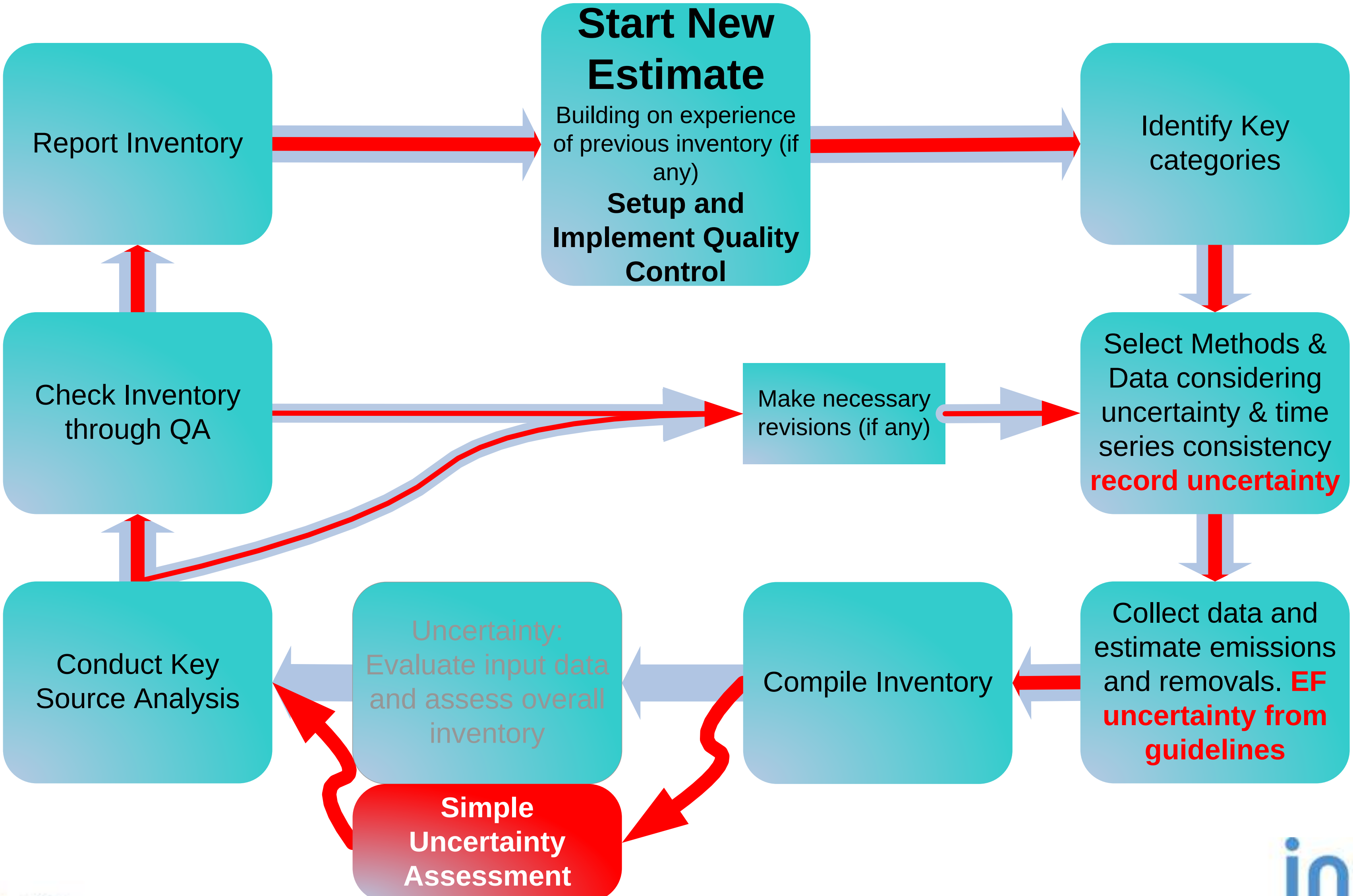
Uncertainty Analysis in Emission Inventories

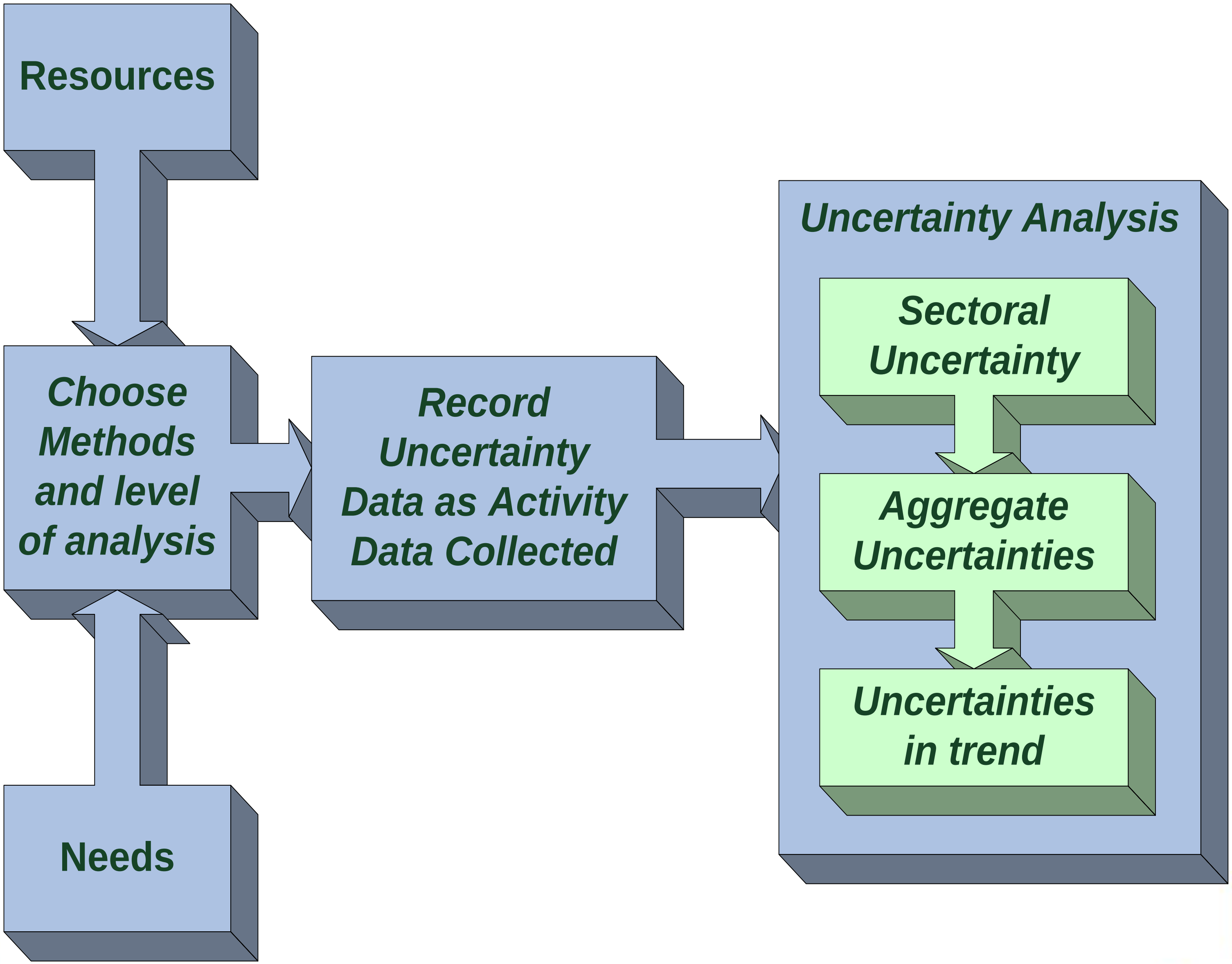
Introduction

- Most important is producing high quality "Good Practice" emission and removal estimates
  - Accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are reduced so far as possible.
- Uncertainty in GHG inventory: a lack of knowledge of the true value of a variable that can be described as a probability density function (PDF) characterising the range and likelihood of possible values.
- 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.
- An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice.

Inventory Cycle



Uncertainty Analysis



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

Specifying Uncertainty

- Uncertainty is quoted as the 2.5 and 97.5 percentile i.e. bounds around a 95% confidence interval

- This can be expressed as percentage of central estimate
  - 234 ± 23%
  - 26400 (- 50%, + 100%) or (i.e. a factor of 2)

Determining Data Uncertainties

Sources of Uncertainty

- Assumptions and methods
  - The method may not accurately reflect the emissions. Good Practice requires that biases be reduced as much as possible. Guidelines aim to be as unbiased and complete as possible.
- Input Data
  - Measured values have errors and EFs may not be truly representative
- Calculation errors
  - Good QA/QC to prevent these

Input Data Uncertainties

- Account for all causes of uncertainties, as far as possible
  - Lack of data
    - Use of proxies, extrapolation etc.
  - Data not truly representative
  - Statistical random sampling error
  - Measurement error
  - Misreporting
  - Missing data (e.g. measurements below detection limit)
- Data collection activities should consider data uncertainties
  - This will ensure the best data is collected and ensures good practice estimates
  - As you collect data you should assess how “good” it is

WMO UNEP

ipcc INTERGOVERNMENTAL PANEL ON climate change

Sources of Data

- National Statistics Agencies
- Sectoral experts, stakeholder organisations
- Other national experts
- IPCC Emission Factor Database
- Other international experts
- International organisations publishing statistics e.g., United Nations, FAO, the International Energy Agency, OECD and the IMF
- Reference libraries (National Libraries)
- Scientific and technical articles in environmental books, journals and reports.
- Universities
- Web search for organisations & specialists
- National Inventory Reports from Parties to the United Nations Framework Convention on Climate Change

Uncertainty Information

Increasing Uncertainty

Census – A complete count – if well designed should have small errors

Survey – A count of a sample – sampling errors should be quoted or determined

Empirical Data – Either measured data or literature. Should have quoted errors derived from measurements.

Expert Judgement – Experts SHOULD give range of possible value or mean and uncertainty

Official Statistics – Official statistics should have errors quoted, otherwise “balancing terms” and “statistical difference” give indication

Guidelines – Guidelines give uncertainty estimates for emission factors and other default parameters

Activity Data

Emission Factors

Expert Judgement

- Expert judgement is always required since one must judge whether the data are a representative random sample and, if so, what methods to use to analyze the data
- This requires both technical and statistical judgement
- The goal of expert judgement may be choosing:
  - the proper methodology
  - the parameter value and uncertainty from ranges provided
  - the most appropriate data to use
  - the most appropriate way to apply a methodology

Aggregating Uncertainties

Methods to Combine Uncertainties

- Error Propagation
  - Simple (standard spreadsheet can be used)
    - Guidelines give explanation and equations
  - Difficult to deal with correlations
  - Strictly (standard deviation/mean) < 0.3
- Monte Carlo Simulation
  - More complex (specialised software is used)
  - Needs shape of pdf
  - Suitable where uncertainties large, non-Gaussian, complex algorithms, correlations exist and uncertainties vary with time

Approach 1: 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

Approach 1 uncertainty calculation

Activity Data uncertainties based on source of data

EF uncertainties based on defaults in guidelines

Note short list of source/sinks

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	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\Sigma D)^2}$	Note B	$\left\lvert\frac{D}{\Sigma C}\right\rvert$	$I \bullet F$	$J \bullet E \bullet \sqrt{2}$	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	[illegible]	[illegible]	[illegible]	[illegible]	1.5	-0.005462727	0.023368679	-0.163881819	0.495724537	0.272600067
4.B. Manure Management.	CH4	1903.28061	[illegible]	[illegible]	[illegible]	[illegible]	0.0	-8.88245E-05	0.003815756	-0.002664735	0.080944413	0.006559099
4.C. Rice Cultivation.	CH4	522.9	[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	[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	[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]	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	[illegible]	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

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 standard data collection QA/QC
  - 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

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