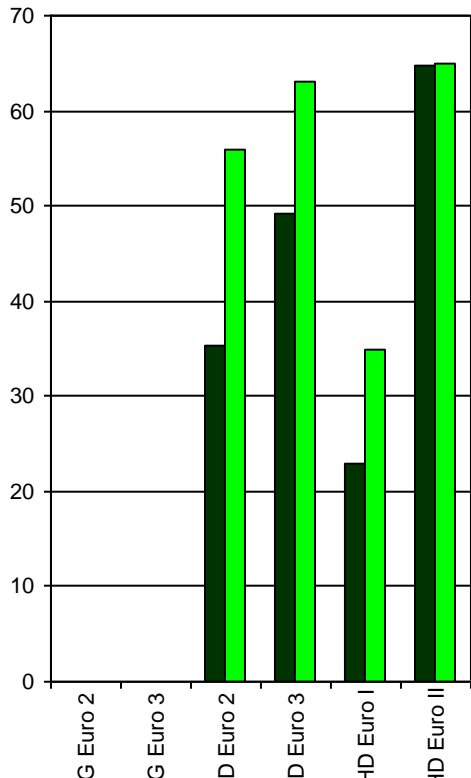
Removal efficiency (%) **HC**



Removal efficiency (%) **NOx**

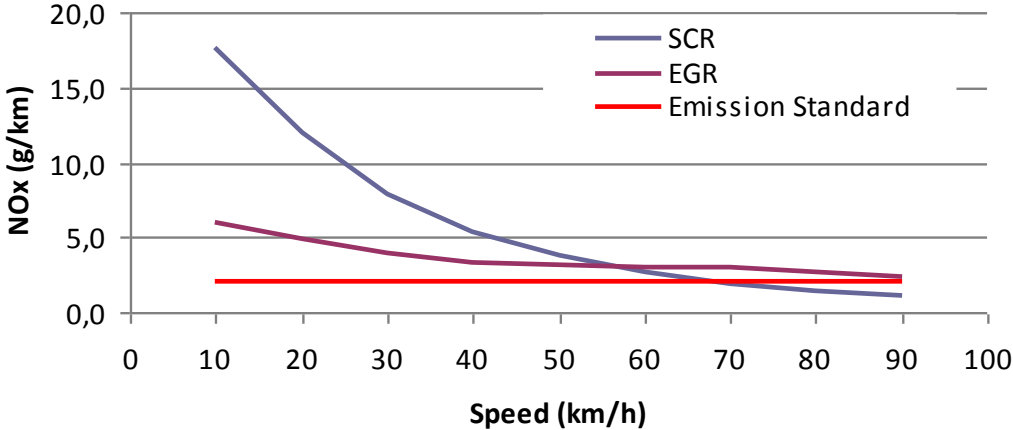


Removal efficiency (%) **PM**

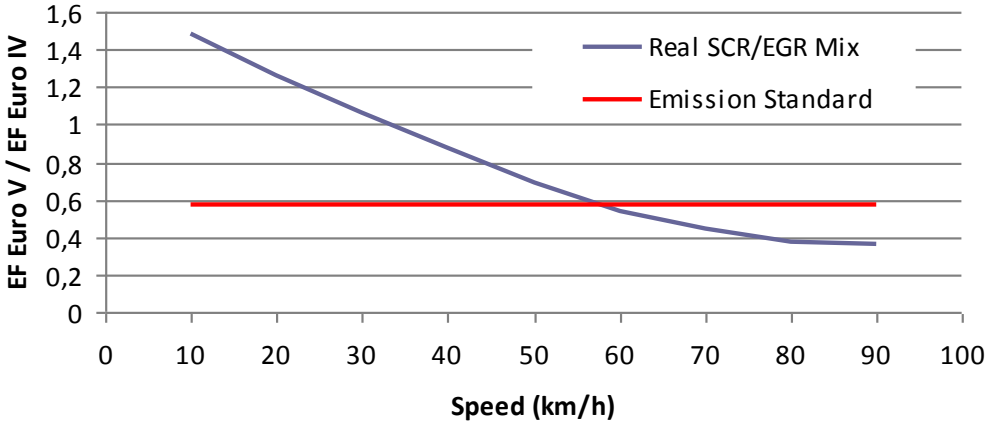


# Example: Euro V trucks NOx

## ➤ Emission Level



## ➤ EF over ES ratios (Euro V over Euro IV)

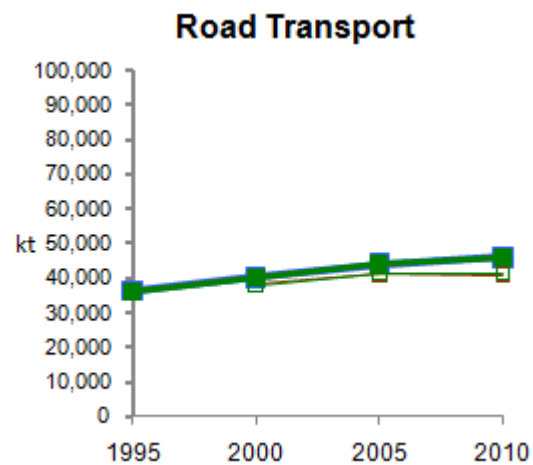
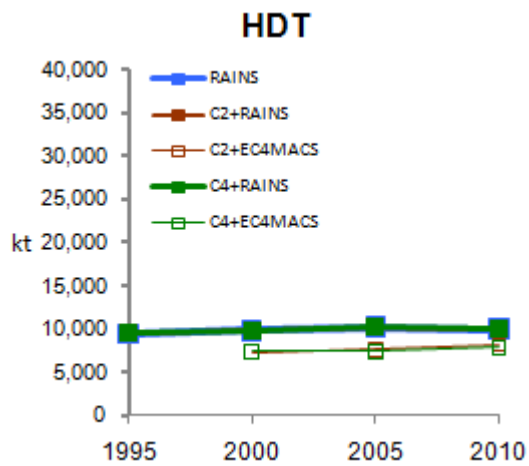
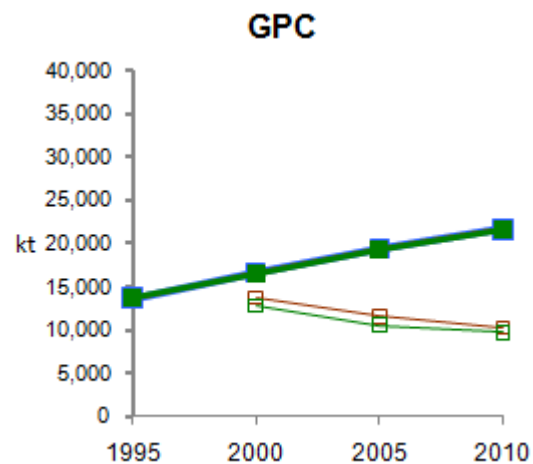
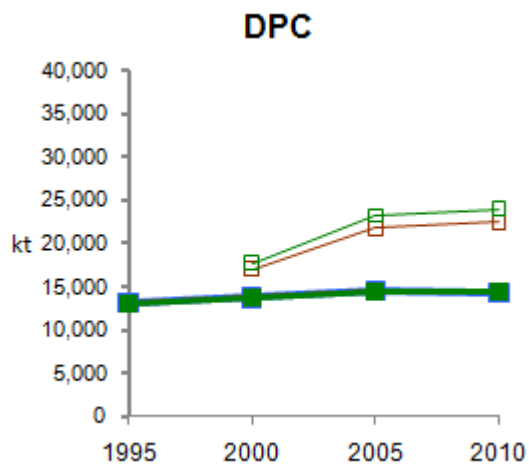


## Runs executed (Germany)

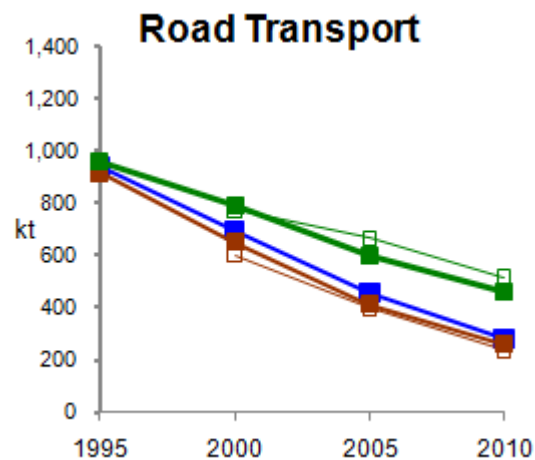
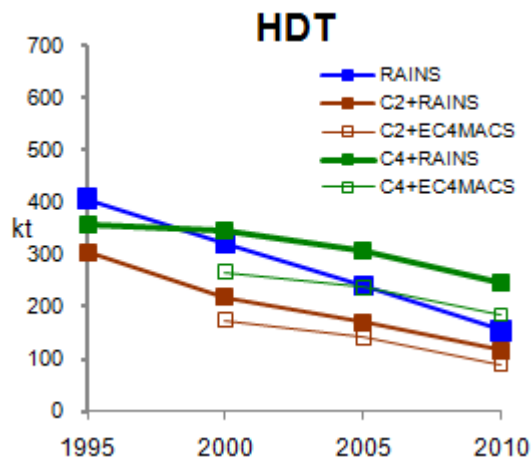
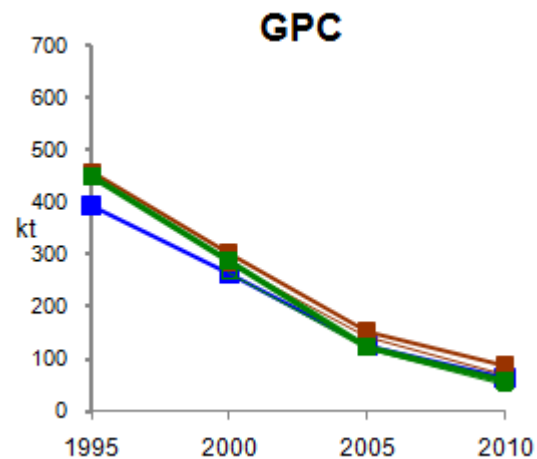
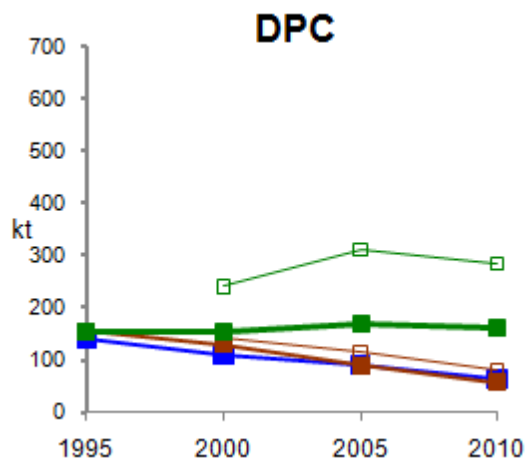
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- Run 1: Original RAINS calculation
- Run 2: COPERT 2 + RAINS Input
- Run 3: COPERT 2 + EC4MACS Input
- Run 4: COPERT 4 + RAINS Input
- Run 5: COPERT 4 + EC4MACS Input

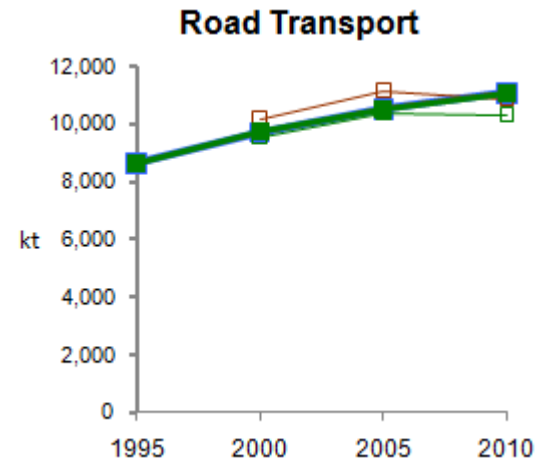
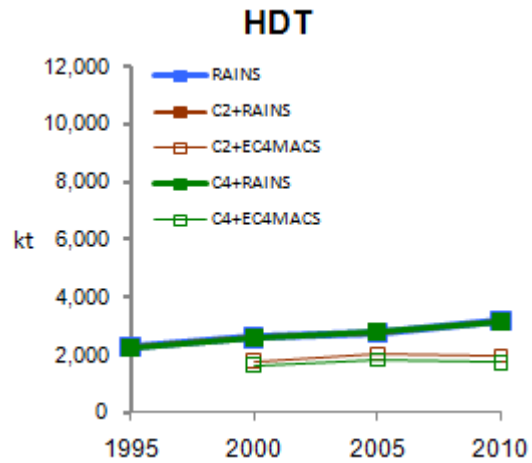
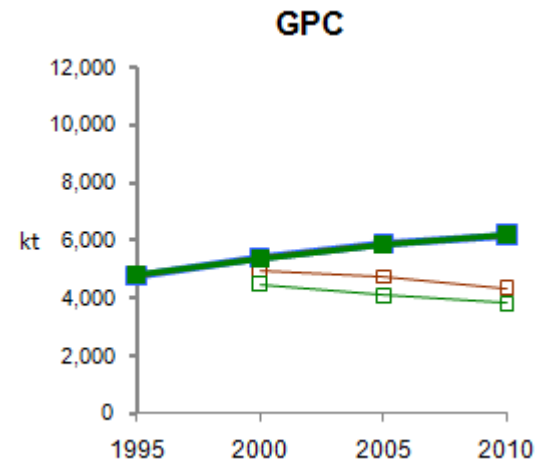
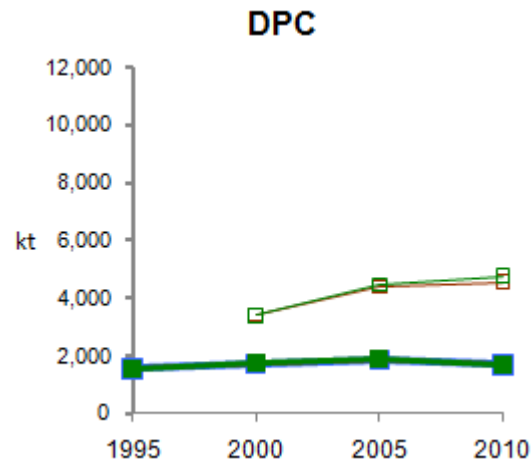
# Fuel consumption - France



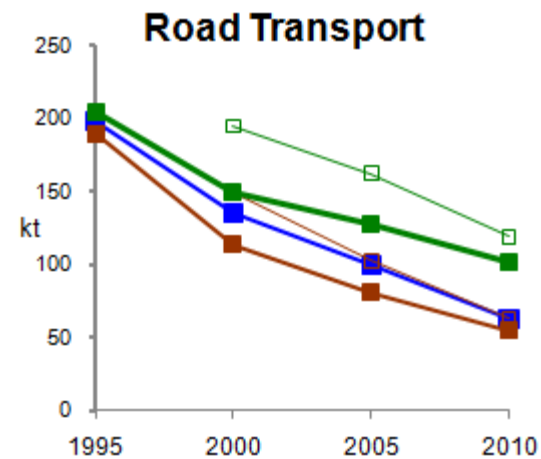
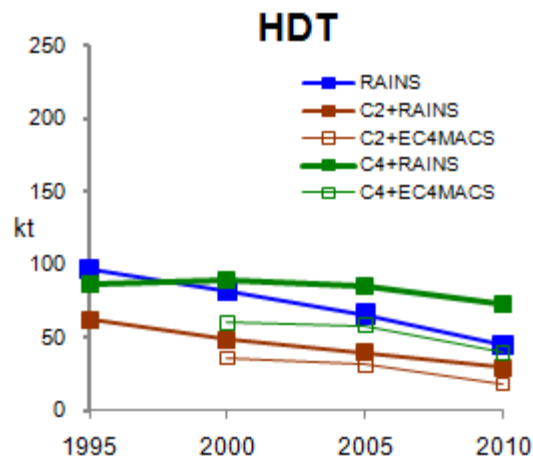
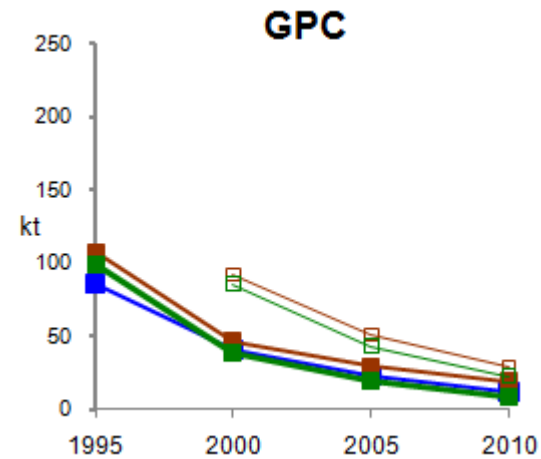
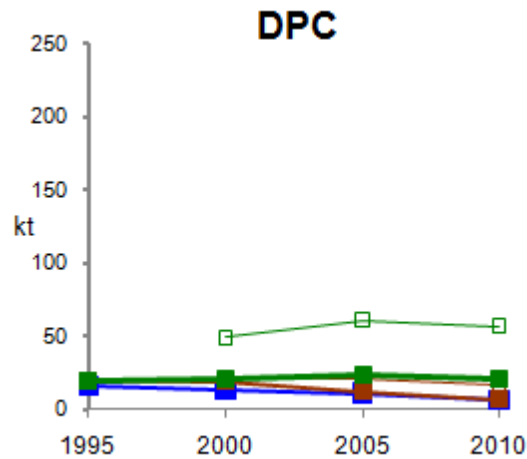
# NO<sub>x</sub> Emissions - France



# Fuel consumption - Netherlands

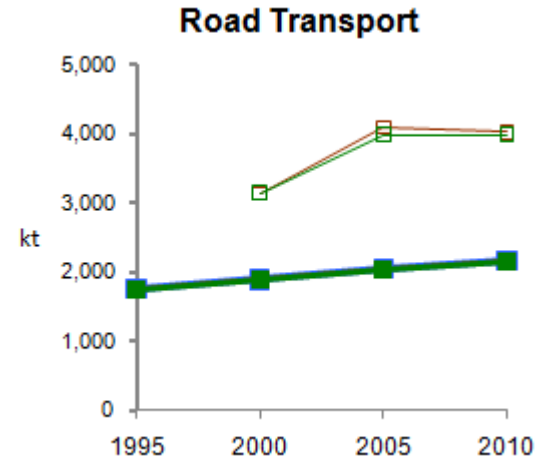
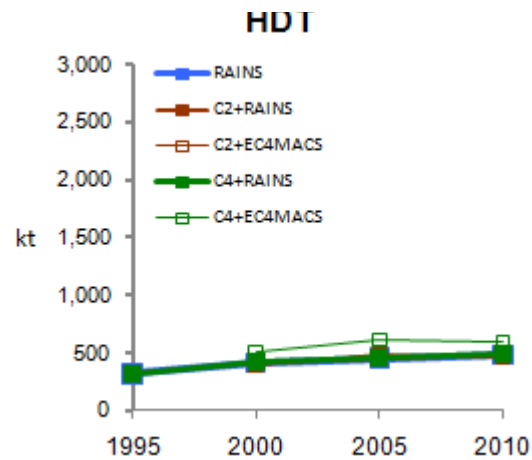
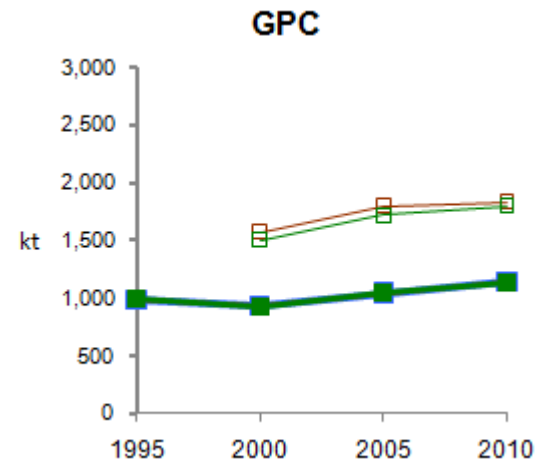
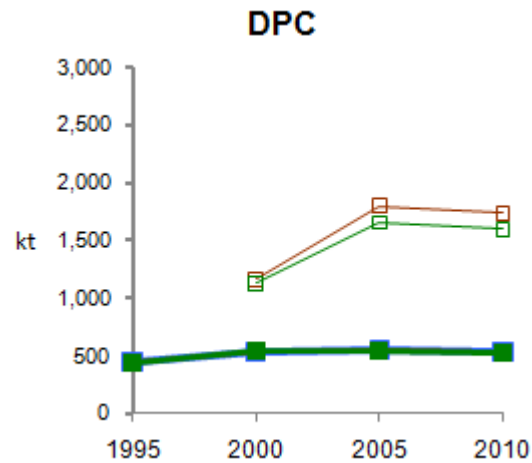


# NOx Emissions - Netherlands

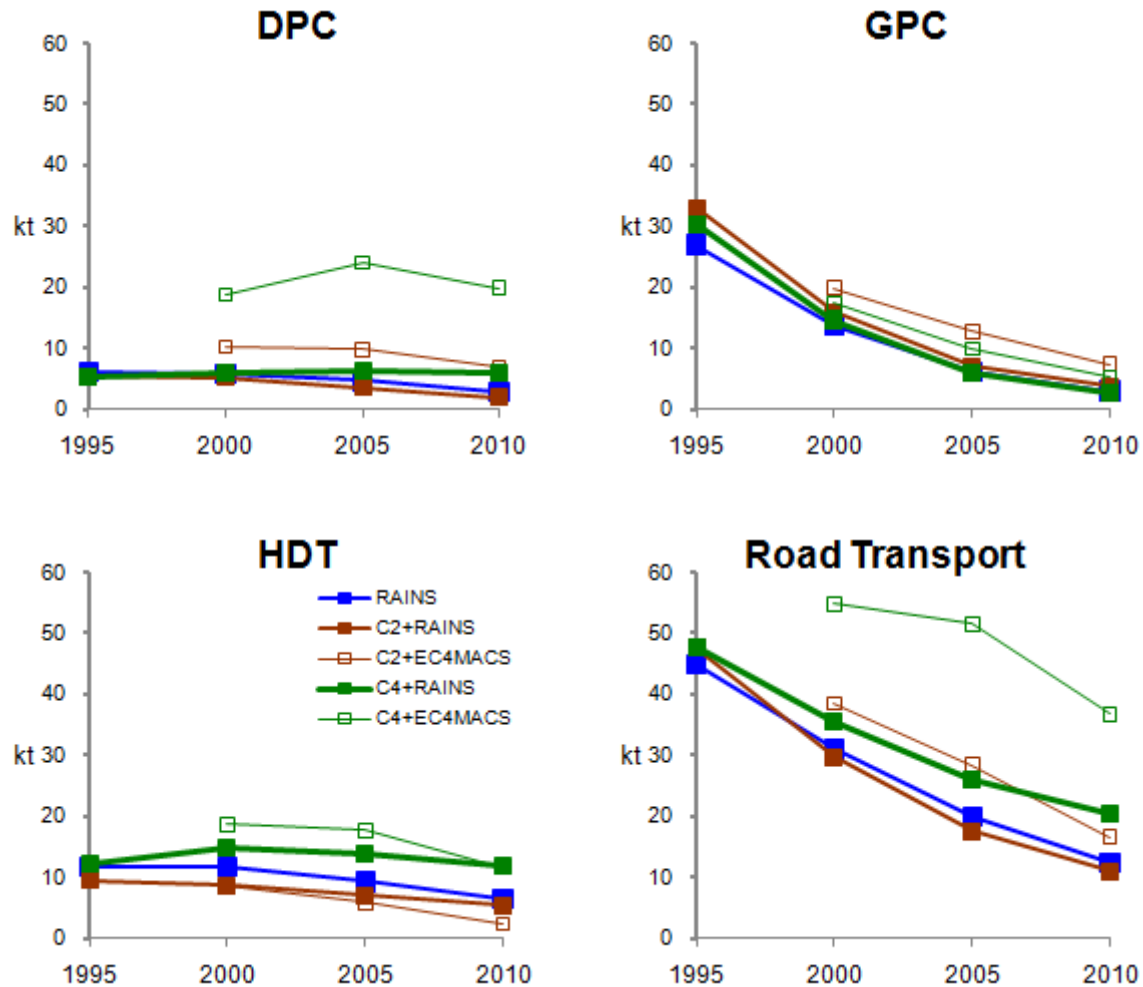




# Fuel Consumption - Ireland



# NOx Emissions - Ireland





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# Outlook



# Summary of expectations for future emission factors

	CO	HC	NOx	NO <sub>2</sub>	N <sub>2</sub> O	PM	PN	NH <sub>3</sub>	CO <sub>2</sub>
Gasoline Cars	😊	😊	😊	😊	😊	😊	😊	😊	?
Diesel Cars	😊	😊	😞	?	?	😊	😊	?	?
HDVs	😊	😊	😞	?	?	😊	😊	?	😊
PTWs	😊	?	😊	😊	😊	😊	😊	😊	😊

# Major Issues

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- Success of electrification (no plan B!)
- Mid-term CO<sub>2</sub> targets vs. real-world improvements
- Nitrogen-species and diesel De-NOx
- OBD Effectiveness
- PM and atmospheric modelling
- How will Europe-based standards evolve in the developing world
  - ◆ Compliance
  - ◆ Tampering
  - ◆ Monitoring

## Further reading

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- Ntziachristos, L., Papageorgiou, Th. 2011. Road transport emission projections in the context of the EU NEC Directive ceiling commitments. Impacts of model versions. ETC/ACC Technical Paper 2010/20, [http://acm.eionet.europa.eu/reports/ETCACC TP 2010 20 Copert2vsCopert4](http://acm.eionet.europa.eu/reports/ETCACC_TP_2010_20_Copert2vsCopert4).
- Kouridis, Ch., Gkatzoflias, D., Kioutsioukis, I., Ntziachristos, L., Pastorello, C., Dilara, P., 2009. Uncertainty estimates and guidance for road transport emission calculations, [http://acm.eionet.europa.eu/reports/ETCACC TP 2010 20 Copert2vsCopert4](http://acm.eionet.europa.eu/reports/ETCACC_TP_2010_20_Copert2vsCopert4)
- Kouridis, Ch., Kioutsioukis, I., Papageorgiou, Th., Mills, St., White, L., Ntziachristos, L. 2011. Uncertainty/Sensitivity analysis of the transport model TREMOVE. <http://www.emisia.com/> (soon on website).