Uncertainty Evaluation of Waste Sector : Korea's experience

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Contents

1. Background

Uncertainty

- **Concept**
  - Lack of knowledge of the true value of a variable that can be described as a probability density function(PDF)
  - Uncertainty depends on the analyst's state of knowledge

  *** Presented in 2006 IPCC Guidelines, Volume Ⅰ, Chapter 3 Uncertainties**

- **Object**
  - Quality improvement and assurance on GHGs Inventory

Uncertainty Evaluation

- **An essential part of an inventory**
  - Helps prioritise efforts to improve accuracy
  - Guides decisions on methodological choice
  - Most inventories and sources are reasonably reliable
  - Some sources may be order of magnitude estimates
  - Difficult or impossible to quantify and completely characterise all inventory uncertainties
  - Pragmatic approach – Use best available data and expert judgement

- **Reporting**
  - Need uncertainties in all parameters used, preferably need PDF as well (activity data and emission factor)
  - These need to be documented, reviewed and used to estimate total inventory uncertainty

Sources of Evaluation

- Measurement errors
- Uncertainties in factors
- Use of Statistics
- Application of emission factors
- Representivity
- Expert Judgement – expert elicitation
- Models - applicability

Generic Method

- **Tier 1 approach**
  - Estimating uncertainties by source category with simplifying assumptions : Using the error propagation equation in two steps.

Rule	Description
A approximation	Used to arrive at the overall uncertainty in national emissions and the trend in national emissions between the base year and the current year.
B approximation	Used to combine emission factor and activity data ranges by source category and greenhouse gas.

* Suggested in IPCC GPG and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 6 Quantifying Uncertainties in Practice

Generic Method

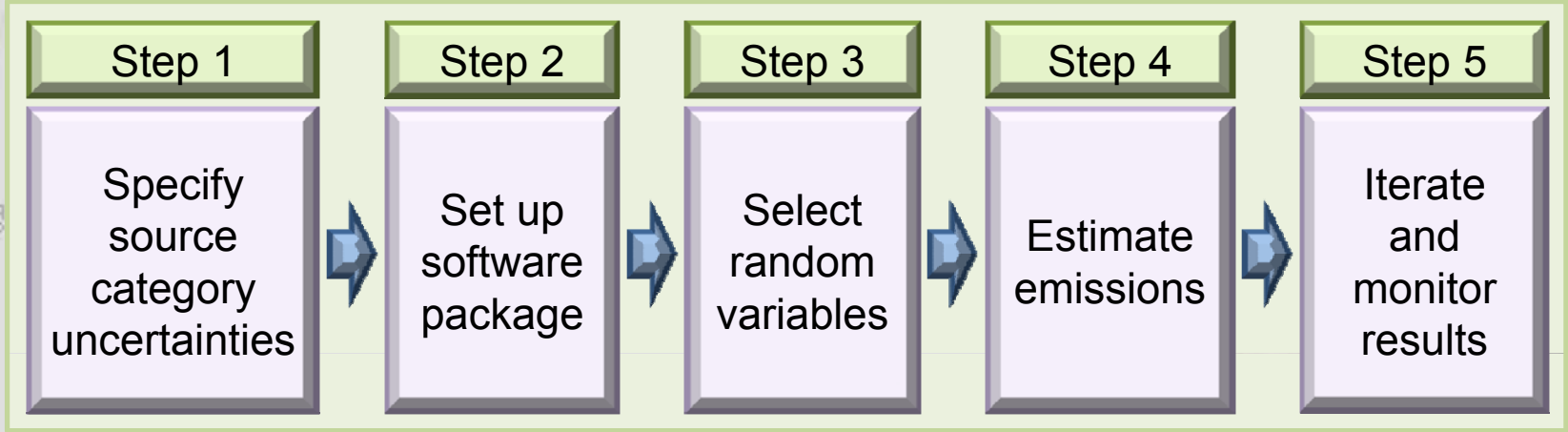
TABLE 6.3

TIER 1 UNCERTAINTY CALCULATION AND REPORTING EXAMPLE

	A	B	C	D	E	F	G	H	I	J	K	L	M
	IPCC Source Category	Gas	Base year emissions 1990	Year t emissions 1997	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
1A	Coal	CO2	238 218	142 266	1.2	6	6.1	1.2	-0.0966	0.1840	-0.58	0.31	0.66
1A	Oil	CO2	208 684	196 161	1	2	2.2	0.6	0.0076	0.2538	0.02	0.36	0.36
1A	Natural Gas	CO2	111 052	181 691	2	1	2.2	0.6	0.1039	0.2351	0.10	0.66	0.67
1A	Other (waste)	CO2	138	741	7	20	21.2	0.0	0.0008	0.0010	0.02	0.01	0.02
1B	Solid Fuel Transformation	CO2	2 573	1 566	1.2	6	6.1	0.0	-0.0010	0.0020	-0.01	0.00	0.01
1B	Oil & Natural Gas	CO2	8 908	6 265		14	14.0	0.1	-0.0024	0.0081	-0.03	0.00	0.03
2A1	Cement Production	CO2	6 693	6 157	1	2	2.2	0.0	0.0001	0.0080	0.00	0.01	0.01
2A2	Lime Production	CO2	1 192	1 703	1	5	5.1	0.0	0.0008	0.0022	0.00	0.00	0.01
2A3	Limestone & Dolomite use	CO2	1 369	1 551	1	5	5.1	0.0	0.0004	0.0020	0.00	0.00	0.00
2A4	Soda Ash Use	CO2	116	120	15	2	15.1	0.0	0.0000	0.0002	0.00	0.00	0.00
2B	Ammonia Production	CO2	1 358	814		5	5.0	0.0	-0.0005	0.0011	0.00	0.00	0.00
2C1	Iron&Steel Production	CO2	3 210	1 495	1.2	6	6.1	0.0	-0.0019	0.0019	-0.01	0.00	0.01
5D	Land Use Change & Forestry	CO2	31 965	27 075	5	54	54.2	2.1	-0.0027	0.0350	-0.14	0.25	0.29
6C	MSW Incineration	CO2	660	29	7	20	21.2	0.0	-0.0007	0.0000	-0.01	0.00	0.01
		CO2 Total	616 137	567 634									
1A	All Fuel	CH4	2 507	1 975	1.2	50	50.0	0.1	-0.0004	0.0026	-0.02	0.00	0.02
1B1	Coal Mining	CH4	17 188	6 687	1	13	13.0	0.1	-0.0116	0.0087	-0.15	0.01	0.15
	Solid Fuel Transformation	CH4	215	173	6	50	50.4	0.0	0.0000	0.0002	0.00	0.00	0.00
1B2	Natural Gas Transmission	CH4	8 103	7 301	2	15	15.1	0.2	-0.0001	0.0094	0.00	0.03	0.03
	Offshore Oil& Gas	CH4	2 402	1 957	10	26	27.9	0.1	-0.0003	0.0025	-0.01	0.04	0.04
2C	Iron & Steel Production	CH4	16	13	1.2	50	50.0	0.0	0.0000	0.0000	0.00	0.00	0.00
4A	Enteric Fermentation	CH4	19 177	18 752	1	20	20.0	0.5	0.0016	0.0243	0.03	0.03	0.05
4B	Manure Management	CH4	2 338	2 325	1	30	30.0	0.1	0.0003	0.0030	0.01	0.00	0.01
4F	Field Burning	CH4	266	0	25	50	55.9	0.0	-0.0003	0.0000	-0.02	0.00	0.02
6A	Solid Waste Disposal	CH4	23 457	17 346	15	46	48.4	1.2	-0.0052	0.0224	-0.24	0.48	0.53
6B	Wastewater Handling	CH4	701	726	15	48	50.3	0.1	0.0001	0.0009	0.01	0.02	0.02
6C	Waste Incineration	CH4	1	1	7	50	50.5	0.0	0.0000	0.0000	0.00	0.00	0.00
		CH4 total	76 571	57 257									

Generic Method

- **Tier 2 approach**
  - Estimating uncertainties by source category using Monte Carlo analysis (principle)
    - Selecting random values of emission factor and activity data from within their individual probability density functions
    - Calculating the corresponding emission values.
  - Monte Carlo approach's five clearly defined steps



Generic Method

TABLE 6.2

TIER 2 UNCERTAINTY REPORTING

A	B	C	D	E	F	G	H	I	J
IPCC Source category	Gas	Base year emissions	Year t emissions	Uncertainty in year t emissions as % of emissions in the category		Uncertainty introduced on national total in year t	% change in emissions between year t and base year	Range of likely % change between year t and base year	
		(Gg CO_2 equivalent)	(Gg CO_2 equivalent)	% below (2.5 percentile)	% above (97.5 percentile)	(%)	(%)	Lower % (2.5 percentile)	Upper % (97.5 percentile)
e.g. 1.A.1 Energy Industries Fuel 1	CO_2								
e.g. 1.A.2 Energy Industries Fuel 2	CO_2								
Etc…	…								
Total									

보성차밭 대한다원 2라원일부

For example

Country	Method	Country	Method
Austria	Tier 1 / Tier 2	Italy	Tier 1
Belgium	Tier 1	Latvia	Tier 1
Bulgaria	-	Lithuania	Tier 1
Cyprus	-	Luxembourg	Tier 1
Czech Republic	Tier 1	Malta	Tier 1
Denmark	Tier 1	Netherlands	Tier 1
Estonia	Tier 1	Poland	Tier 1
Finland	Tier 1 (LULUCF) / Tier 2 (LULUCF excluded)	Portugal	Tier 1 2005
		Romania	-
France	Tier 1	Slovakia	Tier 1
Germany	Tier 2	Solvenia	Tier 1
Greece	Tier 1	Spain	Tier 1
Hungary	Tier 1	Sweden	Tier 1
Ireland	Tier 1	United Kingdom	Tier 1/ Tier 2 2005

2. Scheme of National GHGs Inventory

Plan for National Inventories

Jun.	Collection of Sectoral GHGs emissions	
Jul.	Analysis of whole GHGs emissions	
Aug.	Making out draft on GHGs inventories	
Sept.	Review by Working Group Ⅰ → Review by Working Group Ⅱ	
Oct.	Holding GHGs Inventory Conference	
Nov.	Confirmation and publication of GHGs Inventories	Publication of Report
Dec.	Discussion on Improvements of Inventories	QC
Jan.	Discussion on Improvements of Methodologies	QA, Expert group
Feb.	Preparation on submission of GHGs Inventories	
Mar.	Collection of Sectoral GHGs emissions	

Present Condition

Estimates of Sectoral GHGs Emissions

- Basic data used in estimating GHGs Emissions
  - Methodology estimating GHGs emissions
  - Activity data
  - Implied Emission Factor
  - etc
- **Result of Uncertainty Evaluation** and QA/QC
- Review of sectoral GHGs inventory
- Improvements and prospect of GHGs inventory

Submission

Modification
Complement

↓

Confirmation

3. U.E in Waste sector

System of U.E in Waste sector

1st Stage

Tier 1 approach

Combined Uncertainty

U.E

Activity Data

Emission Factor

Uncertainty in Trend

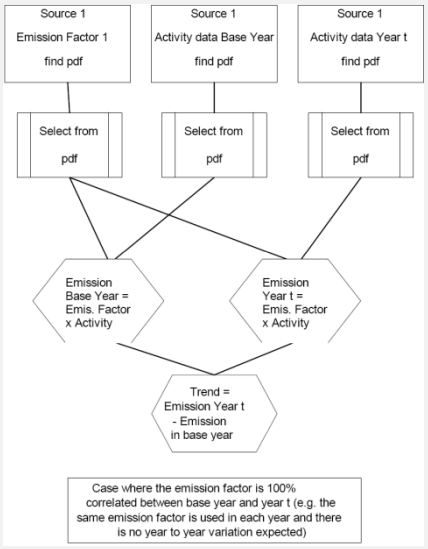
Sensitivity

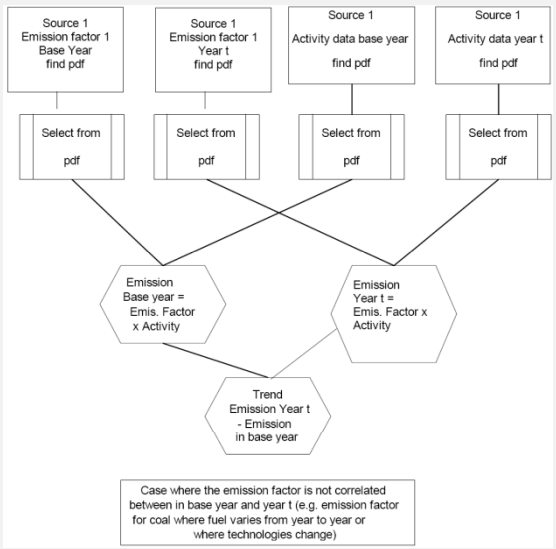
Type B

Type A

2nd Stage

Tier 2 approach





Tier 1 approach

Uncertainty Assessment in Waste sector

A			B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source Category			Gas	Base year emissions (1990)	Year t emissions (2006)	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor 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	Input data	$(E^2+F^2)^{1/2}$	(G D)/ΣD		D/ΣC	I F	J·E·2$^{1/2}$	$(K^2+L^2)^{1/2}$
				(ton CO2 eq.)	(ton CO2 eq.)	%	%	%	%	%	%	%	%	%
SUM				ΣC	ΣD				$(\Sigma H^2)^{1/2}$					
				16,972.7	15,449.5				339.803					
					A	b	a	B						
SWDS	Controlled	MSW & ISW	CH_4	15,469.4	5,680.0	17.321	40.000	43.589	16.026	-0.491	0.335	-19.620	8.197	21.264
		HW & CW	CH_4	0.0	63.9	17.321	40.000	43.589	0.180	0.004	0.004	0.151	0.092	0.177
Incineration	MSW	Rubber and leather	CO_2	18.3	420.6	5.000	10.000	11.180	0.304	0.024	0.025	0.238	0.175	0.296
		Plastics	CO_2	28.3	1,106.8	5.000	10.000	11.180	0.801	0.064	0.065	0.637	0.461	0.786
		Other	CO_2	0.0	212.6	5.000	10.000	11.180	0.154	0.013	0.013	0.125	0.089	0.153
	ISW	Plastics	CO_2	0.0	3,902.5	5.000	10.000	11.180	2.824	0.230	0.230	2.299	1.626	2.816
		Other	CO_2	0.0	143.6	5.000	10.000	11.180	0.104	0.008	0.008	0.085	0.060	0.104
		Textiles	CO_2	0.0	31.3	5.000	10.000	11.180	0.023	0.002	0.002	0.018	0.013	0.023
		Synthetic Rubber	CO_2	0.0	276.6	5.000	10.000	11.180	0.200	0.016	0.016	0.163	0.115	0.200
		Leather	CO_2	0.0	3.7	5.000	10.000	11.180	0.003	0.000	0.000	0.002	0.002	0.003
	HW	Plastics	CO_2	0.0	94.2	5.000	10.000	11.180	0.068	0.006	0.006	0.055	0.039	0.068
		Synthetic Rubber	CO_2	0.0	4.8	5.000	10.000	11.180	0.003	0.000	0.000	0.003	0.002	0.003
		Solvent	CO_2	0.0	423.7	5.000	20.000	20.616	0.565	0.025	0.025	0.499	0.177	0.530
		Paint	CO_2	0.0	253.2	5.000	20.000	20.616	0.338	0.015	0.015	0.298	0.105	0.316
		Oil	CO_2	0.0	697.6	5.000	20.000	20.616	0.931	0.041	0.041	0.822	0.291	0.872
		PCB	CO_2	0.0	0.4	5.000	20.000	20.616	0.001	0.000	0.000	0.001	0.000	0.001
	CW	Plastics	CO_2	0.0	125.7	5.000	10.000	11.180	0.091	0.007	0.007	0.074	0.052	0.091
	MSW		N_2O	4.3	35.4	5.000	10.000	11.180	0.026	0.002	0.002	0.019	0.015	0.024
	ISW		N_2O	2.2	87.8	5.000	10.000	11.180	0.064	0.005	0.005	0.051	0.037	0.062
	HW		N_2O	0.0	14.9	5.000	10.000	11.180	0.011	0.001	0.001	0.009	0.006	0.011
	CW		N_2O	0.0	1.4	5.000	10.000	11.180	0.001	0.000	0.000	0.001	0.001	0.001
	SS		N_2O	13.8	64.6	5.000	10.000	11.180	0.047	0.003	0.004	0.031	0.027	0.041
Wastewater Handling and Discharge	Industrial wastewater		CH_4	70.2	62.3	30.000	31.623	43.589	0.176	0.000	0.004	-0.003	0.156	0.156
	Domestic wastewater	Treated system	CH_4	8.3	71.4	30.000	31.623	43.589	0.202	0.004	0.004	0.119	0.179	0.215
			N_2O	962.3	1,070.1	15.462	4,900.000	4,900.024	339.404	0.011	0.063	56.040	1.379	56.057
		Untreated system	CH_4	395.7	217.2	30.000	58.310	65.571	0.922	-0.008	0.013	-0.491	0.513	0.732
Biological Treatment of Solid waste	Composting		CH_4	0.0	178.4	58.310	100.000	115.758	1.337	0.011	0.011	1.051	0.867	1.363
			N_2O	0.0	197.5	30.000	100.000	104.403	1.336	0.012	0.012	1.164	0.494	1.264
	Anaerobic digestion		CH_4	0.0	7.0	58.310	100.000	102.424	0.318	0.000	0.000	0.288	0.034	0.289

Tier 2 approach

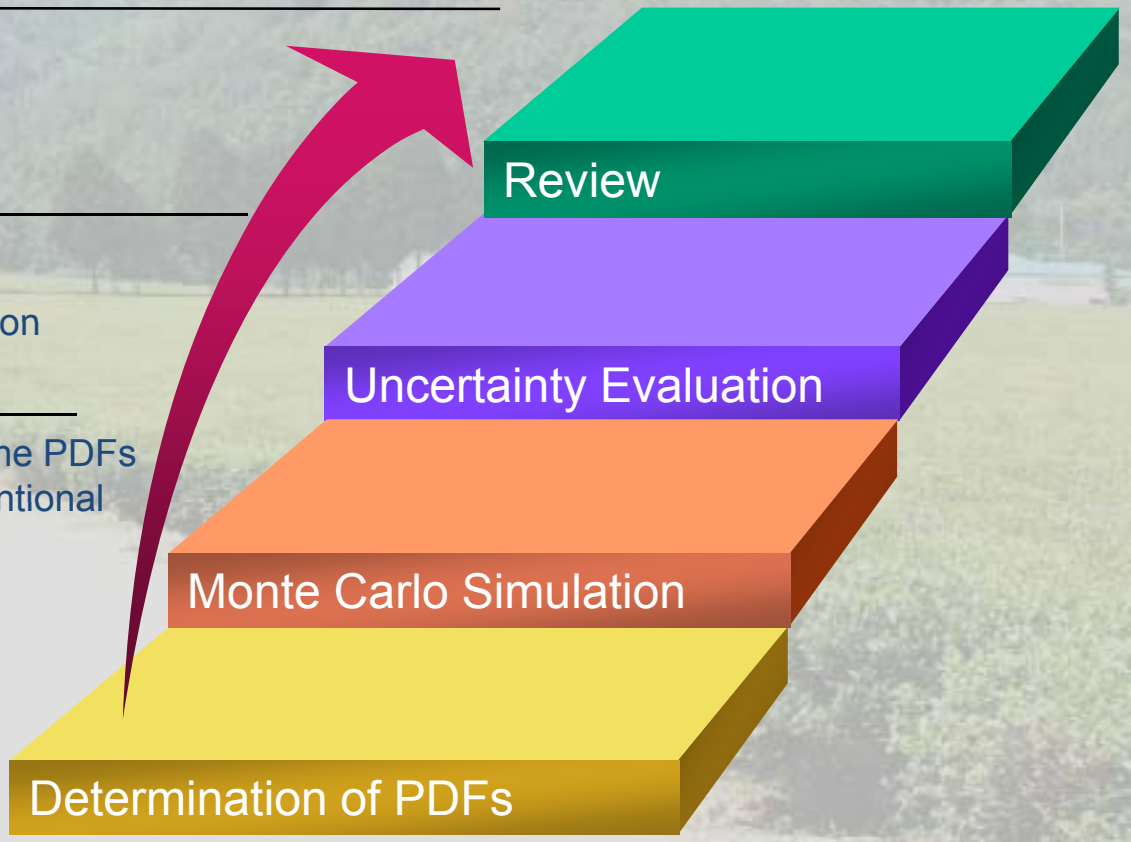
- **SWDS**

Review

Analysis of uncertainty distribution estimated by Monte Carlo Simulation

- Select values for variables from the PDFs
- Calculate emissions in the conventional way
- Iterates and monitor results

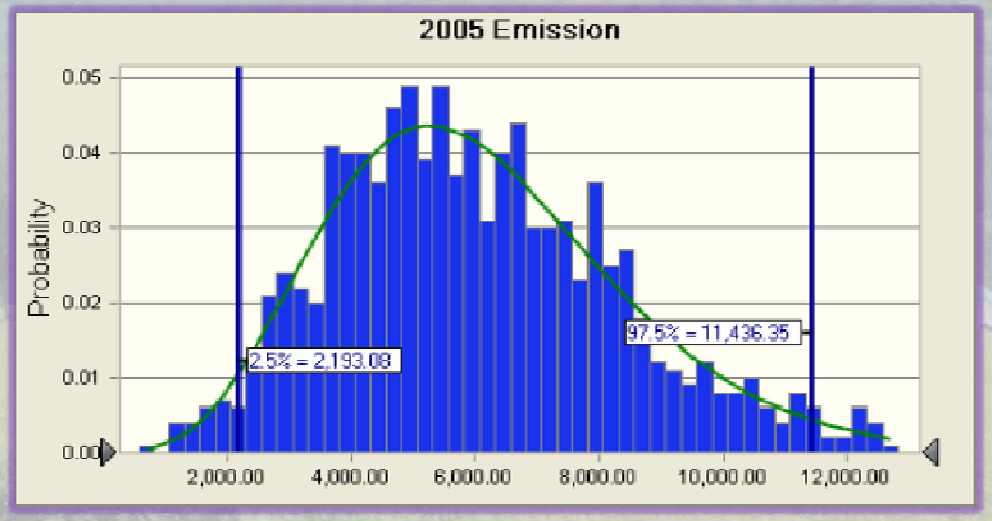
Determine the probability density functions(Normal, Lognormal, Weibull, Gamma) on each parameter



Tier 2 approach

- **SWDS**

• Determination of PDFs
• Monte Carlo Simulation
• Uncertainty evaluation



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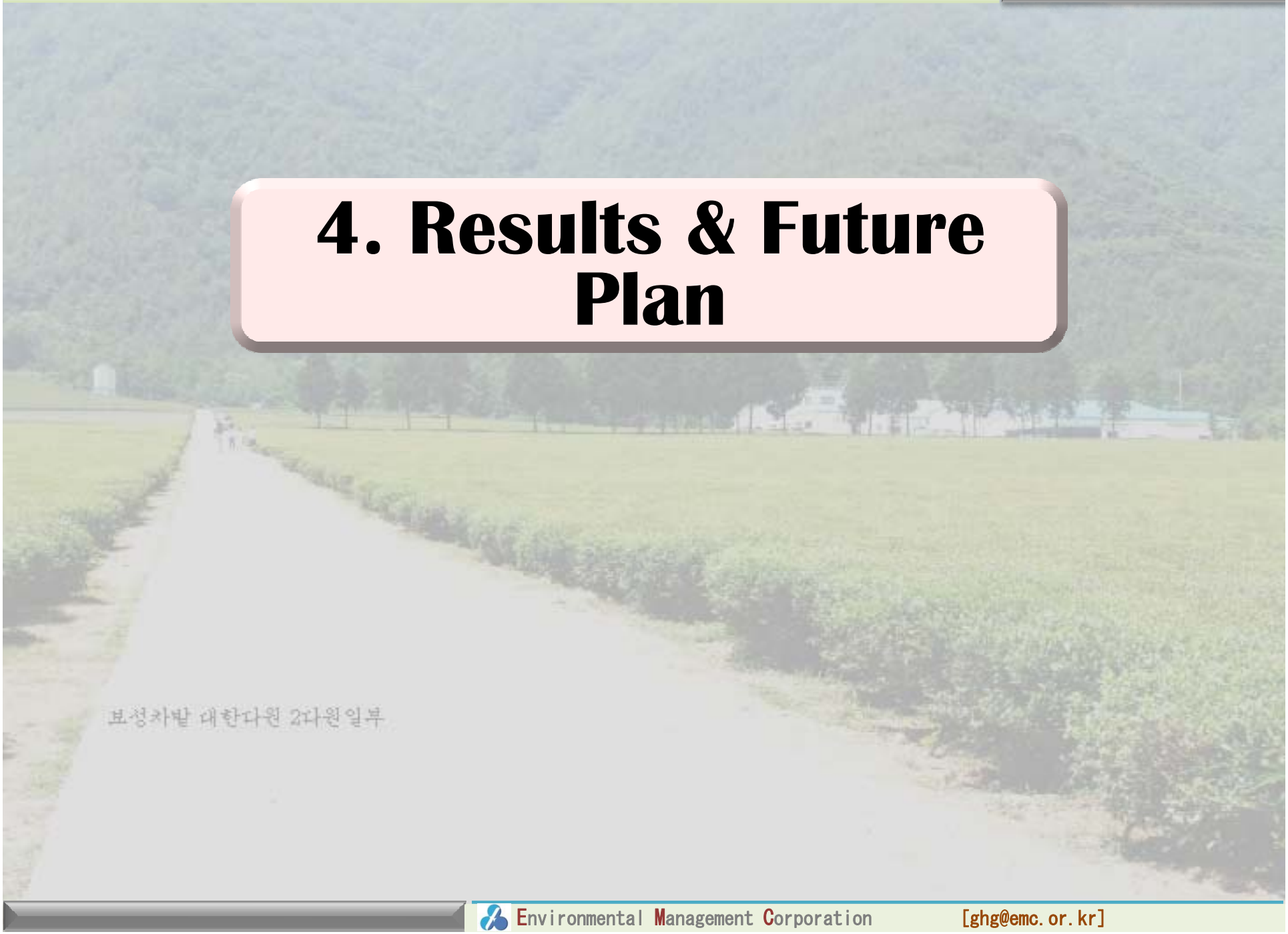
		($Gg\ CO_2$ eq.)	($Gg\ CO_2$ eq.)	% below (2.5)	% above (97.5)	(%)	(%)	Lower % (2.5)	Upper % (97.5)
SWDS	CH_4	8,169	7,483	3,382	12,966	-	-8	-10	-3



4. Results & Future Plan

Results

● Method

- Refer to IPCC GPG 2000 and 2006 IPCC G/L

• Input the uncertainty of activity data and emission factor → Estimate the combined uncertainty

* by Tier 1 and Tier 2(Monte Carlo simulation) approach

● Issues

- Can't know the uncertainty on GHGs emissions of the whole sectors
- Doesn't have information on Probability Density Functions of emission factor and activity data for applying for Tier 2

● Implications

- For advanced uncertainty evaluation, it is meaningful that we only attempted uncertainty evaluation by Tier 1 and Tier 2

Future Plan

- Improvement on Uncertainty Evaluation in the Tier 2
  - Benchmark on the Annex Ⅰ countries
  - Based on the IPCC GPG 2000 or 2006 IPCC G/L

- What we must do,
  - Development of decision tree on uncertainty
  - Decision on estimation method of uncertainty

Thank you for your attention