The challenge of estimating the uncertainty for GHG emission estimates at a continental scale on the example of agriculture

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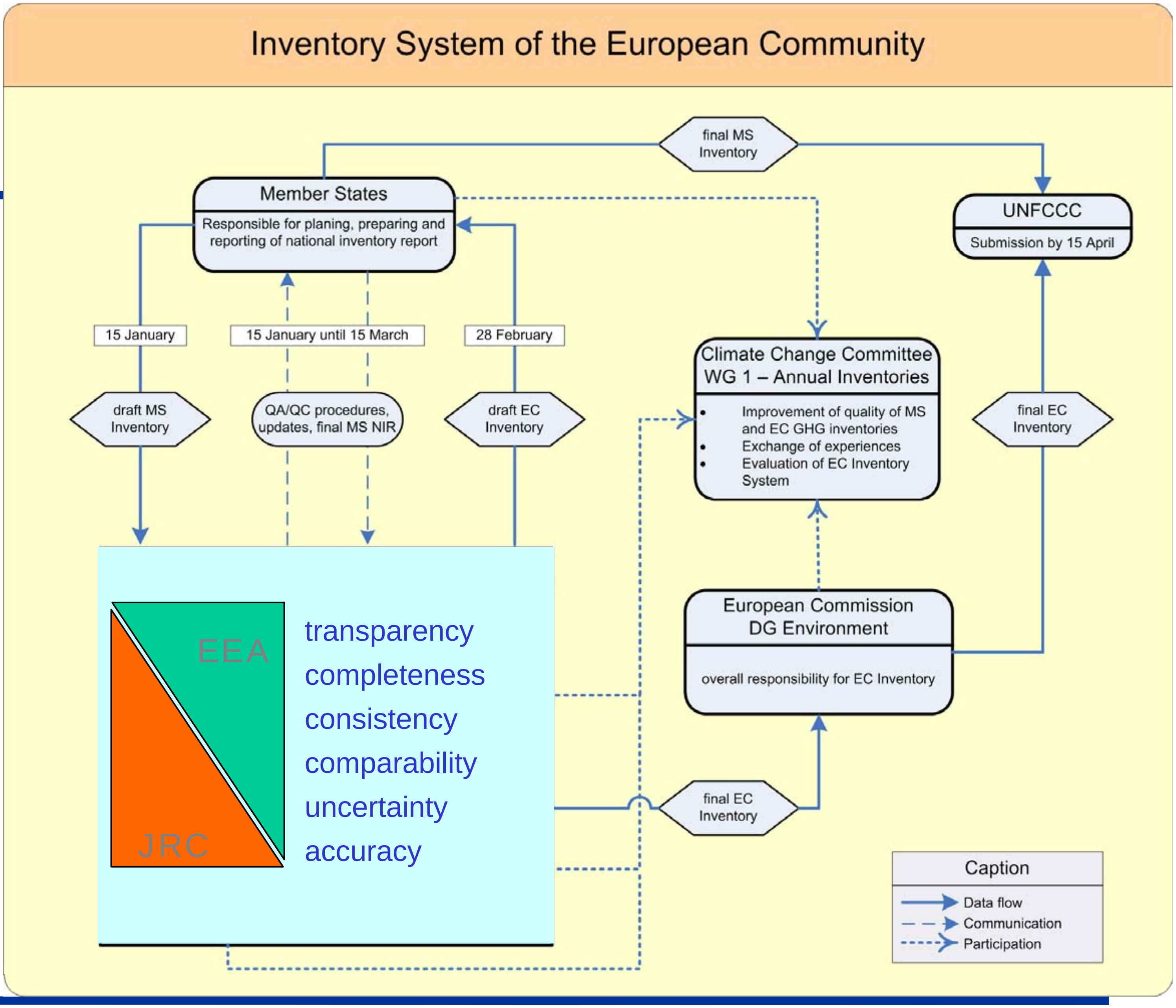
Adrian Leip
Joint Research Centre, Institute for Environment and Sustainability
European Community

Outline

- ⇨ Introduction
- ⇨ Assessing the quality level
- ⇨ Assessing the uncertainty
- ⇨ Conclusions



Inventory System of the European Community
final MS Inventory
Member States
Responsible for planing, preparing and reporting of national inventory report
UNFCCC
Submission by 15 April
15 January
15 January until 15 March
28 February
Climate Change Committee WG 1 – Annual Inventories
Improvement of quality of MS and EC GHG inventories
Exchange of experiences
Evaluation of EC Inventory System
draft MS Inventory
QA/QC procedures, updates, final MS NIR
draft EC Inventory
final EC Inventory
EEA
JRC
transparency
completeness
consistency
comparability
uncertainty
accuracy
European Commission DG Environment
overall responsibility for EC Inventory
final EC Inventory
Caption
Data flow
Communication
Participation

Quality level and Uncertainty

Aggregation from MS to EC level

EC Inventory
Approach Level Uncertainty

$$\sigma^2{}_{X \pm Y} = \sigma^2{}_X + \sigma^2{}_Y \pm 2 \cdot COV_{X,Y}$$

$$\mathrm{COV}_{\mathrm{X,Y}} = \rho_{X,Y} \cdot \sigma_X \cdot \sigma_{\mathrm{Y}}$$

- Range of uncertainty estimates per source category are calculated with $\rho \in \{0,1\}$ for all MS
- Assumption: MS uncertainty estimates per source category are correlated if they use Tier 1 methods and/or default emission factors.
- For N_2O from 4D no single uncertainty estimates were calculated because uncertainties are influenced by too many parameters
- Then uncertainty estimates for total GHG emissions and for the sectors were calculated

New approach
Quality level vs. uncertainty vs. accuracy

Preambel:

- **We propose an enhanced methodology to estimate the uncertainty at EC-level from uncertainty estimates at Member State level.**
- **Correlation between MS uncertainty estimates is quantitatively based on individual quality levels**
- **But trying to accurately estimate the uncertainty does not imply that the emission estimate itself become more accurate.**

Quality levels

Quality levels according to the IPCC

- **Tier 1: The emission estimate is based on minimum information on the national situation. The emission factor is picked-up from a table proposed in the guidelines and multiplied with the national activity level. For the selection of the appropriate emission factor in some cases a rough classification of the national activity, for example according to the milk productivity level or the climate region, is required. No break-down of the activity, for example by disaggregating the animal categories into finer sub-categories, beyond the default level is done.**
- **Tier 2: The emission estimate is based on a more detailed approach described in the Guidelines or the Good Practice Guidance. Usually, the emission factor is estimated using additional national information.**
- **Tier 3: The emission estimate is based on a modeling approach.**

Quality levels
Criteria for aggregation of quality levels

- **A quality level for EU-15 level requires**

Completeness. For each source category and Member State a quality level must be assigned

Quantitativeness. Summation of emission estimated of different quality, the quality level must be measured on an interval scale, allowing 'intermediate' quality levels

Quality levels
Principles to assign a quality level

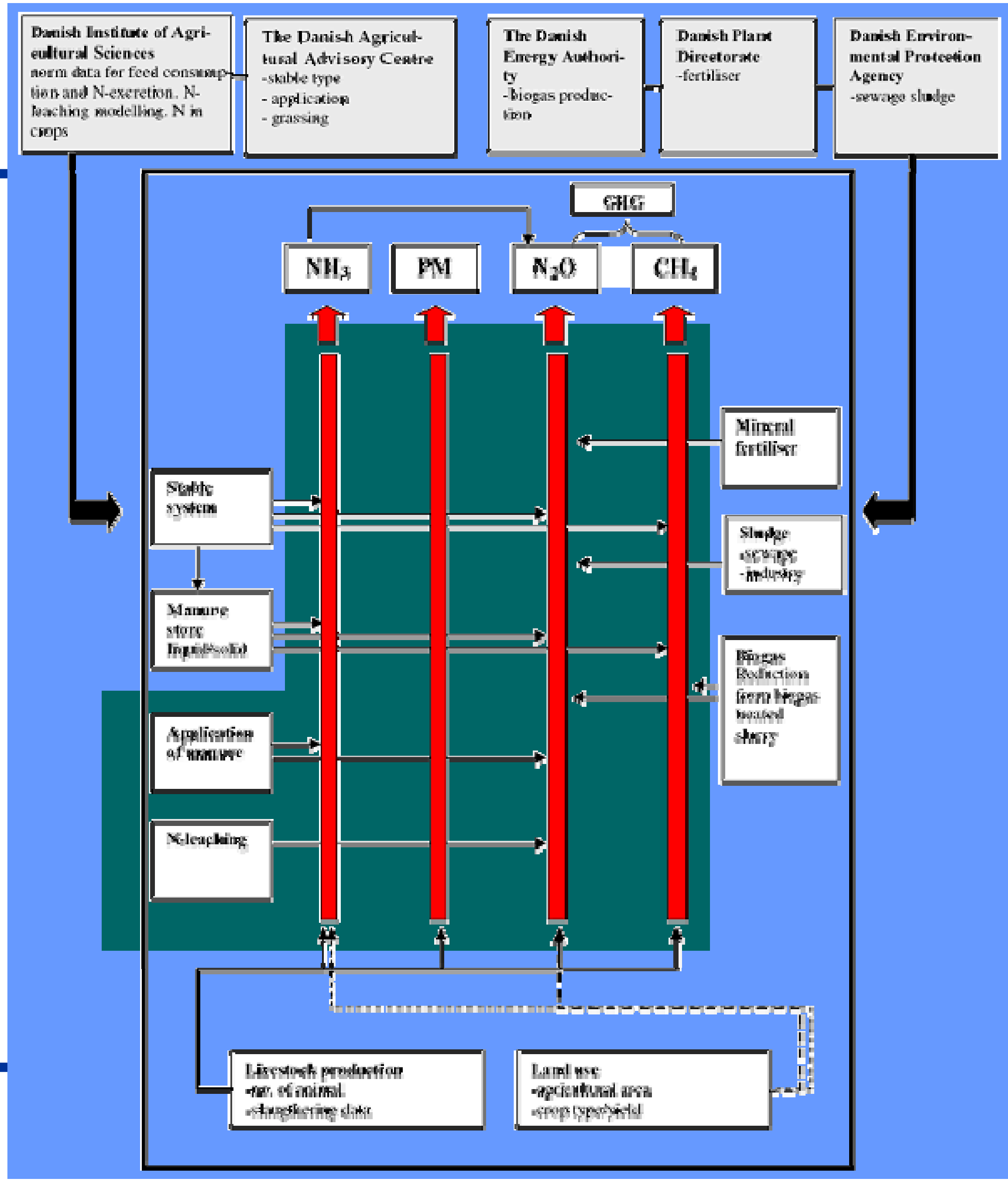
A. A quality level (Tier 1 or Tier 2) is assigned at the lowest level available (individual parameter)

B. Appropriate activity data are considered as basic requirement and do not influence the quality level

C. Quality levels can be aggregated using well-defined and transparent rules

What are activity data?

DIEMA – Danish Intergrated Emission Model for Agriculture



Quality levels
Aggregation rules (i)

- The **MEAN-rule** if an emission estimate is based on the estimates of two or more sub-categories. In this case, the quality levels of the individual estimates are aggregated using an emission-weighted average.

$$E_{A+B} = E_A + E_B$$

$$Q_{A+B} = \frac{Q_A \cdot E_A + Q_B \cdot E_B}{E_{A+B}}$$

Quality levels
Aggregation rules (ii)

- **The MEDIAN-rule for evaluating the quality level of a product of parameters**
  Principles:

$$E_A = \prod_i P_i$$

(i) if parameters with very different quality are multiplied, the higher quality should get more weight;

(ii) if parameters with different uncertainty are multiplied, it should be good practice to estimate the parameter which is associated with the higher uncertainty at a higher quality level (requires uncertainty estimate for each parameter)

$$Q_{\prod_i P_i} = 3 - \prod_i \left[\left(3 - Q_{P_i}\right)^{\frac{w_{r,i}}{\sum_j \{w_{r,j}\}}} \right]$$

with the weighting factors $w_{r,j}$ –
ideally related to uncertainty of parameter $\sigma_{r,X} = \frac{\sigma_X}{E_X}$

Quality levels
Aggregation rules (iii)

- The **MAX-rule**, simplifying the MEDIAN rule when multiplying two parameters.

$$Q_{A\cdot B} = \max\{Q_A, Q_B\}$$

Quality levels
Example 1

CH4 from enteric fermentation

- Gross energy intake, methane conversion factor
- MAX and MEAN rules applied
- EC quality based on the assessment of cattle, sheep, goat, swine, reindeer. Other emissions (<1%) considered as Tier 1

	$E_{4A\text{-}CH4}$ Gg CO_2-eq	$Q_{E,4A\text{-}CH4}$
Austria	3,233	Tier 1.4
Belgium	3,850	Tier 1.4
Denmark	2,630	Tier 2.0
Finland	1,577	Tier 1.9
France	27,632	Tier 1.9
Germany	18,342	Tier 2.0
Greece	2,889	Tier 1.5
Ireland	9,049	Tier 2.0
Italy	10,852	Tier 1.8
Luxembourg	158	Tier 2.0
Netherlands	6,345	Tier 1.9
Portugal	3,038	Tier 2.0
Spain	13,498	Tier 1.9
Sweden	2,804	Tier 1.9
United Kingdom	15,934	Tier 2.0
EU-15	121,830	Tier 1.9
EU-15: Tier 1	7%	
EU-15: Tier 2	93%	

Data in this table refer to 2005

Uncertainty – Quality levels
Example 2

CH4 from manure management

- Volatile solid excretion, Methane producing potential, Methane conversion factor
- MEDIAN and MEAN rules applied with weighting factor: 0.4/0.2/0.4
- EC quality based on the assessment of cattle, sheep, goat, swine, poultry. Other emissions (<1%) considered as Tier 1

	$E_{4B\text{-}CH4}$ Gg CO_2-eq	$Q_{E,4B\text{-}CH4}$
Austria	881	Tier 1.5
Belgium	2,389	Tier 1.0
Denmark	1,016	Tier 1.8
Finland	278	Tier 1.7
France	12,972	Tier 1.5
Germany	4,954	Tier 2.0
Greece	519	Tier 1.5
Ireland	2,224	Tier 1.5
Italy	3,150	Tier 1.9
Luxembourg	79	Tier 2.0
Netherlands	2,459	Tier 1.5
Portugal	1,159	Tier 1.8
Spain	8,871	Tier 1.5
Sweden	479	Tier 1.8
United Kingdom	2,509	Tier 1.7
EU-15	43,940	Tier 1.6
EU-15: Tier 1	41%	
EU-15: Tier 2	59%	

LEVEL

UNCERTAINTY

Member State Activity Data uncertainty	4A	4B		4D			
				Total	Direct	Animal	Indirect
	CH_4	CH_4	N_2O	N_2O	N_2O	N_2O	N_2O
Austria	*(1)	*(6)	10		5		5
Belgium	5	10	10	30			
Denmark	10	10	10	8			
Finland	0	0	0		0	0	0
France	5	5	5	10			
Germany	*(2)	*(7)	7		75	20	75
Greece	5	5	50		20	50	20
Ireland	*(3)	*(8)	11		11	11	11
Italy	20	20	20		20	20	20
Luxembourg							
Netherlands	*(4)	*(9)	10		10	10	50
Portugal	*(5)	*(10)	38			39	
Spain	3	3	16		18		188
Sweden	5	20	20	16			
UK	10	10	100	100			

Uncertainty
Activity data …. (cont'd)

*(1)- Cattle: 10%

*(2)- Dairy and non-dairy cattle, sheep and horses: 10%; swine: 7%

*(3)- Dairy and non-dairy cattle and other animals: 1%

*(4)- Cattle, swine and other animals: 5%

*(5)- Dairy and non-dairy cattle: 6%; Sheep: 84%; goats: 19%; horses: 71%; mules and asses: 272%; poultry: 11%; other animals: 771%

*(6)- Cattle and swine: 10%

*(7)- Dairy and non-dairy cattle, sheep, horses, swine and poultry: 7%

*(8)- Dairy and non-dairy cattle and other animals: 1%

*(9)- Cattle, swine, poultry and other animals: 10%

*(10)- Dairy and non-dairy cattle: 6%; Sheep: 84%; goats: 19%; horses: 71%; mules and asses: 272%; poultry: 11%

Member State Emission factor uncertainty	4A	4B		4D			
				Total	Direct	Animal	Indirect
	CH_4	CH_4	N_2O	N_2O	N_2O	N_2O	N_2O
Austria	*(1)	*(6)	100		150		150
Belgium	40	40	90	250			
Denmark	8	100	100	20			
Finland	17	16	81		138	138	236
France	40	50	50	200			
Germany	*(2)	*(7)	75		150	75	150
Greece	30	50	100		400	100	50
Ireland	*(3)	*(8)	100		100	100	50
Italy	20	100	100		100	100	100
Luxembourg							
Netherlands	*(4)	*(9)	100		60	100	200
Portugal	*(5)	*(10)	100			500	
Spain	11	11	100		25		50
Sweden	25	50	50	69			
UK	20	30	414	424			

Uncertainty
Emission factor …. (cont'd)

*(1)- Cattle: 20%

*(2)- Dairy and non-dairy cattle, sheep and horses: 25%; swine: 40%

*(3)- Dairy and non-dairy cattle and other animals: 15%

*(4)- Cattle: 20%; swine: 50%;other animals: 30%

*(5)- Dairy and non-dairy cattle: 20%; Sheep: 20%; goats: 20%; horses: 50%; mules and asses: 50%; poultry: 20%; other animals: 20%

*(6)- Cattle and swine: 70%

*(7)- Dairy and non-dairy cattle, sheep, horses, swine and poultry: 40%

*(8)- Dairy and non-dairy cattle: 15%; other animals: 30%

*(9)- Cattle, swine, poultry and other animals: 100%

*(10)- Dairy and non-dairy cattle: 61%; Sheep: 59%; goats: 58%; horses: 61%; mules and asses: 61%; poultry: 91%

Uncertainty
Combined uncertainty

Gap filling required to obtain one estimate per country and category

- **Assumptions:**
  - **Aggregation to a sub-category (e.g., dairy and non-dairy cattle to cattle or different direct N2O sources from agricultural soils): uncertainties are correlated**
  - **Aggregation of sub-categories to categories (different animal types, direct and indirect N2O emissions): uncertainties are un-correlated**
  - **Aggregation of categories to sector: uncertainties are un-correlated**

- **Basis for assumptions is weak, but**
  - **Repercussions to the overall uncertainty estimate only for category 4D**
  - **Correlation of uncertainty of direct and indirect emissions seems in-appropriate**
  - **Uncertainties in activity data have not much influence on overall uncertainty**

Member State **<u>Combined uncertainty (%)</u>**	Enteric ferment. (4A)	Manure Managem. (4B)		Agricultural soils (4D)			
				total	direct	animal prod.	indirect
	CH_4	**CH_4**	**N_2O**	**N_2O**	**N_2O**	**N_2O**	**N_2O**
Austria	22	50	100	100	150	150	150
Belgium	40	41	91	252			
Denmark	13	100	100	21			
Finland	17	16	81	115	138	138	236
France	40	50	50	200			
Germany	32	29	75	120	168	78	168
Greece	30	50	112	104	400	112	54
Ireland	23	11	101	58	101	101	51
Italy	28	102	102	67	102	102	102
Luxembourg							
Netherlands	20	70	100	83	61	100	206
Portugal	38	82	107	234	504	502	104
Spain	11	11	101	80	31	31	195
Sweden	25	54	54	71			
UK	22	32	426	436			

$\rho_{X,Y} = \sqrt{(2-Q_X)\cdot(2-Q_Y)}$

Uncertainty
Aggregation from MS level to EU-15

- **To correlate or not to correlate???**

$$\rho_{X,Y} = \sqrt{(2-Q_X)\cdot(2-Q_Y)}$$

- **difference to the approach in the EC-Inventory report**
  - (i) a certain level of correlation is maintained for two countries where one uses a Tier 1 and the other a Tier 2 approach
  - (ii) a correlation coefficient can be calculated for any intermediate situation.

Member State	QUALITY LEVEL OF SOURCE CATEGORY						
	TOTAL	Enteric Fermentation	Manure Management	Manure Management	Rice Cultivation	Agricultural soils	Agricultural soils
	ALL	CH4	CH4	N2O	CH4	CH4	N2O
Austria	**Tier 1.4**	Tier 1.4	Tier 1.5	Tier 1.7	Tier 0.0	Tier 2.0	Tier 1.2
Belgium	**Tier 1.3**	Tier 1.4	Tier 1.0	Tier 1.7	Tier 0.0	Tier 2.0	Tier 1.4
Denmark	**Tier 1.7**	Tier 2.0	Tier 1.8	Tier 2.0	Tier 0.0		Tier 1.5
Finland	**Tier 1.7**	Tier 1.9	Tier 1.7	Tier 1.7	Tier 0.0		Tier 1.5
France	**Tier 1.5**	Tier 1.9	Tier 1.5	Tier 1.4	Tier 1.0		Tier 1.2
Germany	**Tier 1.8**	Tier 2.0	Tier 2.0	Tier 1.8	Tier 0.0	Tier 2.0	Tier 1.7
Greece	**Tier 1.2**	Tier 1.5	Tier 1.5	Tier 1.2	Tier 1.0		Tier 1.1
Ireland	**Tier 1.7**	Tier 2.0	Tier 1.5	Tier 1.7	Tier 0.0		Tier 1.3
Italy	**Tier 1.5**	Tier 1.8	Tier 1.9	Tier 1.7	Tier 2.0		Tier 1.1
Luxembourg	**Tier 1.6**	Tier 2.0	Tier 2.0				Tier 1.0
Netherlands	**Tier 1.9**	Tier 1.9	Tier 1.5	Tier 2.0	Tier 0.0		Tier 1.9
Portugal	**Tier 1.6**	Tier 2.0	Tier 1.8	Tier 1.7	Tier 1.0		Tier 1.1
Spain	**Tier 1.7**	Tier 1.9	Tier 1.5	Tier 1.7	Tier 1.0		Tier 1.7
Sweden	**Tier 1.9**	Tier 1.9	Tier 1.8	Tier 1.6	Tier 0.0		Tier 1.9
United Kingdom	**Tier 1.5**	Tier 2.0	Tier 1.7	Tier 1.6	Tier 0.0		Tier 1.2
EU-15	**Tier 1.6**	**Tier 1.9**	**Tier 1.6**	**Tier 1.7**	**Tier 1.7**	**Tier 2.0**	**Tier 1.4**

Member State	RELATIVE UNCERTAINTY OF SOURCE CATEGORY						
	TOTAL	Enteric Fermentation	Manure Management	Manure Management	Rice Cultivation	Agricultural soils	Agricultural soils
	ALL	CH4	CH4	N2O	CH4	CH4	N2O
Austria	**39.3**	22.4	50.1	100.5			100
Belgium	**91.6**	40.3	41.2	90.6		46.1	252
Denmark	**17.2**	12.8	100.5	100.5			21
Finland	**67.2**	16.6	15.7	81.3			115
France	**103.2**	40.3	50.2	50.2			200
Germany	**70.2**	18.6	28.9	75.3		106.1	120
Greece	**70.0**	30.4	50.2	111.8	40.0		104
Ireland	**24.2**	22.6	11.1	100.6			58
Italy	**36.0**	28.3	102.0	102.0	20.2		67
Luxembourg	**54.8**	25.0	50.0	114.4			139
Netherlands	**41.4**	19.6	70.4	100.5			83
Portugal	**95.3**	38.4	82.0	106.8	55.5		234
Spain	**35.3**	11.4	11.4	101.3			80
Sweden	**40.4**	25.5	53.9	53.9			71
United Kingdom	**244.5**	22.4	31.6	425.9			436
EU-15*	**67.1**	**17.5**	**33.3**	**73.5**	**20.1**	**105.5**	**124.8**
No correlation	**40.5**	**10.8**	**18.0**	**37.5**	**18.1**	**105.5**	**79.5**
Full correlation	**85.4**	**26.0**	**43.1**	**100.9**	**24.7**	**105.7**	**167.3**
Only 4D uncorrelated	**41.8**	**26.0**	**43.1**	**100.9**	**24.7**	**105.5**	**79.5**
Only 4D correlated	**84.8**	**10.8**	**18.0**	**37.5**	**18.1**	**105.5**	**167.3**

Uncertainty
Agriculture and the total GHG inventory

Source category*	Emissions 2005	Uncert. 2005	Lower bound	Upper bound
Fuel combustion stationary	2,423,141	1.3%	1.3%	1.3%
Transport	879,721	3.3%	3.3%	3.3%
Fugitive emissions	54,530	10.9%	10.9%	10.9%
Industrial processes	331,868	7.4%	7.4%	7.4%
Agriculture	385,618	67.1%	40.5%	85.9%
Waste	109,104	17.7%	17.7%	17.7%
Total	4,191,319	6.3%	3.9%	8.0%

Total GHG inventory uncertainty without agriculture: 1.4%

*data of other sectors from EC-IR 2007

TREND

UNCERTAINTY

Trend uncertainty
Approach

- **Assessment of trend uncertainty requires gap-filling of AD and EF uncertainties**
  - **Not yet done … probably for GHG inventory 2008**
- **Approach of EEA (2007) followed:**
  1) **Relative uncertainty of the trend at category level**

$$\sigma^2{}_{X-Y} = \sigma^2{}_X + \sigma^2{}_Y - 2 \cdot COV_{X,Y}$$

  2) **Aggregation from MS to EC according to estimated correlations**
  3) **Calculation of the uncertainty relative to base year emissions**

$$u_{t-p} = \Delta E \cdot \frac{u_{t-r}}{E_0}$$

Trend uncertainty
Example

- N2O emissions from agricultural soils:
  - 1990: 225,785
  - 2005: 195,684

  } Trend: 30,101 Gg CO2-eq (13.3% of base year)

- Trend uncertainty N2O from agricultural soils (error propagation with correlation between years and quality-level correlation between MS)
  - 30,101 ± 136% (higher than level uncertainty: 125%)
- Trend uncertainty expressed as percent-point from base-year emissions
  - 13.3% ± 18.1% of N2O emissions in 1990

	TOTAL	Enteric Ferment.	Manure Managem.	Manure Managem.	Rice Cultivat.	Agricult. soils	Agricult. soils
		CH_4	CH_4	N_2O	CH_4	CH_4	N_2O
EU-15	9.5	1.7	0.2	7.5	1.2	6.2	18.1
No correlation	6.5	1.0	0.1	4.2	1.1	6.2	12.5
Full correlation	12.6	2.5	0.3	10.3	1.6	6.2	24.1
Only 4D uncorrelated	12.5	1.0	0.1	4.2	1.1	6.2	24.1
Only 4D correlated	6.6	2.5	0.3	10.3	1.6	6.2	12.5

Trend uncertainty total GHG inventory: 1-2%

Conclusion

- The presented methodology suggests an objective and quantitative assessment of correlation based on individual parameters
- Representation of correlation is the main reason for differences in uncertainty assessments
- Only the quantitative aggregation of the quality level allows to obtain an objective assessment at EU level
- The “problem 4D” remains nevertheless difficult – and this is the only category that really matters
- Next steps:
  - replace “weighting factors” by uncertainty estimates
  - Improve trend uncertainty analysis

Thank you for your attention!!