CBIT-GSP

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CLIMATE TRANSPARENCY

Uncertainty Analysis

GHG Training Workshop

Morogoro, Tanzania

Sekai Ngarize

23-27 September 2024

Executed by: UN environment programme | copenhagen climate centre

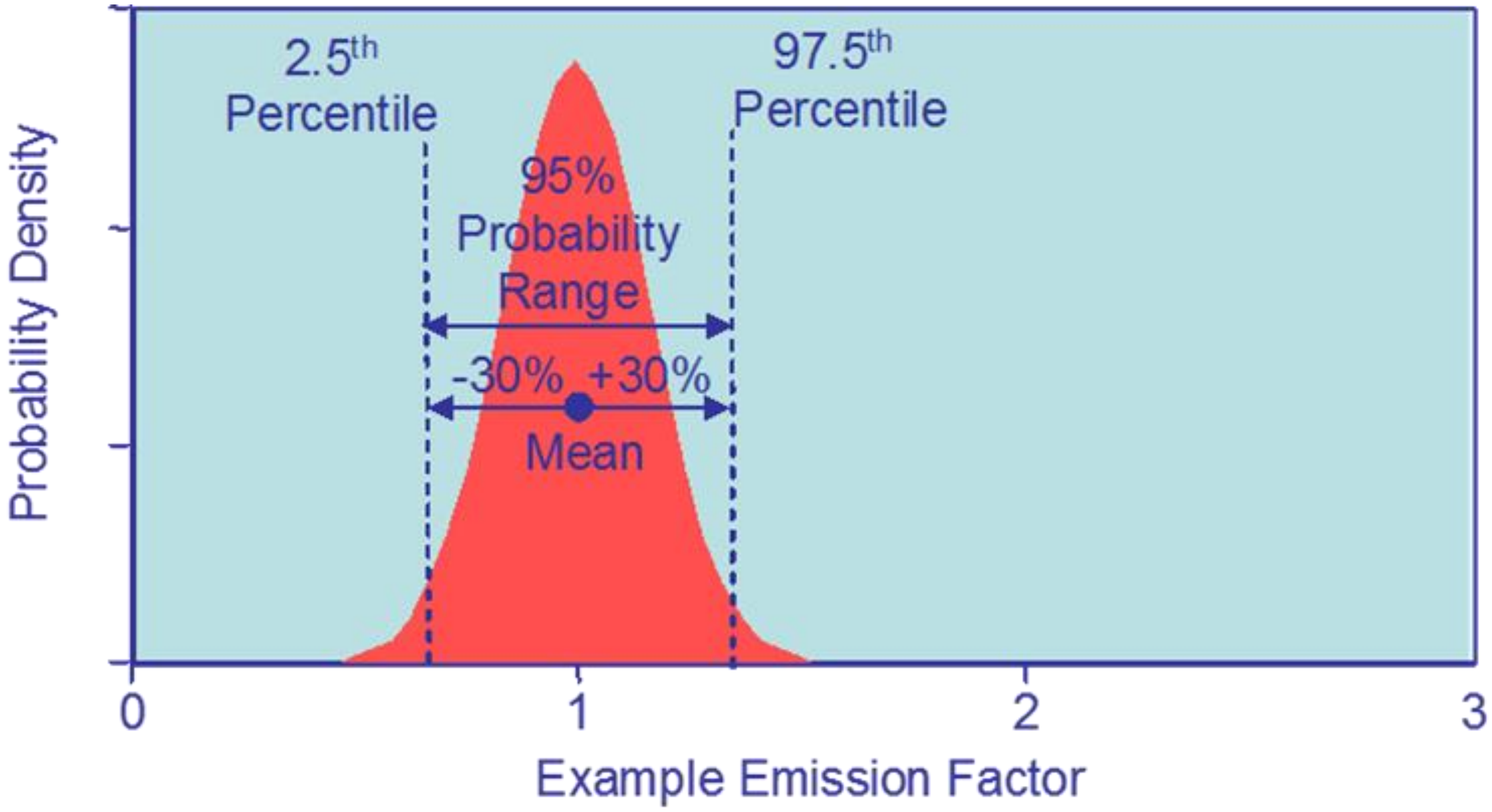
Funded by: gef

Implemented by: UN environment programme

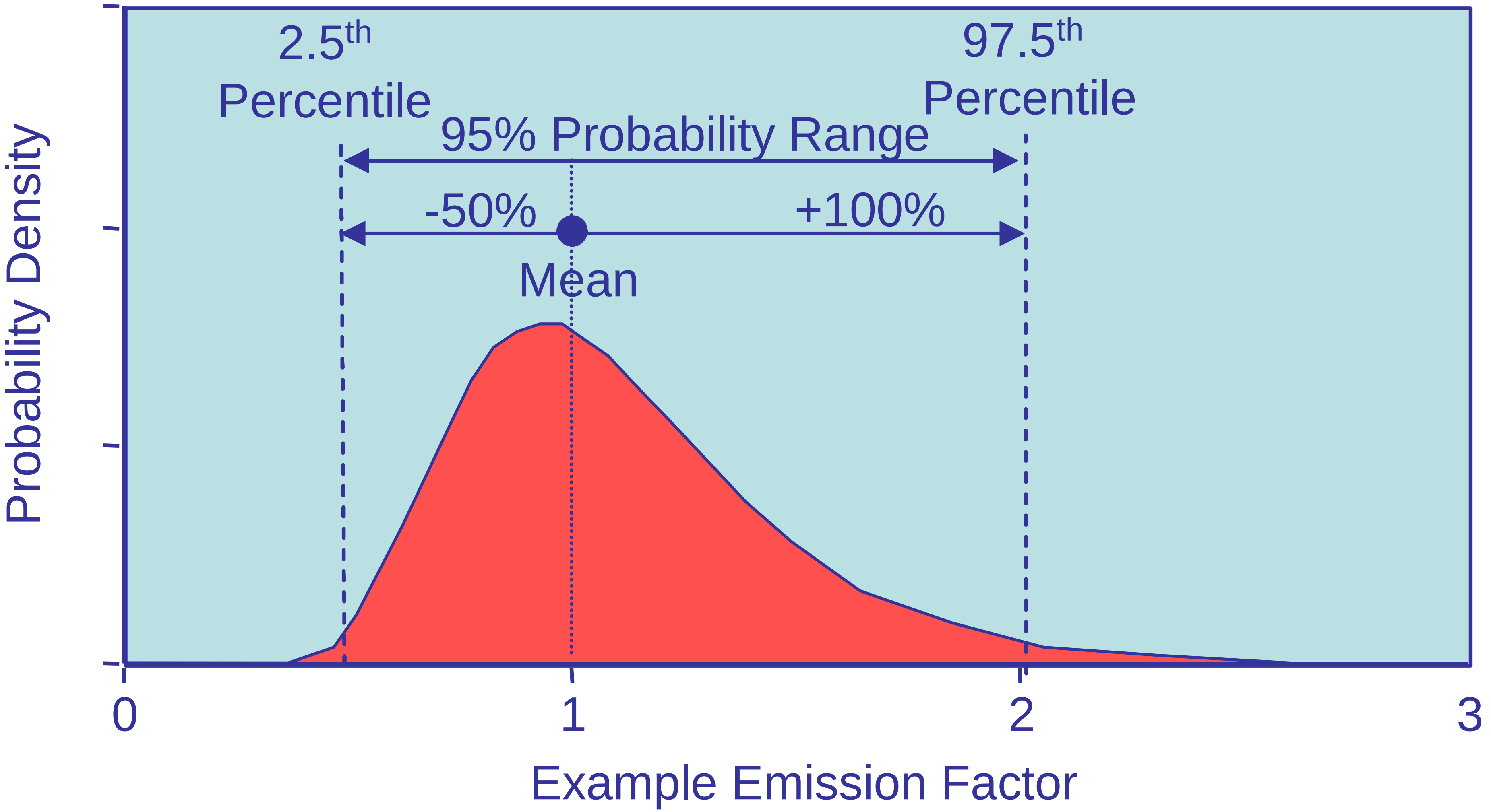
Introduction

- Uncertainty estimates are an essential element of a complete inventory of GHG emissions/removals
- Uncertainty: a lack of knowledge of the true value of a variable that can be described as a probability density function (PDF) which describes the range and relative likelihood of possible values
- The PDF can be used to describe uncertainty in the estimate of a quantity that is a fixed constant whose value is not exactly known or describe inherent variability.
- Quantitative uncertainty analysis is performed by estimating the 95 percent confidence interval of the emissions and removals estimates for individual categories and for the total inventory (in statistics 95% CI has a 95% probability of enclosing the true value but unknown value of a quantity)
  - 95 percent confidence interval is enclosed by the 2.5^{th} and 97.5^{th} percentiles of the PDF
  - Familiarise with section 3.2.3.1 in chapter 3, vol. 1 of the 2006 IPCC guidelines. Table 3.2, chapter 3, Vol.1 2006 IPCC

Probability Density Function

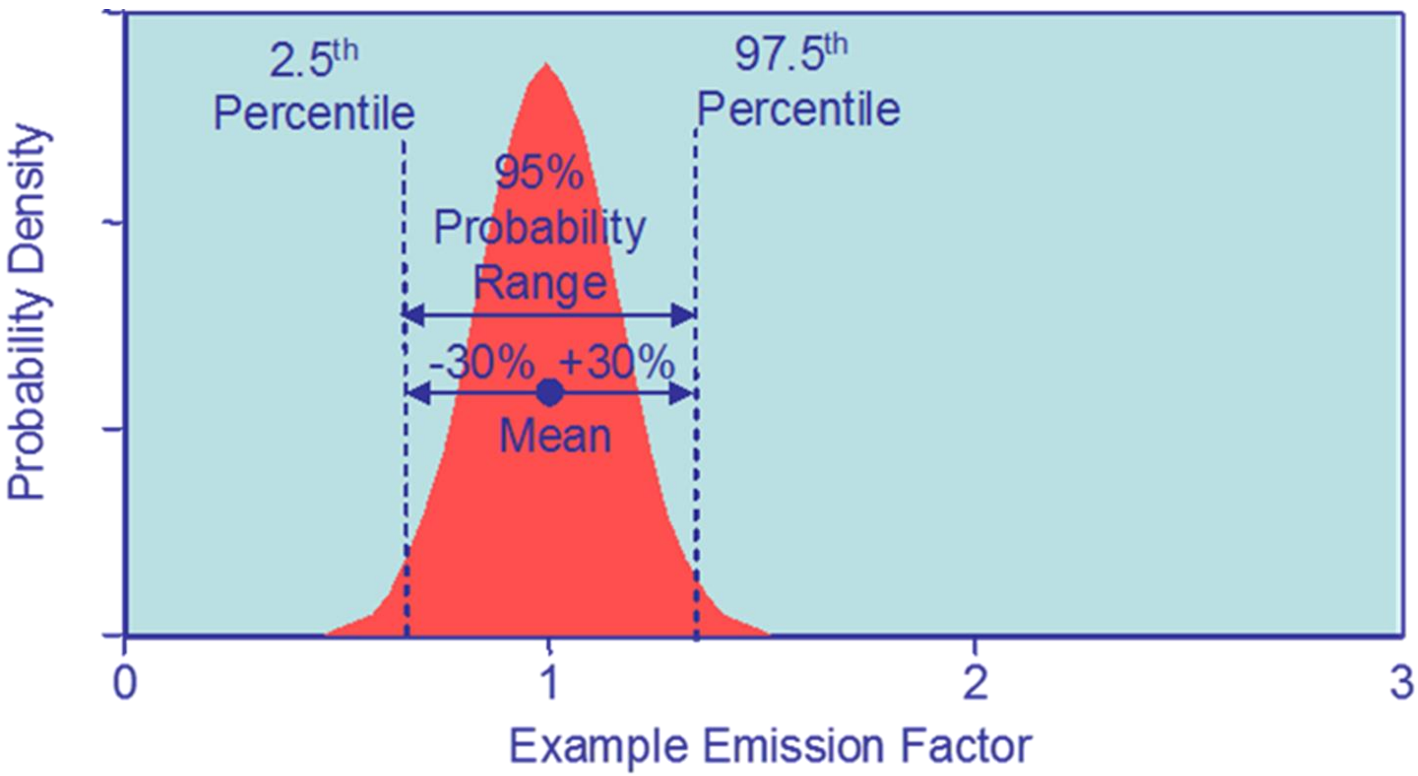


Probability Density Function



Specifying Uncertainty

- Uncertainty is quoted as the 2.5th and 97.5th percentiles i.e. bounds around a 95 percent confidence interval
- This can be expressed, for example:
  - 234 ± 30%
  - 26400 (- 50%, + 100%)



Benefits of Uncertainty Analysis

Credibility

Inventories are estimates – uncertainty analysis gives a clear statement on what we do and do not know

Utility

Users of the inventory need to know how reliable the numbers are – especially if they are input into policy or inventory improvement actions

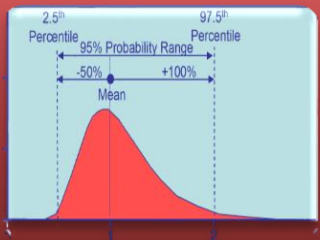
Requirement

Uncertainty analysis is a requirement of all good practice inventories

Scientific

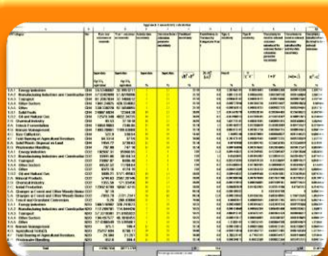
All scientific analysis should include an uncertainty assessment

Uncertainty Estimation



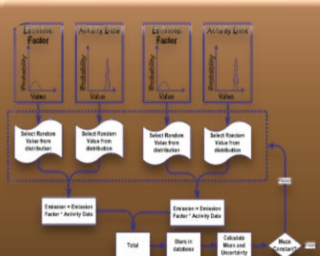
Gather Information

- Collect uncertainty information on activity data and emission factors



Decide approach to use

- Error Propagation
- Monte Carlo



Perform Inventory Analysis

- Spreadsheet
- Software tool

Sources of Uncertainty

- Assumptions and methods
  - The method may not accurately reflect the emissions
- Input Data
  - Measured values have errors and EFs may not be truly representative
  - Lack of data (e.g. use of proxies, extrapolation)
- Calculation errors
  - Good QA/QC to prevent these

Sources of Data and Information

- There are three broad sources of data and information
  - Information contained in models. Models can be as simple as arithmetic multiplication of AD and EF for each category and subsequent summation over all categories, but they may also include complex process models specific to particular categories
  - Empirical data associated with measurements of emissions, and activity data from surveys and censuses
  - Quantified estimates of uncertainties based upon expert judgement
- Data collection activities should consider data uncertainties. This will ensure the best data is collected and ensures good practice estimates
- Wherever possible, expert judgement should be elicited using an appropriate protocol (e.g. Stanford/SRI protocol)

Methods to Combine Uncertainties

- Approach 1: Error Propagation
- The IPCC apply propagation method to estimate uncertainty in trend. Generally, the trend is the difference between the emissions in the base year and in the year t. It is often expressed as % ratio:
  - Simple (standard spreadsheet can be used)
    - Guidelines provide equations and explanations
  - Difficult to deal with correlations
  - Standard deviation/mean < 0.3 (See practice example)
- Approach 2: Monte Carlo Method
  - More complex (specialised software is used)
    - Select random values of input parameters from their pdf and calculate the corresponding emission. Repeat many times and the distribution of the results is the PDF of the result from which mean and uncertainty can be estimated
  - Needs information on PDF (mean, width, shape)
  - Suitable where uncertainties large, non-normal distribution, complex algorithms, correlations exist and uncertainties vary with time

Error Propagation

Enter Emissions Data

Data Calculated using simple equations

Table 3.2
Approach 1 uncertainty calculation

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year *t*	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert \frac{D}{\sum C} \right\rvert$	$I \bullet F$ Note C	$J \bullet E \bullet \sqrt{2}$ Note D	$K^2 + L^2$
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
E.g., 1.A.1. Energy Industries Fuel 1	CO_2											
E.g., 1.A.1. Energy Industries Fuel 2	CO_2											
Etc...	…											
Total		$\sum C$	$\sum D$				$\sum H$					$\sum M$
					Percentage uncertainty in total inventory:		$\sqrt{\sum H}$				Trend uncertainty:	$\sqrt{\sum M}$

Enter Uncertainties

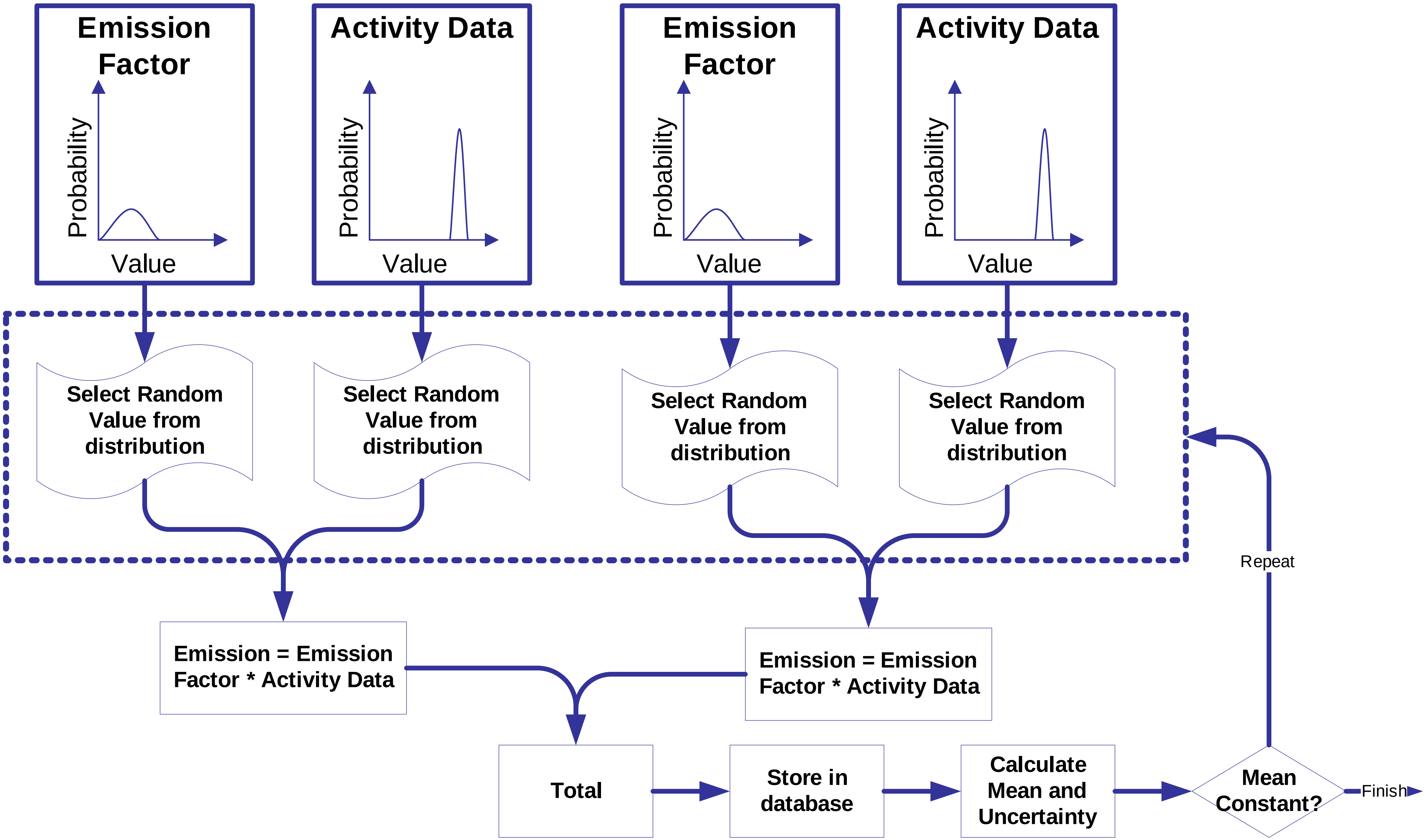
AD uncertainties based on source of data

EF uncertainties based on defaults in guidelines

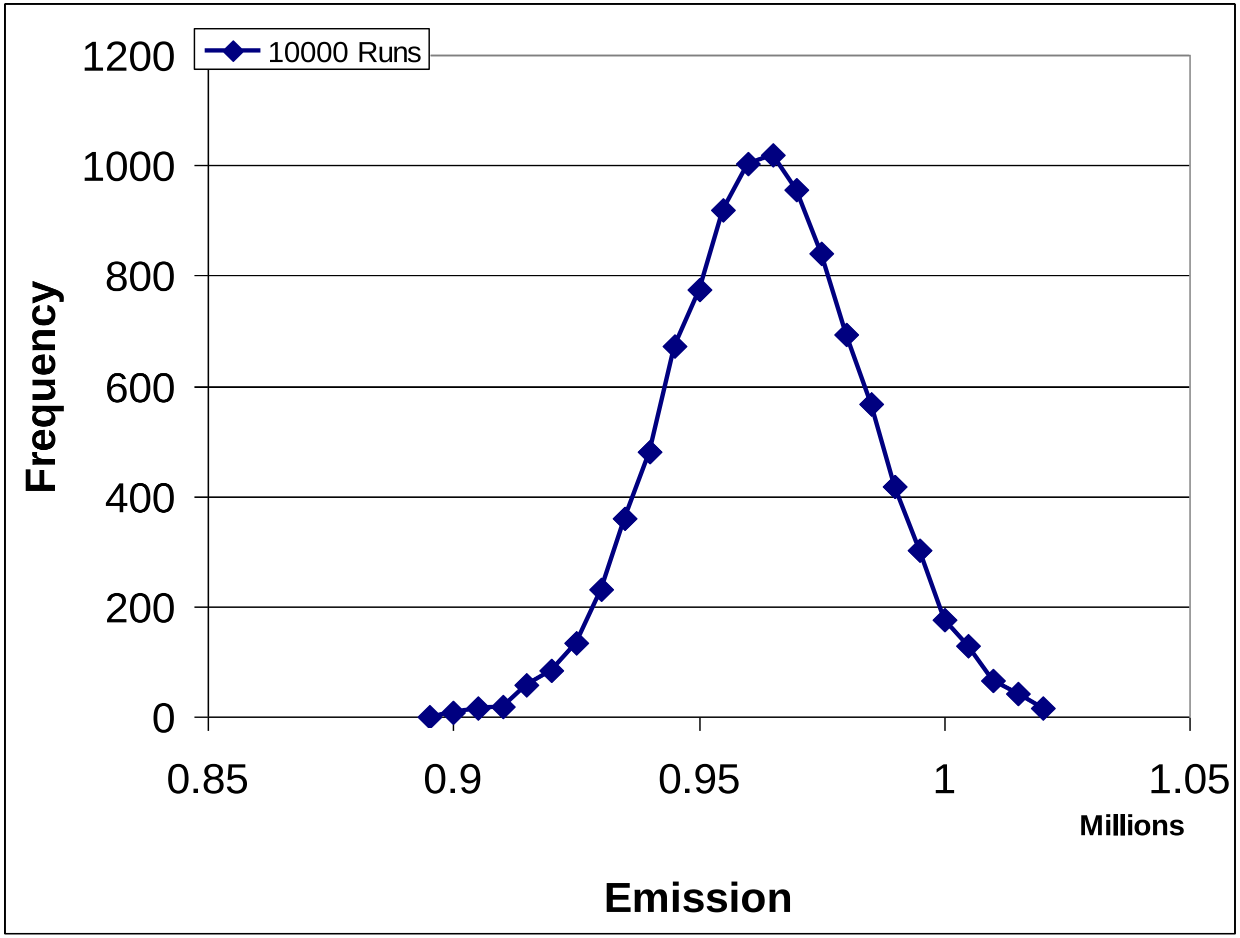
Note short list of source/sinks

Approach 1 uncertainty calculation												
A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national	Uncertainty in trend in national	Uncertainty introduced into the trend in total national emissions
			Input data	Input data	Input data	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I \bullet F$	$J \bullet E \bullet \sqrt{2}$	K^2+L^2
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
1.A.1. Energy Industries	CH4	35.5346662	32.9951217	5	25	25.50	0.0	3.20506E-05	0.00010495	0.000801264	0.000742109	1.19275E-06
1.A.2. Manufacturing Industries and Constructior	CH4	57.0302899	51.8776096	5	25	25.50	0.0	4.80131E-05	0.000165011	0.001200328	0.001166804	2.80222E-06
1.A.3. Transport	CH4	81.7067834	37.1466612	5	25	25.50	0.0	-4.94664E-05	0.000118155	-0.00123666	0.000835483	2.22736E-06
1.A.4. Other Sectors	CH4	1041.24025	428.554682	5	25	25.50	0.0	-0.000772946	0.001363136	-0.019323647	0.009638828	0.00046631
1.A.5. Other	CH4	330.338228	97.5658895	5	25	25.50	0.0	-0.000367351	0.000310335	-0.009183772	0.002194401	8.91571E-05
1.B.1. Solid Fuels	CH4	24867.6834	12364.38	10	25	26.93	2.7	-0.011678579	0.039328314	-0.291964463	0.556186352	0.394586505
1.B.2. Oil and Natural Gas	CH4	12570.348	4022.34735	10	25	26.93	0.3	-0.012988732	0.012794183	-0.324718297	0.180937071	0.138180196
2.B. Chemical Industry .	CH4	40.53	37.5018	10	25	26.93	0.0	3.61373E-05	0.000119285	0.000903433	0.001686942	3.66196E-06
4.A. Enteric Fermentation.	CH4	14054.9863	734[illegible]	[illegible]	[illegible]	[illegible]	1.5	-0.005462727	0.023368679	-0.163881819	0.495724537	0.272600067
4.B. Manure Management.	CH4	1903.28061	1199.6[illegible]	[illegible]	[illegible]	[illegible]	0.0	-8.88245E-05	0.003815756	-0.002664735	0.080944413	0.006559099
4.C. Rice Cultivation.	CH4	522.9	33[illegible]	[illegible]	[illegible]	[illegible]	0.0	5.3609E-06	0.001078092	0.000160827	0.015246523	0.000232482
4.F. Field Burning of Agricultural Residues.	CH4	64.3314	[illegible]	[illegible]	[illegible]	[illegible]	0.0	-1.24107E-05	0.000119565	-0.000372321	0.003381819	1.15753E-05
6.A. Solid Waste Disposal on Land.	CH4	1959.72	373[illegible]	[illegible]	[illegible]	[illegible]	0.4	0.00787088	0.011891742	0.236126385	0.252261939	0.119391756
6.B. Wastewater Handling.	CH4	787.08	747.18	[illegible]	30	33.54	0.0	0.000761896	0.002376612	0.022856865	0.050415547	0.003064164
1.A.1. Energy Industries	CO2	102607.31	9596[illegible]	5	5	7.07	11.2	0.094441853	0.305249301	0.472209267	2.158438506	4.881838378
1.A.2. Manufacturing Industries and Constructior	CO2	33991.06	[illegible]4.34	5	5	7.07	1.1	0.02618491	0.095945987	0.130924551	0.678440577	0.477422855
1.A.3. Transport	CO2	23987.07	8406.48	5	5	7.07	0.1	-0.022453294	0.026739124	-0.11226647	0.189074157	0.048352797
1.A.4. Other Sectors	CO2	44532.52	11784.04	5	5	7.07	0.2	-0.053800014	0.037482383	-0.269000072	0.265040472	0.14260749
1.A.5. Other	CO2	8370.16	4124.19	5	5	7.07	0.0	-0.004052209	0.013118122	-0.020261045	0.092759127	0.009014766
1.B.2. Oil and Natural Gas	CO2	3408.21	5171.49583	10	15	18.03	0.2	0.009456387	0.016449366	0.141845811	0.232629165	0.074236563
2.A. Mineral Products.	CO2	5744.63	2507.20146	10	15	18.03	0.0	-0.003809586	0.007974844	-0.057143788	0.112781331	0.015985041
2.B. Chemical Industry .	CO2	1355.56	171.93456	10	15	18.03	0.0	-0.002233954	0.000546885	-0.033509311	0.007734125	0.001182691
2.C. Metal Production.	CO2	12932.6799	10507.4715	10	15	18.03	0.9	0.006887639	0.033421905	0.103314586	0.47265712	0.234078657
5.A. Changes in Forest and Other Woody Bioma	CO2	97.19		50	80	94.34	0.0	-0.000199385	0	-0.015950798	0	0.000254428
5.A. Changes in Forest and Other Woody Bioma	CO2	-7810.79	-7721.7341	50	80	94.34	12.9	-0.008539362	0.024561101	-0.683148991	1.736732102	3.482930938
5.B. Forest and Grassland Conversion.	CO2	6.26	280.43888	25	75	79.06	0.0	0.00087917	0.000892013	0.065937785	0.031537424	0.005342401
1.A.1. Energy Industries	N2O	388.516902	328.741673	5	50	50.25	0.0	0.000248607	0.001045653	0.012430334	0.007393886	0.000209183
1.A.2. Manufacturing Industries and Constructior	N2O	112.709781	114.844426	5	50	50.25	0.0	0.000134069	0.000365294	0.006703468	0.002583021	5.16085E-05
1.A.3. Transport	N2O	57.3319301	21.6195922	5	50	50.25	0.0	-4.88495E-05	6.87671E-05	-0.002442474	0.000486257	6.20212E-06
1.A.4. Other Sectors	N2O	194.497577	46.1816455	5	50	50.25	0.0	-0.000252117	0.000146893	-0.01260587	0.001038693	0.000159987
1.A.5. Other	N2O	27.4386549	13.5195061	5	50	50.25	0.0	-1.3288E-05	4.30025E-05	-0.000664398	0.000304074	5.33886E-07
4.B. Manure Management.	N2O	375.1	198.4	15	30	33.54	0.0	-0.000138451	0.000631066	-0.004153541	0.013386927	0.000196462
4.D. Agricultural Soils(2).	N2O	25217.694	9798.17	20	30	36.06	3.0	-0.020551916	0.031165777	-0.616557485	0.881501284	1.157187646
4.F. Field Burning of Agricultural Residues.	N2O	24.304	21.297	20	30	36.06	0.0	1.78812E-05	6.7741E-05	0.000536437	0.001916004	3.95884E-06
6.B. Wastewater Handling.	N2O	452.6	384.4	15	30	33.54	0.0	0.000294175	0.00122269	0.008825264	0.025937172	0.000750622
Keep Blank!	…										0	
Total		314388.7626	202771.1719			∑H	34.6				∑M	11.4670044
					Percentage uncertainty in total inventory:		5.880740472				Trend uncertainty:	3.386296561

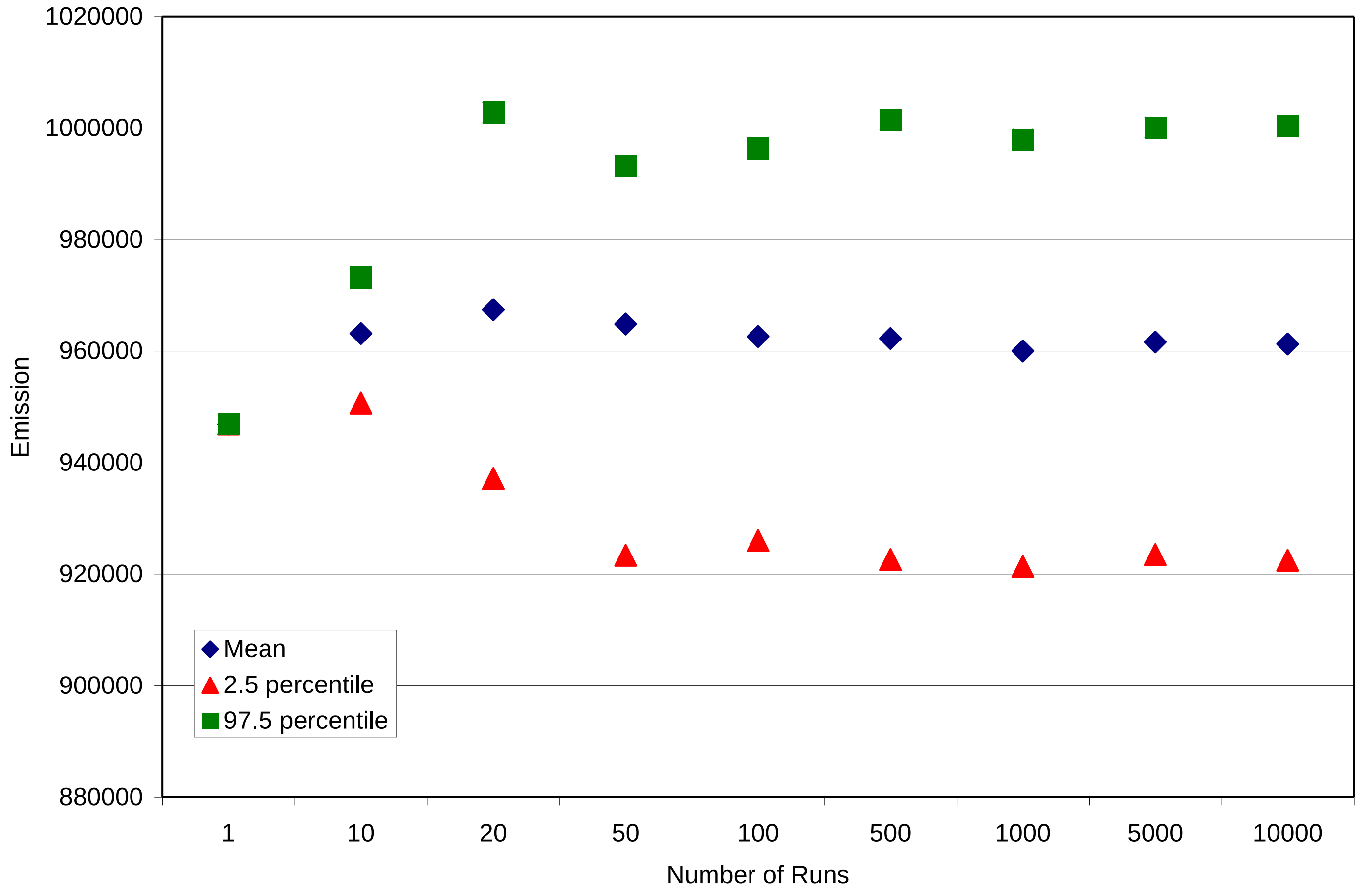
Illustration of Monte-Carlo Method



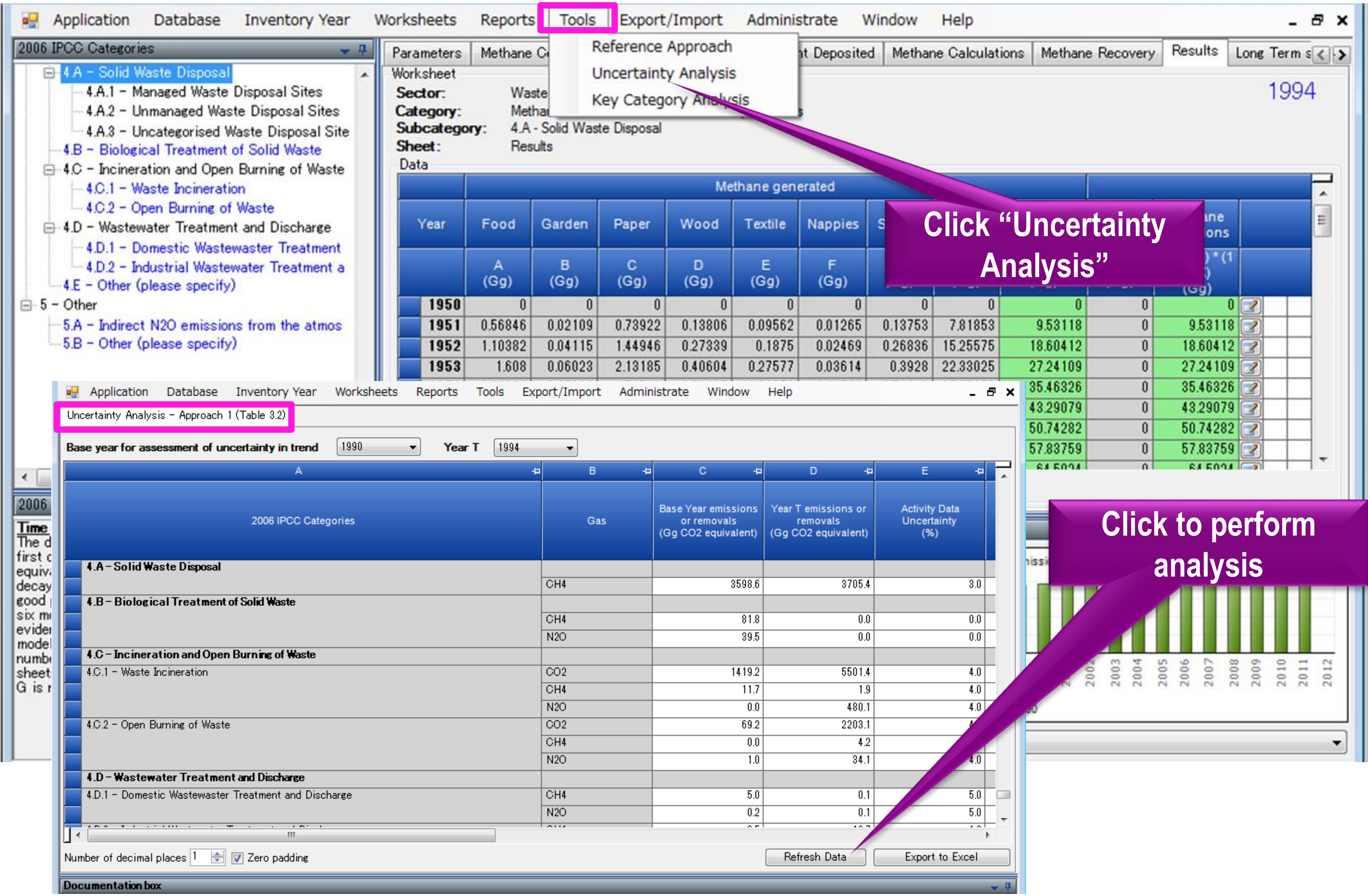
Example of Monte Carlo Results



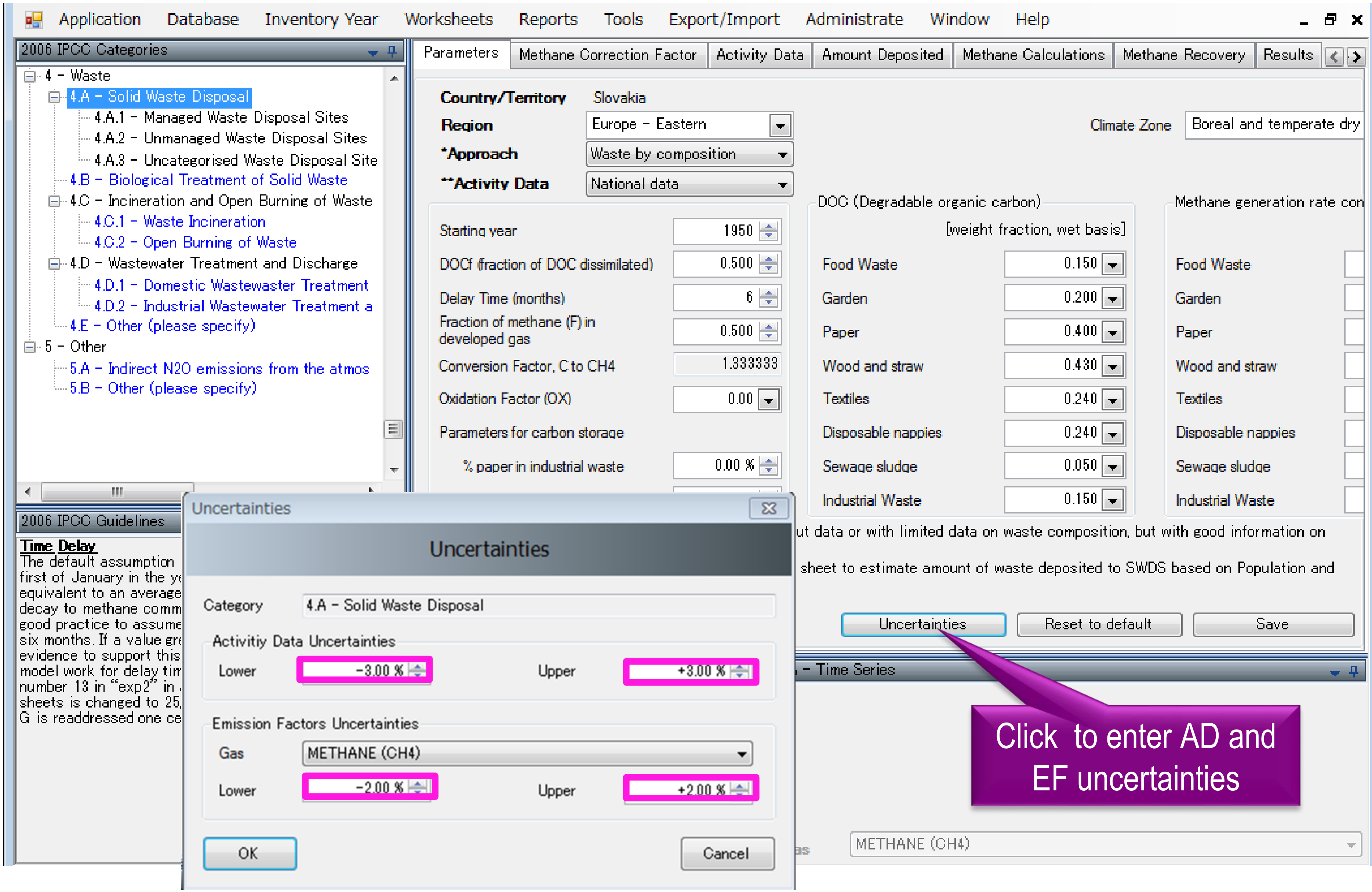
Summary Results



IPCC Inventory Software: Uncertainty Analysis



IPCC Inventory Software: Uncertainty Analysis (cont.)



Summary

- Even simple uncertainty estimates give useful information - If they are performed well
- Assessment of uncertainty in the input parameters **should** be part of the data collection
  - Careful consideration will improve estimates as well as providing input data for uncertainty analysis
- If resources limited: effort spent on uncertainty analysis should be small compared with total effort

- **At its simplest a well planned uncertainty assessment should only take a few extra hours!**
  - Uncertainty in AD assessed as data collected
  - Uncertainty in EFs from guidelines now available
  - Aggregate categories/gases to independent groups of sources/sinks
  - Use Approach 1

Thank you