Case Study for Application of Provincial Guidance for Measurement, Reporting and Verification of Greenhouse Gas Inventory Based on IPCC Tier 2 Method in Hebei Province for Intensive Swine Farm

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Case Study for Application of Provincial Guidance for Measurement, Reporting and Verification of Greenhouse Gas Inventory Based on IPCC Tier 2 Method in Hebei Province for Intensive Swine Farm

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Content

ABSTRACT

The greenhouse gas (GHG) emissions in an intensive swine farm include two parts: methane (CH_4) emissions from manure management, and nitrous oxide (N_2O) emissions from manure management. In order to ensure the transparency, consistency, comparability, completeness and accuracy of the inventory, the inventory is prepared in accordance with the “Provincial guidance for the measurement, reporting and verification of GHG inventories in China's livestock based on IPCC tier 2 method”(Hereinafter referred to as "Provincial MRV Guidance ").

In 2018, the GHG emissions from the studied intensive swine farm were 11,446.9 tons carbon dioxide equivalent (CO_2e). According to the analysis of emission sources, the N_2O emission from manure management was the major emission sources, which contribute to 7567.1 tons CO_2e, accounting for 66.1% of total emission; the CH_4 emission from manure management was 3,879.8 tons CO_2e, accounting for 33.9%. Regarding to the growth stage, the emission from manure management of growing-finishing swine, sows and nursery was 8057.0, 2023.2, and 1366.7 tons CO_2e, accounting for 70.4% 17.7%, and 11.9%, respectively.

In order to ensure the quality of GHG emission inventory in the studied intensive farm, the methods, activity data and emission factors applied in the inventory preparation process were verified in accordance with the requirements of verification check list of Provincial MRV Guidance.

1. SUMMARY

The case study for application of “Provincial guidance for the measurement, reporting and verification of GHG inventories in China's livestock based on IPCC tier 2 method” (Hereinafter referred to as "Provincial MRV Guidance") was carry out in Hebei province, the objective of the case study for intensive swine farm is to test the applicability of "Provincial MRV guidance") and provide examples of intensive swine farm’s GHG inventory MRV in China or in other countries.

This case study is an intensive swine farm in Hebei province. The GHG measurement and reporting year is 2018. The main breeds of swine are Changbai and Dabai. The average annual stock of swine was 66,360, of which 15,000 were nursery, 44,160 were growing and finishing, and 7,200 were sows. In 2018, about 139 thousand fattening swine were slaughtered with an average slaughter weight of 110 kg. The average annual temperature of is 12.9 ℃ in this area in 2018.

Based on "Provincial MRV Guidance", tier 2 method is not used to calculate CH_4 emissions from swine enteric fermentation because swine are monogastric animals. Tier 2 method is used to calculate CH_4 and N_2O emissions from manure management.

The field survey was conducted on the studied farm. Values for the parameters of swine production characteristics, population structure in different growth stages, feed intake, feed quality, feed digestibility and usage of manure management systems were obtained; Nitrogen excretion of swine from different growth stages came from the second national survey on pollution source.

In 2018, the GHG emissions from the studied intensive swine farm were 11,446.9 tons CO_2e. According to the analysis of emission sources, the N_2O emission from manure management was the major emission sources, which contribute to 7567.1 tons CO_2e, accounting for 66.1% of total swine emission; the CH_4 emission from manure management was 3,879.8 tons CO_2e, accounting for 33.9%. Regarding to the growth stage, the emission of growing-finishing swine was 8057.0 tons CO_2e, accounting for 70.4%; the emission of sows was 2023.2 tons CO_2e, accounting for 17.7%, and the emission of nursery was 1366.7 tons CO_2e, accounting for 11.9%.

In order to ensure the quality of GHG emission inventory in the studied intensive farm, the methods, activity data and emission factors applied in the inventory preparation process were verified in accordance with the requirements of verification check list of Provincial MRV Guidance.

2. INVENTORY INTUITION ARRANGEMENTS

The inventory compiling agencies are the Institute of Environment and Sustainable Development in Agriculture of Chinese Academy of Agricultural Sciences (IEDA-CAAS) and the case studied farm. IEDA-CAAS is responsible for the selection of methods, collection and calculation of parameters values used for the emission factors, calculation and verification of emissions. The case studied farm is responsible for collecting activity data and assisting in the field survey of parameters required for emission factors, such as

population structure in different growth stages, feed intake, feed quality, feed digestibility and usage of manure management systems. The detail information about investigation data was listed in annex table 1.

3. MEASUREMENT OF INTENSIVE SWINE FARM GHG EMISSIONS

According to "Provincial MRV Guidance", GHG emissions from intensive swine farm include CH_4 emissions from manure management, and N_2O emissions from manure management. Based on the availability of data, a typical intensive swine farm in 2018 was selected as the case study to measurement, reporting and verification of GHG emissions in Hebei Province.

3.1 MEASUREMENT CH_4 EMISSIONS FROM MANURE MANAGEMENT

3.1.1 Activity data of swine

According to "Provincial MRV Guidance", it is necessary to collect swine population in different growth stages (nursery, growing-finishing, sows). The activity data is derived from the statistic book in the swine farm in 2018. According to the classification of the growth stages of the swine, the activity data under different growth stages were listed in Tables 1.

Table 1 Activity data for swine in the case studied farm

Year-end Population in stocks (heads)	Population in each growth stages (heads)		
	Nursery	Growing-finishing	Sows
66360	15000	44160	7200

3.1.2 Measurement and calculation of emission factors and key parameters of swine

Based on " Provincial MRV Guidance ", the emission factors under different growth stages were calculated as Equation 1:

$$EF_{CH_4\_MM,\ (T,P)} = \left(VS_{(T,P)} \cdot 365\right)\left[B_{0(T,P)} \cdot 0.67 \cdot \sum_{(S,K)} \frac{MCF_{(S,K)}}{100} \cdot \frac{MS_{(T,P,S)}}{100}\right] \quad (1)$$

Where:

$EF_{CH4\_MM(T,P)}$ — CH_4 emission factor from manure management for swine in feeding situation P in growth stage T, kg CH_4 $head^{-1}$ yr^{-1};

$VS_{(T,P)}$ — daily volatile solids excreted in feeding situation P in growth stage T, kg VS day^{-1};

$B_{0(T,P)}$ — CH_4 production capacity for manure produced by swine in feeding situation P in growth stage T, m^3 CH_4 kg^{-1} of VS;

$MCF_{(S,K)}$ — CH_4 conversion factors for each manure management system *S* by climate region *K*, %;

$MS_{(T,P,S)}$ — fraction of manure handled using manure management system *S* in feeding situation P in growth stage T, %;

0.67 — density of CH_4, kg m^{-3};

S	index for manure management system;
K	index for climate region;
P	index for feeding situation. In this case, the feeding situation is intensive feeding situation.

3.2.2.1 Calculation of volatile solids excretion of swine

Based on "Provincial MRV Guidance ", volatile solid excretion in swine manure was calculated as Equation 2:

$$VS = \left[GE \cdot \left(1 - \frac{DE}{100}\right) + (UE \cdot GE)\right] \cdot \left(\frac{1-ASH}{18.45}\right) \quad (2)$$

Where:

VS volatile solid excretion per day on dry matter basis, kg VS day^{-1};

GE gross energy intake, MJ day^{-1};

Calculation formula: $GE = DMI \times 18.45$ (2.1)

Collection method of parameters:

DMI: feed dry matter intake, kg $d^{-1}head^{-1}$

The DMI was obtained by the field survey (table 2). According to formula 2.1 GE was calculated at different growth stages of swine (Table 2)

Table 2 DMI and GE value of swine at different growth stages

Growth stage	Nursery	Growing-finishing	Sows
DMI （kg $d^{-1}head^{-1}$）	0.52	1.64	2.55
GE （MJ $d^{-1}head^{-1}$）	9.58	30.32	47.08

DE feed digestibility %.

The data was obtained by the field survey. The result was shown in table 3.

Table 3 Feed digestibility (%).

Growth stage	Nursery	Growing-finishing	Sows
Feed digestibility	75	75	75

UE . *DE* urinary energy expressed as fraction of GE.

Typically, 0.02 GE was used for this case study based on 2006 IPCC guidelines.

ASH the ash content of manure, %.

The default value recommended by the IPCC guidelines is applicable to the value for ash content, which is 8%

18.45 conversion factor for dietary GE per kg of dry matter, MJ kg^{-1}.

Note: The volatile solids excreted by swine should be calculated by feeding situation and feeding stage. The above formula and main parameters are not marked with indexes for feeding situation (*P*) or growth stage (*T*).

Based on the above-mentioned related parameters, the volatile solids excretion of swine manure in different growth stages in this case study was calculated. The specific results are shown in Table 4.

Table 4 the volatile solids excretion of swine manure (kg VS day^{-1})

Growth stage	Nursery	Growing-finishing	Sows
VS	0.13	0.41	0.63

3.1.2.2 Maximum CH_4 producing capacity (B_0)

The maximum CH_4 producing capacity of manure (B_0) varies by species and diet. As there are no research results in China, B_0 default values recommended in the "Provincial MRV Guidance" were applied. In this case, the B_0 of intensive swine was taken as 0.45 m^3 CH_4 $kg^{-1}VS$.

3.1.2.3 Fraction of manure handled using different manure management systems

In accordance with the requirements of a typical survey of "Provincial MRV Guidance ", the field survey of swine farm was conducted to determine the usage of different manure management systems. There are three major manure management system in this farm: pit storage under ground (< 1 month), anaerobic digester and composting. The proportion of different manure management was list in Table 5.

Table 5 the proportion of swine manure handled by manure management system (%)

Manure management	Pit storage under ground(< 1 month)	Anaerobic digester	Composting
Percentage（%）	20	50	30

3.1.2.4 CH_4 Conversion Factor（MCF）

MCFs are determined for each specific manure management system and local climate conditions. The average annual temperature in the area of swine farm in 2018 was 12.9℃. According to Table 2-5 in the "Provincial MRV Guidance", the CH_4 conversion factors for different manure management system at a temperature of 12.9 ℃ were shown in Table 6.

Table 6 CH_4 conversion factors of manure management systems for swine (%)

Manure management	Pit storage under ground(< 1 month)	Anaerobic digester	Composting
MCF（%）	3	10	0.5

3.1.2.5 CH_4 emission factors from manure management of swine

According to the calculated VS, MCF in different manure management systems and the B_0 in swine manure calculated CH4 emission factors using Equation 1 were shown in Table 7.

Table 7 CH_4 emission factor for manure management (kg CH_4 head^{-1}yr^{-1})

Growth stage	Nursery	Growing-finishing	Sows
CH_4 EF of manure management	0.82	2.58	4.01

3.1.3 CH_4 emission from manure management of swine

Based on activity data of swine in different feeding situation and different growth stages, and corresponding CH_4 emission factors, equation 3 is used to calculate CH_4 emission from manure management (Table 8).

$$E_{CH_4\_MM} = \sum_{T,P} \frac{\left(EF_{CH4\_MM,\ (T,P)} \cdot N_{(T,P)}\right)}{10^3} \qquad (3)$$

Where:

E_{CH4_MM}	CH_4 emissions from manure management for swine in the intensive swine farm, t CH_4 yr^{-1};
$EF_{CH4\_MM(T,P)}$	emission factor for animals in feeding situation P in growth stage T, kg CH_4 $head^{-1}$ yr^{-1};
$N_{(T,P)}$	activity data, the number of head of livestock in feeding situation *P* in growth stage *T*, average annual animal population in stock, head;
P	index for feeding situation;
T	index for growth stage.

Table 8 CH_4 emission from manure management for swine (t CH_4 yr^{-1})

Growth stage	Nursery	Growing-finishing	Sows	Total
CH_4 emission	12.2	114.1	28.9	155.2

3.2 MEASUREMENT N_2O EMISSIONS FROM MANURE MANAGEMENT

N_2O emission from manure management for swine include direct N_2O emission and indirect N_2O emission, the parameters required to calculate N_2O emission factor include the nitrogen excreted by swine, the fraction of manure managed in different manure management and N_2O emission factor for manure management.

3.2.1 Direct N_2O emission from manure management of swine

3.2.1.1 Activity data

Activity data on N_2O emission from manure management of swine for different growth stages is the same as in chapter 3.1.1, as shown in Table 1.

Annual average N excretion rates is key parameter for estimating N_2O emissions. The annual nitrogen excretion of swine in different growth stages was obtained according to the second national pollution source survey data (Table 9). The annual nitrogen excretion of swine in different growth stages and manure management was calculated based on the fraction of manure managed in different manure management in section 3.1.2.3, as shown in Table 10.

Table 9 The nitrogen excretion of swine in different feeding situation and growth stages (kg $yr^{-1}head^{-1}$).

Growth stage	Nursery	Growing-finishing	Sows
Nex（kg $yr^{-1}head^{-1}$）	4.5	7.5	11.5

Table 10 The nitrogen excretion of swine managed in different manure management systems, in growth stages (kg $yr^{-1}head^{-1}$).

Growth stage	Manure management		
	Pit storage under ground (< 1 month)	Anaerobic digester	Composting
Nursery	13500	33750	20250
Growing-finishing	66240	165600	99360
Sows	16560	41400	24840

3.2.1.2 The choice of direct N_2O emission factor form manure management of swine

The manure management systems and fraction of usage of different manure management used to calculate N_2O emission are the same as in section 3.1.2.3 (Table 5).

According to the Table 2-6 in "Provincial MRV Guidance " and investigation of manure management systems (Table 5), direct N_2O emission factor for different manure management were selected (Table 11).

Table 11 Direct N_2O emission factor for swine manure management

Manure management system	Pit storage under ground (< 1 month)	Anaerobic digester	Composting
EF_3 (kg N_2O-N kg^{-1}N)	0.002	0	0.1

3.2.1.3 Direct N_2O emission from manure management of swine

Direct N_2O emission was calculated used equation 4 based on "provincial MRV Guidance ", the results are shown in Table 12.

$$E_{N_2O_D,MM} = \left[\sum_S \left[\sum_{T,P} \left(\left(N_{(T,P)} \bullet Nex_{(T,P)}\right) \bullet \frac{MS_{(T,P,S)}}{100}\right)\right] \bullet EF_{3(S)}\right]/1000 \bullet \frac{44}{28} \quad (4)$$

Where:

$E_{N2O\_D,MM}$	direct N_2O emissions from manure management, t N_2O $year^{-1}$;
$N_{(T,P))}$	activity data for livestock in feeding situation P in growth stage T, head;
$Nex_{(T,P)}$	annual average N excretion in feeding situation P in growth stage T, kg N $year^{-1}$;
$MS_{(T,P,S)}$	fraction of manure handled using manure management system *S*, from animals in feeding situation P in growth stage T, %;
$EF_{3(S)}$	emission factor for direct N_2O emissions from manure management system *S*, kg N_2O-N kg^{-1}N.

S	index for manure management system;
T	index for growth stage;
P	index for feeding situation;
44/28	conversion of N_2O-N emissions to N_2O emissions, kg N_2O (kg N_2O-N)$^{-1}$

Table 12 The direct N_2O emission from manure of swine in different manure management systems, in different feeding situation and growth stages (t N_2O yr^{-1}).

Manure management / Growth stage	Pit storage under ground (< 1 month)	Anaerobic digester	Composting	Total
Nursery	0.042	0.000	3.182	3.220
Growing-finishing	0.208	0.000	15.614	15.820
Sows	0.052	0.000	3.903	3.960
Total	0.303	0.000	22.699	23.000

3.2.2 Indirect N_2O emission from manure management of swine

Indirect N_2O emissions from manure management include the emission due to the deposit of NH_3 and NO_x volatilization indirectly during the storage and treatment of manure before it is applied to land, as well as the nitrogen lost due to leaching and runoff. Indirect N_2O emission factors during the storage and treatment of manure mainly depend on the N content in daily-excreted manure for swine and manure management methods. Indirect emissions can be calculated using Equation 8:

$$E_{N_2O\_ID,MM} = N_2O_{volatilization,MM} + N_2O_{leach,MM} \quad (8)$$

Where:

$E_{N2O\_ID,\ MM}$	indirect N_2O emissions from manure management, kg N_2O yr^{-1};
$N_2O_{volatilization,\ MM}$	indirect N_2O emissions due to volatilization of N from manure management, kg N_2O yr^{-1}
$N_2O_{Leach,\ MM}$	indirect N_2O emissions due to leaching and runoff from manure management, kg N_2O yr^{-1}

3.3.2.1 Activity data

- **Activity data of swine:**

Activity data of swine in different feeding situation and growth stages are the same as in section 3.1.1, as shown in Table 1.

- **Nitrogen excretion rate:**

Nitrogen excretion rate of swine in different feeding situation and growth stages are the same as in section 3.1.1, as shown in Table 9.

- **Nitrogen that is lost due to the volatilization of NH_3 and NO_x (i.e. nitrogen deposition).**

Nitrogen losses due to volatilization of NH_3 and NO_x under different feeding situation, growth stages and manure management methods that is calculated as shown in equation 6:

$$N_{volatilization,MM} = \sum_S \left[\sum_{T,P}\left[\left(\left(\left(N_{(T,P)} \cdot Nex_{(T,P)}\right) \cdot \frac{MS_{(T,P,S)}}{100}\right) \cdot \left(\frac{Frac_{GasMS(T,S)}}{100}\right)\right)\right]\right] \quad (6)$$

Where:

$N_{volatilization,MM}$	amount of manure nitrogen that is lost due to volatilization of NH_3 and NO_x, kg N yr^{-1}
$N_{(T,P)}$	number of animals in growth stage T in feeding situation P, head;
$Nex_{(T,P)}$	annual average N excretion per head of animals in growth stage T in feeding situation P, kg N $head^{-1}$ yr^{-1};
$MS_{(T,P,S)}$	fraction of manure handled using manure management system *S*, from animals in feeding situation P in growth stage T, %;
P	index for feeding situation;
$Frac_{GasMS}$	percent of managed manure nitrogen for animals in feeding situation P and growth stage T that volatilizes as NH_3 and NO_x in the manure management system *S*, %; Refer to Table 2-10 for the recommended values of some manure management systems. For manure management systems not included in the table, the unified value is 20%.

Table 13 Percent of nitrogen loss due to volatilization of NO_x and NH_3 from manure management (%).

Manure management	Pit storage under ground (< 1 month)	Anaerobic digester	Composting
Percent of nitrogen loss	28	40[a]	20[b]

Note:[a] The proportion of NH_3 and NO_x volatilization of biogas residue and biogas digestate shall refer to the liquid slurry storage and manure management;
[b] Take the default value of 20.

N loss due to volatilization of NH_3 and NO_x from manure of swine managed in different manure management systems, and in different feeding situation and growth stages, was calculated used equation 6 based on "Provincial MRV Guidance", the results are shown in Table14.

Table 24 Nitrogen loss due to volatilization of NO_x and NH_3 from manure management, in different growth stages (kg N yr^{-1}).

Manure management / Growth stage	Pit storage under ground (< 1 month)	Anaerobic digester	Composting	Total
Nursery	3780	13500	4050	21330

Growing-finishing	18547	66240	19872	104659
Sows	4637	16560	4968	26165
Total	26964	96300	28890	152154

- **Amount of N loss due to leach/runoff**

As the precipitation is less than the evaporation in the area of intensive swine farm, the proportion of nitrogen loss due to leaching and runoff from various manure management systems is assumed to be zero in this case study. The N loss due to leaching and runoff from different manure management systems in different feeding situation and different growth stages was calculated used equation 10 based on "Provincial MRV Guidance ".

$$N_{leach,MM} = \sum_S \left[\sum_{T,P} \left[\left(\left(\left(N_{(T,P)} \cdot Nex_{(T,P)}\right) \cdot \frac{MS_{(T,P,S)}}{100}\right) \cdot \left(\frac{Frac_{Leach,MS(T,P,S)}}{100}\right)\right)\right]\right] \quad (10)$$

Where:

$N_2O_{Leach,\ MM}$	indirect N_2O emissions due to leaching and runoff from Manure Management in the intensive swine farm, kg N_2O yr^{-1};
$N_{(T,P)}$	number of animals in growth stage T in feeding situation P, head;
$Nex_{(T,P)}$	annual average N excretion per head of animals in growth stage T in feeding situation P, kg N $head^{-1}$ yr^{-1};
$MS\ (T,\ P,\ S)$	fraction of manure from animals in feeding situation P in growth stage T, handled using manure management system *S*, %;
$_{Leach,\ MS(T,P,S)}$	percent of managed manure nitrogen for animals in growth stage T that is leached from the manure management system *S*, %; The default value is zero where evaporation is greater than precipitation.

3.2.2.2 Indirect N_2O emission factor from nitrogen deposition form manure management of swine

According to "Provincial MRV Guidance", indirect N_2O emission factor from nitrogen deposition in manure management of swine is 0.01 kg N_2O-N kg^{-1}N. Indirect N_2O emission factor from leaching and runoff in manure management is 0.0075 kg N_2O-N kg^{-1}N.

3.2.2.3 Indirect N_2O emission from manure management of swine

According to "Provincial MRV Guidance", equation 8 and 9 were used to calculated indirect N_2O emission due to N deposition and leaching/runoff from manure management, respectively.

$$N_2O_{volatilization,MM} = \left(N_{volatilization,MM} \cdot EF_4\right) \cdot \frac{44}{28}/1000 \quad (8)$$

Where:

$N_2O_{volatilization,\ MM}$	indirect N_2O emissions due to volatilization of N from manure management, t N_2O yr^{-1};
$N_{volatilization,MM}$	amount of manure nitrogen that is lost due to volatilization of NH_3

and NO_x, kg N yr^{-1}; the results are shown in Table 24.

EF_4 emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH_3-N + NO_x-N volatilized)$^{-1}$; The default value recommended by this IPCC is 0.01.

$$N_2O_{Leach,MM} = (N_{Leach,MM} \cdot EF_5) \cdot \frac{44}{28} / 1000 \quad (9)$$

Where:

$N_2O_{Leach, MM}$ indirect N_2O emissions due to leaching and runoff from manure management, t N_2O yr^{-1};

$N_{Leach, MM}$ amount of manure nitrogen that is lost due to leaching, kg N yr^{-1}, the result is 0

EF_5 emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and runoff, this guide uses the IPCC recommended default value of 0.0075.

Based on the equation 5 and the relevant parameters determined, indirect N_2O emission emissions from manure management in this case are shown in Table 15.

Table 15 Indirect N_2O emission from manure management of swine (t N_2O yr^{-1})

	Nitrogen deposition	Leaching/runoff	Total
Indirect N_2O emission	2.39	0.00	2.39

3.2.3 Total N_2O emission from manure management of swine

The total N_2O emissions from manure management of swine is equal to the sum of direct N_2O emissions and indirect N_2O emissions from intensive swine farm. The total N_2O emissions from manure management of the case farm was 25.39 t N_2O in 2018.

Table 16 Total N_2O emission from swine manure management (t N_2O yr^{-1})

source	Direct emission	Indirect emission	Total
Total N_2O	23.0	2.39	25.39

3.3 TOTAL GHG EMISSIONS OF THE CASE SWINE FARM

The total GHG emissions from swine farm is equal to the sum of CH_4 emissions from manure management, and N_2O emissions from manure management. According to the "Provincial MRV Guidance", the GWP value for CH_4 and N_2O was selected 25 and 298(Table 17).

Table 17 Total GHG emission of case swine farm

Source	CH_4 emission from manure management (t CO_2e)	N_2O emission from manure management (t CO_2e)	Total (t CO_2e)
Total GHG	3879.8	7567.1	11446.9

In 2018, the GHG emissions from the studied intensive swine farm were 11,446.9 tons CO_2e. According to the analysis of emission sources, the N_2O emission from manure management was the major emission sources, which contribute to 3 7567.1 tons CO_2e, accounting for 66.1% of total swine emission; the CH_4 emission from manure management was 3,879.8 tons CO_2e, accounting for 33.9%. Regarding to the growth stage, the emission of growing-finishing swine was 8057.0 tons CO_2e, accounting for 70.4%; the emission of sows was 2023.2 tons CO_2e, accounting for 17.7%, and the emission of nursery was 1366.7 tons CO_2e, accounting for 11.9%.

3.4 UNCERTAINTY ANALYSIS

Since the case calculation is data from a single farm, the relevant activity data and emission factor data are actual data, and the relevant parameters have no error analysis results, and the GHG emissions calculation results of a single farm are not analyzed with uncertainty.

3.5 SIMULATION OF EVALUATION OF MITIGATION EFFECTS

In this case study, the GHG mainly comes from manure management N_2O emission, so the priority mitigation technology should be given to reducing N_2O emission technology from manure management. A key factor is nitrogen excretion. At present, China is promoting the use of low-protein diet technology. This technology can improve feed conversion efficiency and reduce manure nitrogen excretion. If this technology is promoted in this farm, and it can reduce the crude protein content of 1% on the basis of the existing protein diet of pig farms which can reduce the nitrogen excretion about 10%. According to the method of the "Provincial MRV Guidance ", the total N_2O emission from manure management can be reduced by 10%, the total GHG emissions of the case farm can be reduced by 6.8%.

4. VERIFICATION OF GHG MEASUREMENT

According to the "Provincial MRV Guidance", the inventory compilation team has carried out the internally check on applied methods, activity data, emission factors, value of relevant parameters, calculation process of emission from each source for the case study farm. The verification was implemented in according to the verification checklist, and comments are as shown in Table 18.

The results of verification show that the GHG inventory of this case study is in accordance with the requirements of The Provincial MRV Guidance, The adopted method are from Provincial MRV Guidance, the activity data was correct. The swine are further classified into 3 growth stages, the values of parameters for determining the emission factors are come from the field survey which samples from typical farms, and the emission factors were comparable with that in national inventory.

Table 18 Checklist of Verification for GHG inventory

NUMBER	VERIFIED CONTENT	DETAILED LIST OF VERIFICATION	CONCLUSION OF VERIFICATION	COMMENTS / SUGGESTIONS	STATUS ON IMPROVE OR MODIFICATION
1. METHODOLOGICAL CHOICE					
1.1	Methodological choice	● Whether according to the methodology of the MRV guidelines？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the tier of the methodology applied for CH_4 emissions from enteric fermentation appropriate?	Yes ☐ No☒ issues： Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the tier of the methodology applied for CH_4 from manure management CH_4 appropriate?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the tier of the methodology applied for N_2O emissions from manure management appropriate?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
2. ACTIVITY DATA					
2.1	The source of activity data	● Is the animal population data source clearly described?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Is the population data correct?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
2.2	Detailed classification description and animal population data	● Have the detailed livestock categories/subcategories classification data and reasons been transparently documented？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● whether the detailed animal feeding situation in accordance with the classification of MRV Guidance? Is there evidences for detailed classification of grazing and backyard feeding situation, and is it correct?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Is the animal growth stage classification appropriate?	Yes ☒ No ☐ issues：：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Is the method of obtaining data on animal population of detailed	Yes ☒ No ☐	comments：	Solved ☐

		classification correct?	issues：		Partly ☐ Unsolved ☐
2.3	Calculation of animal population in stock based on numbers of animal produced	If the stocks is calculated based on the output， ● Are the calculation methods of animal population in stock clearly described？ ● Are numbers of animal produced correct？ ● Are the hypothesis of alive of animals days appropriate？	Yes ☐ No ☒ issues： The in stock data can obtain directly.	comments：	Solved ☐ Partly ☐ Unsolved ☐
2.4	Cross-checking of animal population in stock	● Are of total animal population in stock of the livestock categories/subcategories equal to the total amount of livestock population?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are animal population among each emission sources consistent？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the activity data comparable to previous years？ ● Are there detailed explanation in inventory if there is a significant change?	Yes ☐ No ☒ Issues: The in stock data can obtain directly	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are animal population data comparable with that in China Statistical Yearbook, Yearbook of Animal Husbandry and Veterinary in China, Statistical Yearbook of Provincial, Statistical Yearbook of County, and Statistical Yearbook of City?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
3. EMISSION FACTORS					
3.1	Implied emission factor（IEF ）	● Are the estimated implied emission factors of CH_4 from enteric fermentation comparable with the default values of IPCC, the values of the national inventory and inventories of other provinces？	Yes ☒ No ☐ issues ： Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the estimated implied emission factors of CH_4 from manure management comparable with the default values of IPCC, the values of the national inventory and inventories of other provinces？	Yes ☒ No ☐ Issues:	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the estimated implied emission factors of N_2O from swine cows and swine manure management comparable with the default values of IPCC, the values of the national inventory and inventories of other provinces？	Yes ☒ No ☐ Issues:	comments：	Solved ☐ Partly ☐ Unsolved ☐

3.2	Calculation method of CH_4 emission factors from enteric fermentation	● Does the calculation equations and units of net energy to determine maintenance, net energy for activity, net energy for growth, net energy for lactation, net energy for work, net energy for pregnancy correctly be applied? are the ratio of net energy for maintenance to digestible energy in a diet, ratio of net energy for growth to digestible energy in a diet, gross energy, emission factors, etc. correctly applied?	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Does the evidences be provided to identify the parameters for calculating net energy for maintenance, net energy for activity, net energy for growth, net energy for lactation, net energy for work, net energy for pregnancy. is there description of the selection of parameters for ratio of net energy for maintenance to digestible energy in a diet, ratio of net energy for growth to digestible energy in a diet, gross energy, emission factors?	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
3.3	Method of obtaining key parameters to determine CH_4 emission factors from enteric fermentation	● Have the characteristics on animal production and feed applied in the calculation of CH_4 emission factors been clearly described, such as swine weight, mature swine weight, weight gain per day, feed intake, feed digestibility, milk production etc?	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the survey methods clearly described if the characteristics on animal production and feed are obtained through the survey？ ● Have the representativeness of survey methods and results been demonstrated？	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● If the characteristics on animal production and feed are obtained through the literature, have the references been provided？ ● Have the representativeness and applicability of the literature results been demonstrated？	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
3.4	The comparability of key parameters to determine CH_4 emission factors for enteric fermentation	● Are the parameters such as swine weight, mature swine weight, feed intake, weight gain per day, milk production, feed consumption, feed digestibility comparable with the default values of IPCC Guidelines, values applied in national inventory and other similar provinces？	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Whether the calculated results of net energy for maintenance, net energy for activity, net energy for growth, net energy for lactation, net energy for work,	Yes ☐ No☒ Issues: Not applicable in	comments：	Solved ☐ Partly ☐

		the ratio of net energy for maintenance to digestible energy in a diet, the ratio of net energy for growth to digestible energy in a diet, gross energy, emission factors, are comparable with the default values of IPCC Guidelines, values applied in national inventory and other similar provinces？	this case		Unsolved ☐
		● Are the milk yield per lactating swine cows comparable with that of FAO, national statistical yearbook and other data？	Yes ☐ No☒ Issues: Not applicable in this case	comments：	Solved ☐ Partly ☐ Unsolved ☐
3.5	Calculation methods of CH_4 emission factors from manure management	● Does the equations and unit of volatile solid excretion and emission factor correctly be applied？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Does the evidences be provided to identify the parameters in the formula of volatile solid excretion and emission factors？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the values of gross energy intake and feed digestibility of swine used in calculation of CH_4 emission factors from enteric fermentation and manure management consistent?	Yes ☐ No☒ Issues: The GE was obtain though DMI value directly	comments：	Solved ☐ Partly ☐ Unsolved ☐
3.6	Methods of obtaining key parameters to determine CH_4 emission factors of manure management	● Have the classification and description of manure management systems been clear and correct？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the survey methods on the usage of different manure management systems clearly described?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the data on the usage of different manure management systems comparable to that in the national guidance, neighboring provinces, IPCC defaults, Nationally/Provinces representative pollution survey, direct collecting and Direct reporting system？	Yes ☐ No☒ Issues: Not applicable in this case, The data is a farm level data	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the survey methods and values of local temperature clearly described？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
3.7	Method for obtaining key parameters to determine CH_4	● Are the values of volatile solid content comparable to IPCC defaults, applied values in national inventory and other province?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐

	emission factor of manure management	● Are values of CH_4 potential comparable to IPCC defaults, applied values in national inventory and other province?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Are values of CH_4 conversion coefficients comparable to IPCC defaults, applied values in national inventory and other province?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
3.8	Calculation method of N_2O emission factor from manure management	● Are the calculation equations and unit to determine the direct and indirect N_2O emission from manure management correctly applied？	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Are the calculation equations and unit to determine manure nitrogen excretion, volatile nitrogen, runoff and leaching nitrogen correctly applied?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Does the evidences be provided to identify direct and indirect N_2O emission factors from manure management?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Have the nitrogen excretion, methods and data sources for determining various coefficients been clearly described?	Yes ☒ No ☐ issues:	comments:	Solved ☒ Partly ☐ Unsolved ☐
		● Are the nitrogen excretion, coefficients of direct emissions and indirect emissions comparable to IPCC default values and related literature data?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Are the fraction of manure management systems used to calculate the direct N_2O emission from manure management consistent with that used to calculate CH_4 emissions from enteric fermentation?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
4. EMISSION CALCULATION					
4.1	emission calculation	● Are the emissions calculation repeatable and correct?	Yes ☒ No ☐ issues:	comments:	Solved ☐ Partly ☐ Unsolved ☐
4.2	Uncertainty analysis	● Have uncertainties been reported? ● Is the uncertainty calculation method appropriate?	Yes ☐ No☒ Issues: Not applicable in this case, The data is a farm level data	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Have the data source and evidence to determine the parameters for the calculation of uncertainty been clearly described?			
5. Reporting on GHG emissions					

5.1	Reporting on GHG emissions	● Have the reports been compiled in line with the requirements of MRV Guidance？ ● Have the emission sources been fully reported？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
5.2	General report form（Excel）	● Are the date in reporting forms consistent with the inventory reporting data？ ● Have the data unreported been noted?	Yes ☐ No☒ Issues: Not applicable in this case, The data is a farm level data	comments：	Solved ☐ Partly ☐ Unsolved ☐

5. ANNEX

Annex table 1 Basic performance parameters of swine at different growth stages of the case farm

Item		Nursery	Growing-Finishing	Sow
Average in stock (heads)		15000	44160	7200
Feeding period (days)		42	120	365
Average weight (kg)		25	70	220
Daily gain (kg/day)		0.40	0.71	0
Feed composition	Full mixed feed (kg/day)	0.6	1.9	2.95
	moisture content (%)	13.5	13.5	13.5
DMI (kg/d/head)		0.52	1.64	2.55
GE (kg/d/head)		9.58	30.32	47.08
Feed digestibility (%)		75	75	75