Effects of Values and Calculation Changes in Three IPCC Guidelines on Greenhouse Gas Inventories

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EAAP + WAAP + Interbull 2023
Lyon, August 26th- September 1st 2023

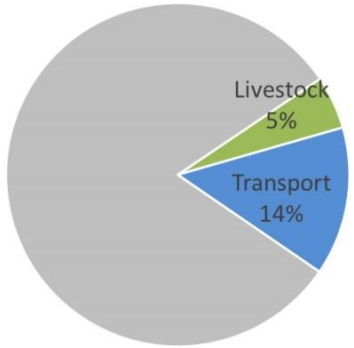
This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, and Forestry (IPET) and Korea Smart Farm R&D Foundation (KosFarm) through Smart Farm Innovation Technology Development Program, funded by Ministry of Agriculture, Food, and Rural Affairs (MAFRA) and Ministry of Science and ICT (MSIT), Rural Development Administration (RDA) (RS-2023-00221189)

Overview

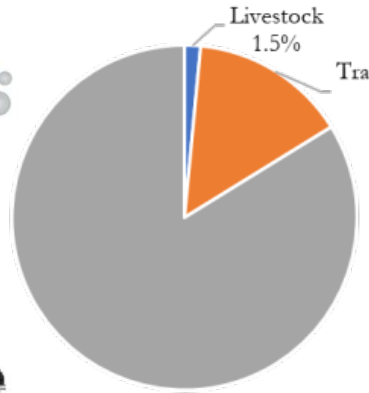
- How GHG emissions from livestock sector is calculated
- Why we use GHG inventory
- IPCC Guidelines (1996 GL, 2006 GL, 2019 Refinement) to estimate GHG inventory
- Calculation of GHG emissions from Korea using IPCC guidelines (study case)
- How the use of different IPCC guidelines impacts the estimated GHG inventory

How GHG emissions from livestock are calculated?

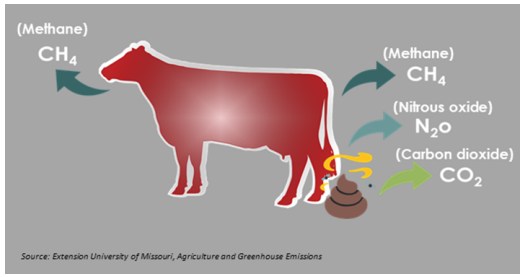
Global Direct Emissions
(IPCC sectoral approach)



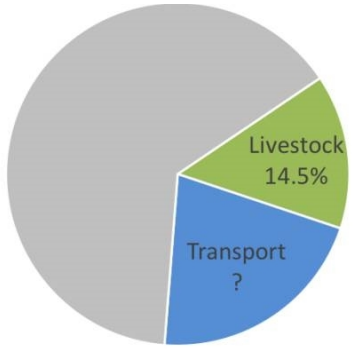
Korea Direct Emissions

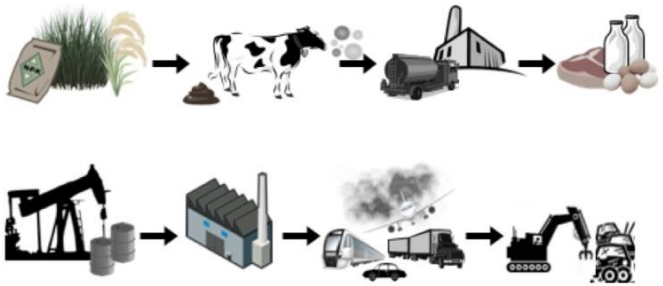


(Korea's Ministry of Environment, 2022)

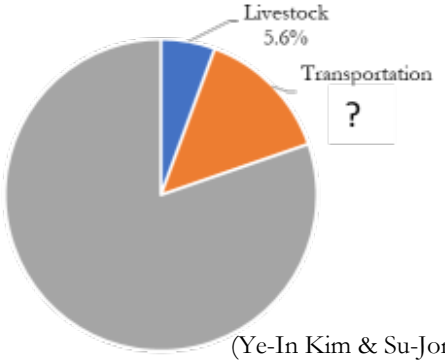


Global Life Cycle Assessment (LCA)





Korea LCA



(Ye-In Kim & Su-Jong Jeong, 2021)

Greenhouse Gas Inventory (GHG inventory)

- Estimation of sectoral emissions
- Main tool for GHG report

Source of emission

- Enteric fermentation (CH_4)
- Manure management (CH_4, N_2O)

Life Cycle Assessment (LCA)

- Identifies impacts on environment
- Overlooks importance of livestock industry (food security, other industry)

Whole production system
(gate-to-cradle)

Kohlman, T., & Bjurstrom, A. (2023). Feeding for efficiency: Dietary impacts on greenhouse gas production.
Korea Ministry of Environment. (2022). South Korea's Greenhouse Gas Emissions decreased by 6.4% year-on-year to 656.22 million tons in 2020.
Mottet, A., & Steinfeld, H. (2018). Cars or livestock: which contribute more to climate change?
Ye-In, Ki., & Su-Jong, J. (2021). Analysis of greenhouse gas emission from Korean livestock industry through life cycle assessment. Proceedings of the Autumn Meeting of KMS 2021.

Why we use GHG inventory?

- National emissions are not yet able to be measured due to its complexity, but able to be estimated
- Policy and decision-making:

  → The need of setting emission limit/target/goals

  → Monitor progress in transparent ways
- Internationally accepted methods and guidelines
- Comprehensive scheme on prioritizing sectoral mitigation
- The main tool to report GHG emissions under international treaties and agreement
- Estimated emissions should be maintained its Transparency, Accuracy, Completeness, Consistency, Comparability (TACCC) principles.

GHG Inventory reporting under United Nation Framework Convention on Climate Change (UNFCCC)

THE CONVENTION (1992 ~)

Commitment	Stabilize GHG concentration "at a level that would prevent dangerous anthropogenic interference with the climate system"
Signatories	197 countries
Reporting	Measurement, Reporting, Verification (MRV)
Developed countries (Annex I)	Annual GHGI, National Communication (NC) every 4 years, Biennial Reports (BR) every 2 years
Developing countries (Non-Annex I)	National Communication (NC) including GHGI every 4 years, Biennial Update Reports (BUR) including GHGI every 2 years

KYOTO PROTOCOL (1992 ~ 2020)

Commitment	1st commitment: reduce 5% emissions below 1990 baseline during 2008-2012 for 37 industrialized countries in EU 2nd commitment: reduce 18% emission below 1990 baseline during 2013-2020
Signatories	192 countries
Reporting	Based on existing reporting and review procedures under the Convention Commitment has ended in 2020, thus, no reporting requirements at the moment

PARIS AGREEMENT (2015 ~)

Commitment	Limit the temperature increase well below 2.0°C, further 1.5°C above pre-industrial levels, decline of GHG emission by 43% by 2030
Signatories	195 countries
Reporting	Enhanced Transparency Framework (ETF)
Developed countries (Annex I)	Annual GHGI, Nationally Determined Contribution (NDC) every 5 years, Biennial Transparency Report (BTR) every 2 years, National Communication (NC) every 4 years
Developing countries (Non-Annex I)	Nationally Determined Contribution (NDC) every 5 years, Biennial Transparency Report (BTR) including GHGI every 2 years, National Communication (NC) including GHGI every 4 years

IPCC Guidelines to estimate GHG inventory

- Intergovernmental Panel on Climate Change Guidelines (IPCC GL) issued guidelines as the standard guideline to estimate GHG inventory
- Currently there are: 1996 GL, 2000 Good Practice Guidelines (GPG 2000), 2006 GL, 2019 Refinement
- Developed countries are required to use 2006 GL, whilst developing countries are not required to use 2006 GL, thus, use 1996 GL
- Reporting under Paris Agreement (ETF) will be effective no later than 31 December 2024
- Under ETF, all countries are required to use 2006 GL, in correspondence with 2019 Refinement as supplementary
- Therefore, developing countries will transition from using 1996 GL to 2006 GL

IPCC Guidelines

Element	Description
Versions	1996 GL, 2000 Good Practice Guidelines (GPG 2000), 2006 GL, 2019 Refinement
Tier	Tier 1 (default values), Tier 2 (country-specific values), Tier 3 (country-specific methodology)
Changes in guidelines	• Default values changes • Changes in climate zone • Equation change for CH_4 from manure management in 2019 Refinement

Consequences of the changes in guidelines

- Changes in estimated emission
- Overestimation/ underestimation of emission may be used for specific reason
- The difference of estimated emission may impact the decision making for mitigation approach

While changing the guidelines may have above-mentioned consequences, there is still no obligation for countries to 'adjust' the estimated emissions in previous reporting with the new estimated emissions using new guideline.
Therefore, the impact of these changes of estimated emissions (due to change of guidelines) remain unknown.

The Question

Would the use of newer guideline create better inventory?

Would the change of guideline be necessary?

Calculation of GHG emission from livestock sector in Korea

- Korea is currently using 1996 GL
- Korea is consistently developing its GHG inventory through its National Inventory Report

Element	Description
Guidelines	1996 GL, 2006 GL, 2019 GL
Methodology	Tier 1
Emissions	CH_4 from enteric fermentation, CH_4 from manure management, direct N_2O from manure management
Estimation year	1990, 2020
Livestock category	Dairy cattle, Hanwoo, Beef cattle, Swine, Layer chicken, Broiler chicken
Emission factors	Default values
Activity data	• Number of population • Manure management system
GWP (CO_2-eq)	25 (CH_4), 298 (N_2O)

GWP: Global Warming Potential, expressed in carbon dioxide equivalent (CO_2-eq)

Activity data used to estimate Korean GHG emissions

Animal category	Population (head)		Manure treatment system (MS)		
	1990	2020	Solid storage and dry lot	Liquid system	Other
Dairy cattle	499,689	408,243	0.666	0.004	0.330
Hanwoo cattle	-	3,190,768	0.754	0.004	0.243
Beef cattle	-	161,855	0.667	0.003	0.329
Swine	4,412,205	11,184,873	0.173	0.050	0.777
Chicken layer	40,127,223	73,541,183	0.579	0.001	0.420
Chicken broiler	24,049,627	97,557,487	0.524	0.001	0.475
Duck	-	8,676,228	0.508	0.004	0.488

KOSIS, 2022. Statistical database [WWW Document]. URL https://kosis.kr/eng/statisticsList/statisticsListIndex.do?parentId=K1.1&menuId=M_01_01&vwcd=MT_ETITLE&parmTabId=M_01_01

Region characteristic to calculate CH_4 emission from enteric fermentation for Korea

Animal category	Region characteristic		
	1996 GL	2006 GL	2019 Refinement
Dairy cattle	North America	North America	North America
Hanwoo cattle	North America	North America	North America
Beef cattle	North America	North America	North America
Swine	Developed country	Developed country	High productivity system
Chicken layer	N/A	N/A	N/A
Chicken broiler	N/A	N/A	N/A
Duck	N/A	N/A	N/A

GIR, 2019. 2021 national greenhouse gas inventory (1990-2019) [WWW Document]. URL http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=54&boardMasterId=2&boardCategoryId=

IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL (www.ipcc-nggip.iges.or.jp/%0Apublic/gl/invs1.html

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Region characteristic and climate zone to calculate CH_4 emissions from manure management for Korea

Animal category	Region characteristic			Climate zone		
	1996 GL	2006 GL	2019 Refinement	1996 GL	2006 GL	2019 Refinement
Dairy cattle	North America	North America	North America, high productivity	Cool	Cool 12°	Warm temperate, moist
Hanwoo cattle	North America	North America	North America, high productivity			
Beef cattle	North America	North America	North America, high productivity			
Swine	East Europe	East Europe	Eastern Europe, high productivity			
Chicken layer	Developed country	Developed country	Eastern Europe, high productivity			
Chicken broiler	Developed country	Developed country	Eastern Europe, high productivity			
Duck	Developing country	Developing country	Eastern Europe, high productivity			

GIR, 2019. 2021 national greenhouse gas inventory (1990-2019) [WWW Document]. URL http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=54&boardMasterId=2&boardCategoryId=
IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL (www.ipcc-nggip.iges.or.jp/%0Apublic/gl/invs1.html
IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
KMA, 2022. Climate of Korea [WWW Document]. URL https://web.kma.go.kr/eng/biz/climate_01.jsp

Region characteristic and climate zone to calculate direct N_2O emissions from manure management for Korea

Animal category	Region characteristic			Climate zone		
	1996 GL	2006 GL	2019 Refinement	1996 GL	2006 GL	2019 Refinement
Dairy cattle	North America	North America	North America, high productivity	Cool	Cool 12°	Warm temperate, moist
Hanwoo cattle	North America	North America	North America, high productivity			
Beef cattle	North America	North America	North America, high productivity			
Swine	East Europe	East Europe	Eastern Europe, high productivity			
Chicken layer	East Europe	East Europe, developed country	Asia, high productivity			
Chicken broiler	East Europe	East Europe, developed country	Asia, high productivity			
Duck	East Europe	East Europe, developing country	Asia, high and low productivity			

GIR, 2019. 2021 national greenhouse gas inventory (1990-2019) [WWW Document]. URL http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=54&boardMasterId=2&boardCategoryId=
IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL (www.ipcc-nggip.iges.or.jp/%0Apublic/gl/invs1.html
IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
KMA, 2022. Climate of Korea [WWW Document]. URL https://web.kma.go.kr/eng/biz/climate_01.jsp

Emission factor (EF) to calculate CH_4 emissions from enteric fermentation for Korea

Animal Category	EF (kg CH_4/head/year)		
	1996 GL	2006 GL	2019 Refinement
Dairy cattle	118	121	138
Hanwoo cattle	47	53	64
Beef cattle	47	53	64
Swine	1.5	1.5	1.5
Chicken layer	0	0	0
Chicken broiler	0	0	0
Duck	0	0	0

GIR, 2019. 2021 national greenhouse gas inventory (1990-2019) [WWW Document]. URL http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=54&boardMasterId=2&boardCategoryId=
IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL (www.ipcc-nggip.iges.or.jp/%0Apublic/gl/invs1.html
IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Emission factor (EF) to calculate CH_4 emissions from manure management for Korea

Animal Category	1996 GL	2006 GL	2019 Refinement					
	EF (kg CH_4/head/year)	EF (kg CH_4/head/year)	VS_{rate} (kg VS/1000 kg animal mass/day)	ABW (kg)	VS (kg/animal/year)	EF (g CH_4/kg VS)		
						Solid storage	Liquid system	Other
Dairy cattle	36	53	9.3	650	2,206.43	6.4	59.5	0
Hanwoo cattle	1	1	7.6	407	1,129.02	4.8	44.6	0
Beef cattle	1	1	7.6	407	1,129.02	4.8	44.6	0
Swine	3	3	4.9	59	105.52	12.1	111.6	0
Chicken layer	0.078	0.03	9.4	1.9	6.52	10.5	96.7	0
Chicken broiler	0.078	0.02	16	1.1	6.42	10.5	96.7	0
Duck	0.078	0.01	7.4	2.7	7.29	10.5	96.7	0

EF: emission factor, VS: volatile solid, ABW: average body weight
VS = VSrate • ABW/1000 • 365

GIR, 2019. 2021 national greenhouse gas inventory (1990-2019) [WWW Document]. URL http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=54&boardMasterId=2&boardCategoryId=
IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL (www.ipcc-nggip.iges.or.jp/%0Apublic/gl/invs1.html
IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Nitrogen excretion (N_{ex}) and emission factor (EF_3)to calculate N_2O emissions from manure management

Animal Category	1996 GL	2006 GL			2019 Refinement		
	N_{ex} (kg N/head/year)	N_{rate} (kg N/1000 kg animal mass/day)	ABW (kg)	N_{ex} (kg N/head/year)	N_{rate} (kg N/1000 kg animal mass/day)	ABW (kg)	N_{ex} (kg N/animal/year)
Dairy cattle	100	0.44	604	97.002	0.60	650	142.4
Hanwoo cattle	70	0.31	389	44.015	0.40	407	59.4
Beef cattle	20	0.31	389	44.015	0.40	407	59.4
Swine	0.60	0.55	50	10.038	0.77	59	16.6
Chicken layer	0.60	0.82	1.80	0.539	0.81	1.9	0.6
Chicken broiler	0.60	1.10	0.90	0.361	1.12	1.1	0.4
Duck	0.60	0.83	0	0	0.83	2.7	0.8

N: nitrogen, N_{ex}: nitrogen excretion, Nrate: nitrogen excretion rate, ABW: average body weight

N_{ex}: Nrate • ABW/1000 • 365

Manure treatment system	EF_3 (kg N_2O-N/kg N)		
	1996 GL	2006 GL	2019 Refinement
Solid storage and dry lot	0.02	0.005	0.010
Liquid system	0.001	0.005	0.005
Other	0.005	0	0

GIR, 2019. 2021 national greenhouse gas inventory (1990-2019) [WWW Document]. URL http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=54&boardMasterId=2&boardCategoryId=

IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL (www.ipcc-nggip.iges.or.jp/%0Apublic/gl/invs1.html

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [WWW Document]. URL http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

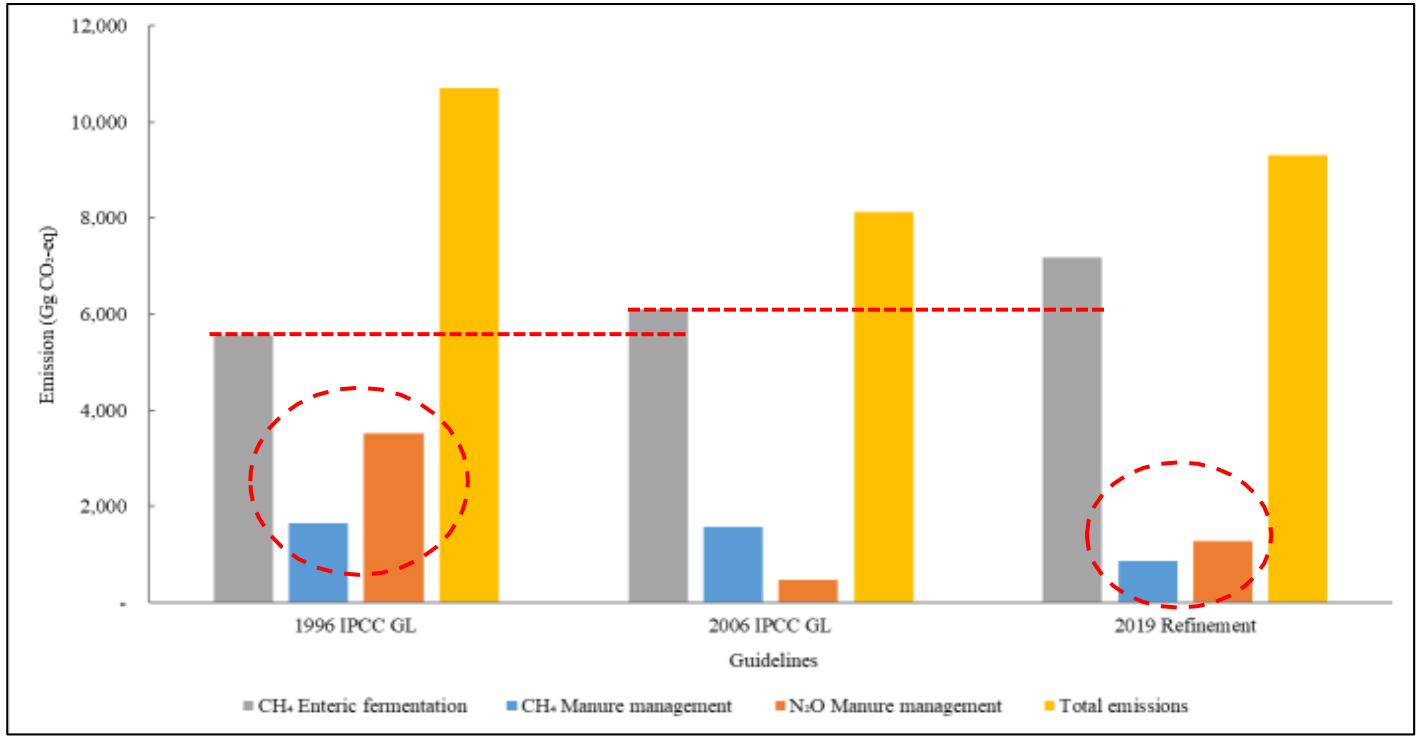
Equations to estimate GHG emissions based on IPCC Guidelines

Sources	1996 GL	2006 GL	2019 Refinement
CH_4 from enteric fermentation	$CH_4 = \sum \frac{EF \bullet N}{10^6}$		
CH_4 from manure management	$CH_4 = \sum \frac{EF \bullet N}{10^6}$		$CH_4 = \sum \frac{N \bullet VS \bullet MS \bullet EF}{1000}$
N_2O from manure management	$N_2O = \sum [N \bullet N_{ex} \bullet MS \bullet EF_3] \bullet \frac{44}{28}$		

EF: emission factor, N: numbers of heads of animal, VS: volatile solids, MS: manure treatment system, N_{ex}: nitrogen excretion, EF_3: emission factor for direct N_2O from manure management

- GWP for CH_4 is 25, for N_2O is 298 CO_2-equivalent (IPCC, 2007)
- The result was divided by 10^6 for total emissions expressed with kg/year to give the result of Gg/year

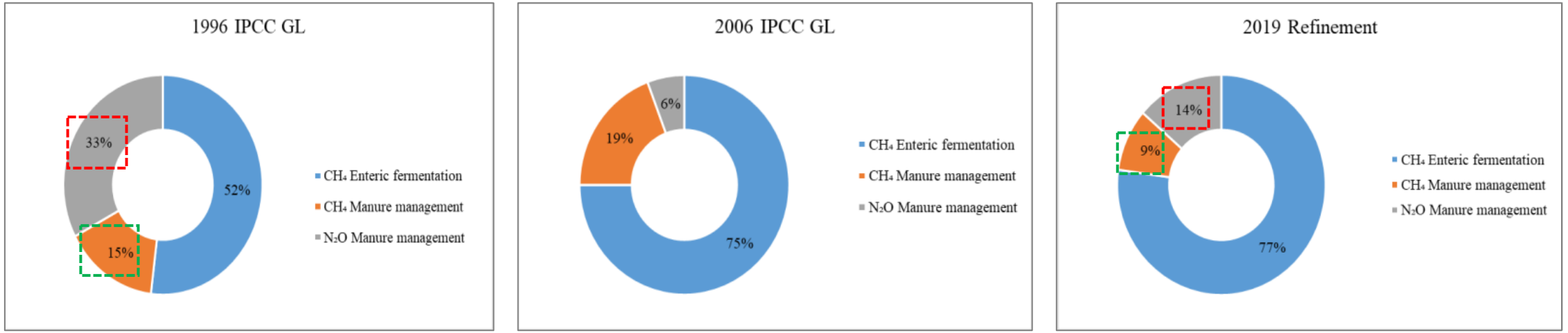
Figure 1. GHG emissions from livestock sector in Korea in 2020



Base GL	Comparing GL	Ratio
1996 GL	2006 GL	0.8
1996 GL	2019 Refinement	0.9
2006 GL	2019 Refinement	1.1

- Emission from enteric fermentation is inevitable
- Trend of emissions (decrease/increase) are not consistent
- However, 1996 GL and 2019 Refinement show consistent trend despite of the changes in "numbers"

Figure 2. Contribution of GHG emission sources in livestock sector in Korea in 2020



- Enteric fermentation contributes more than 50% of total emissions
- The trend of contribution of emissions are not consistent
- However, the trend of contribution of emissions from manure management is identical in 1996 GL and 2019 Refinement

Changing the guideline would cause change in mitigation priority

Table 1. Comparison of Korean estimated GHG emissions from year 1990 and 2020 using 1996 GL, 2006 Gl, and 2019 Refinement

Emission source	Year	1996 GL	2006 GL	2019 Refinement
CH_4 enteric fermentation	**1990**	1,640	1,677	1,889
	2020	5,563	6,097	7,192
	Trend 1990-2020	+239%	+264%	+281%
CH_4 manure management	**1990**	906	1,035	276
	2020	1,641	1,570	854
	Trend 1990-2020	+81%	+52%	+210%
N_2O manure management	**1990**	897	134	369
	2020	3,510	465	1,270
	Trend 1990-2020	+291%	+247%	+244%
Total emission	**1990**	3,442	2,846	2,535
	2020	10,714	8,131	9,316
	Trend 1990-2020	+211%	+182%	+268%

Inconsistent

The calculation approach in 2019 Refinement creates huge change

Changing the guideline would cause difficulties in monitoring the progress of established policy and reduction effort

TAKE HOME MESSAGE

Would the use of newer guideline create better inventory?

Newer guidelines → More data

More data ≠ Better inventory

Where do the data come from?

Do they represent each country's unique circumstance?

IPCC GL Tier 2 (Country-specific values)

Represent country's circumstances

Risk to be inconsistent:

- Partially use default values
- Following established IPCC equations

IPCC GL Tier 3 (Country-specific methodology)

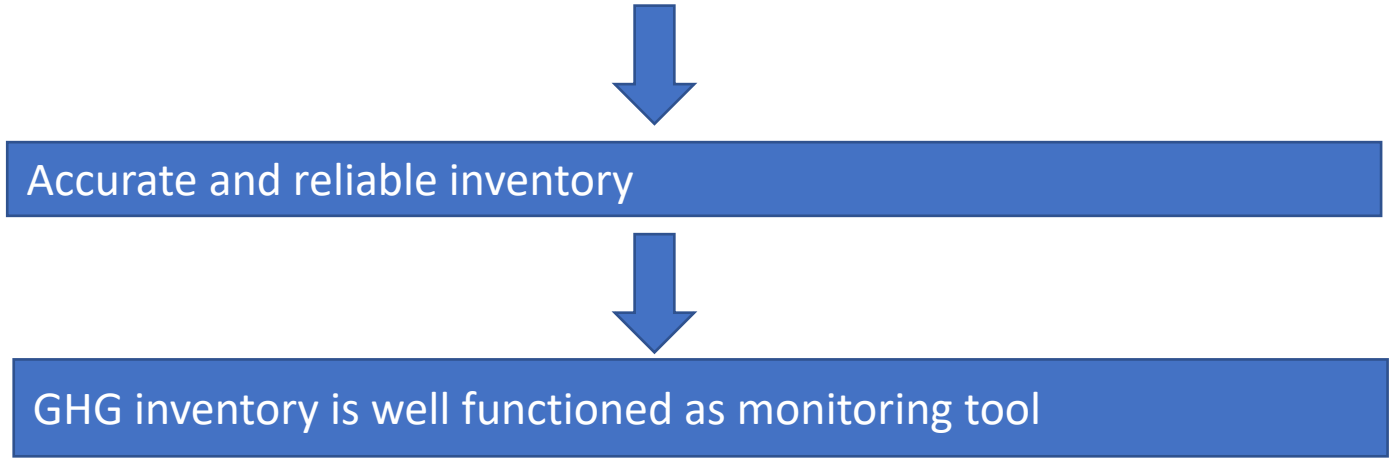
Represent country's circumstances

Consistency is assured

TAKE HOME MESSAGE

Would the change of guideline be necessary?

The focus shall be placed on developing country-specific methodology



Thank you
For your attention

This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, and Forestry (IPET) and Korea Smart Farm R&D Foundation (KosFarm) through Smart Farm Innovation Technology Development Program, funded by Ministry of Agriculture, Food, and Rural Affairs (MAFRA) and Ministry of Science and ICT (MSIT), Rural Development Administration (RDA) (RS-2023-00221189)