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 Dairy Farm

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Content

ABSTRACT

The greenhouse gas (GHG) inventory of the intensive dairy farm in Hebei Province includes three parts: methane (CH_4) emissions from enteric fermentation, 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” (Here in after referred to as "Provincial MRV Guidance").

In 2018, the GHG emissions from the intensive dairy cattle farm in Hebei Province were 5299.1 tons carbon dioxide equivalent (CO_2e). According to the analysis of emission sources, the CH_4 emission from enteric fermentation was the major emission sources, which contribute to 3321.0 tons CO_2e, accounting for 62.7% of total dairy emission; the CH_4 emission from manure management was 286.4 tons CO_2e, accounting for 5.4%; and the N_2O emission from manure management was 1691.7 tons CO_2e, accounting for 31.9%. Regarding to the growth stages, the emission of mature dairy cow was the major sources, which contribute to 3974.1 tons CO_2e, accounting for 75.0%; the emission of other cattle was 1099.9 tons CO_2e, accounting for 20.8%, the emission of calves was 225.1 tons CO_2e, accounting for 4.2%. Regarding to the type of gases, the main emissions were CH_4, with a total emission of 3607.4 tons CO_2e, accounting for 68.1%, and N_2O emissions of 1691.7 tons CO_2e, and accounting for 31.9%.

In order to ensure the quality of GHG inventory for dairy 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 intensive dairy farm in Hebei province, the objective of the case study for intensive dairy farm is to test the applicability of "Provincial MRV Guidance" and provide examples of GHG inventory MRVs in China or in other countries.

This case was carried out on an intensive dairy farm located in Baoding city, Hebei Province. The GHG monitoring and accounting year is 2018. The animal population in stock of dairy cattle in case farm was 1,158 heads, of which 173 were calves, 369 were other cattle, and 616 were mature dairy cow.

In accordance with the requirements of the typical survey of "Provincial MRV Guidance", the parameters of animal production characteristics, population structure, feeding situation, feed intake, feed quality, feed digestibility and manure management were obtained; Nitrogen excretion from dairy cows came from the second national survey on pollution source.

In 2018, the GHG emissions from an intensive dairy cattle farm in Hebei Province were 5299.1 tons CO_2e. According to the analysis of emission sources, the CH_4 emission from enteric fermentation was the major emission sources, which contribute to 3321.0 tons CO_2e, accounting for 62.7% of total dairy emission; the CH_4 emission from manure management was 286.4 tons CO_2e, accounting for 5.4%; and the N_2O emission from manure management was 1691.7 tons CO_2e, accounting for 31.9%. Regarding to the growth stages, the emission of mature dairy cow was the major sources, which contribute to 3974.1 tons CO_2e, accounting for 75.0%; the emission of other cattle was 1099.9 tons CO_2e, accounting for 20.8%, the emission of calves was 225.1 tons CO_2e, accounting for 4.2%. Regarding to the type of gases, the main emissions were CH_4, with a total emission of 3607.4 tons CO_2e, accounting for 68.1%, and N_2O emissions of 1691.7 tons CO_2e, and accounting for 31.9%.

In accordance with the requirements and verification checklist of "Provincial MRV Guidance", the internal verification on adopted the method, activity data, calculation of emission factors, calculation and value of the parameters, the calculation of the emissions of various GHG sources, and the report of GHG inventory for the preparation of GHG inventories for the intensive dairy farm in Hebei Province was implemented by the inventory compilation team. and the problems existing in the data processing and accounting process were corrected.

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 Hebei Green Agriculture Limited Company. IEDA-CAAS is responsible for the selection of methods, collection and calculation of parameters values used for the emission factors, calculation and verification of emission factors and emissions; Hebei Green Agriculture Limited Company is responsible for collecting activity data and assisting in the field survey of parameters required for emission factors.

The inventory compiling agencies obtained related information about this case dairy farm through field surveys. The annual average ambient temperature of this farm is 13.2 ℃, and the main breeding specie of cattle is Holstein. The annual stock of dairy cattle is 1,158, of which calves, other cattle and mature dairy cattle are 173, 369 and 616, respectively, the average daily milk production of mature dairy cattle is 34.7 kg, and the total milk output of this study farm was 6.954 tons in 2018. For manure management, including daily spread, static pile composting, anaerobic digester and pit storage below animal confinements (less than 1 month). The main production performance parameters including age, weight and feed intake are shown in Annex table 1.

3. MEASUREMENT OF DAIRY FARM GHG EMISSIONS

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

3.1. MEASUREMENT CH_4 EMISSIONS FROM ENTERIC FERMENTATION OF DAIRY COWS

3.1.1 Activity data of Dairy cattle

According to "Provincial MRV Guidance", it is necessary to collect animal population in stock of dairy cattle in different growth stages (calves, other cattle, mature dairy cow). The activity data of dairy cattle is derived from dairy farm statistic book, according to the classification of the growth stages of the cows, the stocks data obtained at the different growth stages of the dairy farm in this case are shown in Table 1.

Table 1 Activity data for dairy cattle

Year-end Population in stocks (heads)	Population in each growth stages (heads)		
	Calves	Other cattle	Mature dairy cow
1158	173	369	616

3.1.2 Monitoring and calculation of emission factor and key parameters

The CH_4 emission factors from enteric fermentation from dairy cattle under different growth stages were calculated using Equation 1. Because the case is a single dairy farm, there are only 1 type of intensive feeding situation:

$$EF_{CH_4\_EN\ (T,P)} = \left(GE_{\ (T,P\ )} \cdot \frac{Y_{m(T,P)}}{100} \cdot 365\right)/55.65 \qquad (1)$$

Where:

$EF_{CH4\_EN(T,\ P)}$ CH_4 emission factor from enteric fermentation in feeding situation P in

growth stage T, kg CH_4 head^{-1} yr^{-1};

$GE_{(T,\ P)}$ gross energy intake of dairy cattle in feeding situation P in growth stage T; MJ head^{-1} day^{-1};

$Y_{m(T,\ P)}$ CH_4 conversion factor for dairy cattle in feeding situation P in growth stage T, percent of gross energy in feed converted to CH_4, %;

365 total days in a year, day year^{-1};

55.65 the energy content of CH_4, MJ kg^{-1} CH_4.

T index for growth stage

P index for feeding situation. In this case, the feeding situation is intensive feeding situation.

3.1.2.1 Gross Energy (GE) intake of dairy cattle

The GE intake for dairy cattle can be determined based on the formula provided by the "Provincial MRV Guidance". The calculation using Equation 2 is as follows:

$$GE = \left[\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM} + \frac{NE_g}{REG}\right] / \left(\frac{DE}{100}\right) \qquad (2)$$

Note: Dairy feed can always be calculated separately by feeding situation and growth stage. The above formulas and main parameters are not marked with animal feeding situation(P) and growth stage (T). The following net energy calculations are not marked with subclass codes.

Where:

- NE_m: net energy required by dairy cattle for maintenance, MJ head^{-1} day^{-1};

  Calculation formula: $NE_m = Cf_i\ (BW)^{0.75}$ (2.1)

  Collection method of parameters:

  - BW: live-weight of the animal, kg.

    Obtained by typical survey, the weight results of dairy cattle in this case are shown in Table 2:

    Table 2. Live-weight of dairy cattle under different growth stage (kg)

Growth stage	Calves	Other cattle	Mature dairy cow
Live-weight	230	550	750

  - Cf_i: a coefficient which varies for each growth stage, MJ kg^{-1} day^{-1};

    Use the default value recommended by IPCC.

    Dry cattle in Mature dairy cows, Calves, other cattle Cf_i=0.322;

    Lactating cows Cf_i=0.386

    In order to calculate the net maintenance energy of mature dairy cow, the case study obtained the lactation rate, and calculated the animal population in stocks of dry and lactating cattle (Table 3)

Table 3 Population in stocks of dry and lactating cow (heads).

	Lactation rate (%)	Dry dairy cattle	Lactating dairy cattle
Lactation rate and stocks	90.3	60	556

- NE_a: net energy for dairy cattle activity, MJ head^{-1} day^{-1};

  Calculation formula: $NE_a = C_a \cdot NE_m$ (2.2)

  Collection method of parameters:

  - *Ca*: a coefficient corresponding to dairy cattle's feeding situation, Use the default value recommended by IPCC.
  - Intensive and Backyard: Ca= 0

    Grazing: Ca= 0.17

- NE_g: net energy for growing, MJ head^{-1} day^{-1}.

  Calculation formula: $NE_g = 22.02 \cdot \left(\frac{BW}{C \cdot MW}\right)^{0.75} \cdot WG^{1.097}$ (2.3)

  Collection method of parameters:

  - *BW*: the average live body weight (BW) of dairy cattle, kg; The results are shown in Table 2.
  - *MW*: the mature live body weight of an adult female in moderate body condition, kg; The *MW* was obtained by typical survey. In this case, the *MW* in intensive farming was 750 kg.
  - *WG*: the average daily weight gain of dairy cattle, kg day^{-1}.

  The *WG* was obtained by typical survey, the survey results of the *WG* in this case are shown in Table 4.

Table 4 The average daily weight gain of dairy cattle under growth stage (kg day^{-1}).

Growth stage	Calves	Other cattle	Mature dairy cow
Daily weight gain	0.94	0.67	0

C: a coefficient with a value of 0.8 for dairy cattle;

- NE_l: net energy for lactation, MJ day^{-1};

  Calculation formula: $NE_l = M_{milk} \cdot (1.47 + 0.40 \cdot F_{fat})$ (2.4)

  Collection method of parameters:

  - M_{milk}: amount of milk produced, kg day^{-1};

    The milk yield was obtained by typical survey. The results of the milk yield in this case are shown in Table 5.

Table 5 The daily milk yield, kg day^{-1}

Growth stage	Calves	Other cattle	Mature dairy cow
Milk yield	0	0	34.70

- F_{fat}: fat content of milk, % by weight.

  The milk fat content was obtained by typical survey. The results of the fat content of milk in this case are shown in Table 6.

Table 6 The fat content of milk (%)

Growth stage	Calves	Other cattle	Mature dairy cow
Fat content of milk	0	0	4.01

- NE_{work}: net energy for work, MJ day^{-1};

  Calculation formula: $NE_{work} = 0.10 \cdot NE_m \cdot H$ (2.5)

  Collection method of parameters:

  - H: number of hours of work per day, hour;

    The H was obtained by typical survey. The value of the H in this case in different feeding situation and growth stage is 0.

- NE_p: net energy required for pregnancy, MJ day^{-1};

  Calculation formula: $NE_p = C_{pregnancy} \cdot NE_m \cdot R_{pregnancy}/100$ (2.6)

  Collection method of parameters:

  - $C_{pregnancy}$: pregnancy coefficient with a value of 0.10 for dairy cattle.
  - $R_{pregnancy}$: percentage of mature dairy cow pregnancy, %.

    The percentage of mature dairy cow pregnancy was obtained by typical survey. The results of the percentage of mature dairy cow pregnancy in this case are shown in Table 7.

Table 7 percentage of pregnancy for Mature dairy cow (%).

Growth stage	Calves	Other cattle	Mature dairy cow
$R_{pregnancy}$	0	0	90.0

- REM: ratio of net energy available in a diet for maintenance to digestible energy consumed;

  Calculation formula:

$$REM = \left\{\left[1.123 - (4.092 \cdot 10^{-3} \cdot DE) + [1.126 \cdot 10^{-5} \cdot (DE)^2]\right] - \frac{25.4}{DE}\right\} \quad (2.7)$$

  Collection method of parameters:

  - DE: feed digestibility, %.

    The DE was obtained by typical survey. The results of the DE in this case are shown in Table 8.

Table 8 Feed digestibility (%)

Growth stage	Calves	Other cattle	Mature dairy cow
Feed digestibility	70	70	70

- REG: ratio of net energy available for growth in a diet to digestible energy consumed;

  Calculation formula:

$$REG = \left\{\left[1.164 - (5.160 \cdot 10^{-3} \cdot DE) + [1.308 \cdot 10^{-5} \cdot (DE)^2]\right] - \frac{37.4}{DE}\right\}$$

(2.8)

Collection method of parameters:

- *DE*: feed digestibility, %.

  See Table 8 for parameter values.

- *GE*: gross energy in dairy cattle feed intake, MJ $head^{-1}$ day^{-1};

  According to the Equation 2 and the calculation result of NE_m, NE_a, NE_l, NE_{work}, NE_p, *REM and REG*, the total gross energy intake of dairy is calculated; the results are shown in Table 9.

Table 9 The total gross energy intake of dairy cattle under different growth stage (MJ $head^{-1}day^{-1}$).

Growth stage	Calves	Other cattle	Mature dairy cow
GE	94.4	155.9	420.3

3.1.2.2 Determination of the CH_4 conversion factor (Y_m)

The CH_4 conversion factor (Y_m) is directly related to the feed quality and feed intake. At present, there is no systematic experimental data on Y_m for dairy cattle in China. The recommended range of Y_m in the "Provincial MRV Guidance" is 6.5 ± 1.0. In this case, the Y_m values for different growth stages are shown in Table 10.

Table 10 Selected CH_4 conversion factor for dairy cattle (Y_m, %)

Growth stage	Calves	Other cattle	Mature dairy cow
Y_m	6.0	6.5	6.0

3.1.2.3 CH_4 emission factor for dairy cattle

According to Equation 1, calculated the total gross energy intake, CH_4 conversion rate (Y_m) of dairy cattle, CH_4 emission factors for dairy enteric fermentation was calculated (Table 11).

Table 11 CH_4 emission factor from enteric fermentation of dairy cattle (kg CH_4 $head^{-1}$ yr^{-1})

Growth stage	Calves	Other cattle	Mature dairy cow
CH_4 emission factor	37.2	66.5	165.4

3.1.3 CH_4 emissions from enteric fermentation of dairy cattle

Based on the activity data of dairy cattle in different feeding situation and different growth stages and the calculated CH_4 emission factors of enteric fermentation, Equation 3 was used to calculate the CH_4 emissions from enteric fermentation of dairy cattle. The calculation results are shown in Table 12.

$$E_{CH4\_EN} = \sum_{TP} EF_{CH4\_EN\ (T,P)} \cdot \left(\frac{N_{(T,P)}}{10^3}\right) \quad (3)$$

Where:

E_{CH4_EN}	CH_4 emissions from dairy cattle enteric fermentation in the intensive dairy farm, t CH_4 yr^{-1};
$E_{CH4\_EN(T, P)}$	enteric fermentation CH4 emission factor for dairy cattle in feeding situation *P* in growth stage *T*, kg CH_4 $head^{-1}$ yr^{-1};
$N_{(T, P)}$	activity data for the feeding situation *P* in growth stage *T*, average annual animal population in stock, head;
P	index for feeding situation (intensive, backyard, grazing);
T	index for growth stage (calves, other cattle, mature dairy cow).

Table 12 CH_4 emission from enteric fermentation of dairy cattle in 2018 (t CH_4 yr^{-1})

Growth stage	Calves	Other cattle	Mature dairy cow	Sum
CH_4 emission	6.4	24.5	101.9	132.8

3.2 CH_4 EMISSIONS FROM MANURE MANAGEMENT OF DAIRY CATTLE

3.2.1 Activity data of dairy cattle

The activity data of dairy cattle in this section, including the activity data of dairy cattle in different growth stages, is similar to that shown in Table 1 in chapter 3.1.1.

3.2.2 Measurement and calculation of emission factors and key parameters of dairy cattle

Based on "Provincial MRV Guidance ", CH_4 emission factors of dairy manure management systems were calculated as Equation 4:

$$EF_{CH_4\_MM,(T,P)} = \left(VS_{(T,P)} \cdot 365\right)\left[B_{0(T,P)} \cdot 0.67 \cdot \sum_{(S,K)} \frac{MCF_{(S,K)}}{100} \cdot \frac{MS_{(T,P,S)}}{100}\right] \quad (4)$$

Where:

$EF_{CH4\_MM(T,P)}$	CH_4 emission factor from manure management for animals 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 animal 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.

3.2.2.1 Calculation of volatile solids excretion

Based on "Provincial MRV Guidance", volatile solid excretion in dairy manure is calculated as Equation 5:

$$VS = \left[GE \cdot \left(1 - \frac{DE}{100}\right) + (UE \cdot GE)\right] \cdot \left(\frac{1-ASH}{18.45}\right) \quad (5)$$

Where:

VS	volatile solid excretion per day on dry matter basis, kg VS day^{-1};
GE	gross energy intake, MJ day^{-1}; The result is shown in table 9.
DE	feed digestibility %. The result is shown in table 8.
UE . *DE*	urinary energy expressed as fraction of GE. Typically 0.04 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 dairy cattle or 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 dairy manure in different growth stages in this case study was calculated. The specific results are shown in Table 13.

Table 13 the volatile solids excretion of dairy manure (kg VS day^{-1})

Growth stage	Calves	Other cattle	Mature dairy cow
VS	1.60	2.64	7.13

3.2.2.2 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 feeding was taken as 0.24 m^3 CH_4 kg^{-1}VS.

3.2.2.3 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 was conducted to determine the usage of different manure management systems in the dairy farm. In this case, the dairy farm mainly has four management systems: daily spread, composting, pit storage and anaerobic fermentation. Usage of the four manure management systems were listed in Table 14.

Table 14 the proportion of dairy manure handled by manure management systems (%)

Manure management	Daily spread	Pit storage（<1month）	Anaerobic fermentation	composting
Proportion	10	25	25	40

3.2.2.4 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 case farm in 2018 was 13.2℃. According to Table 2-5 in the “Provincial MRV Guidance”, the CH_4 conversion factors for different manure management methods at a temperature of 13.2℃ are shown in Table 15.

Table 15 CH_4 conversion factors of manure management systems for dairy cattle (%)

Manure management	Daily spread	Pit storage（<1month）	Anaerobic fermentation	composting
MCF（%）	0.1	3	10	0.5

3.2.2.5 CH_4 emission factors from manure management of dairy cattle

According to the calculated VS, MCF in different manure management systems and the B_0 in dairy manure, calculated CH_4 emission factors using Equation 4 were shown in Table 16.

Table 16 CH_4 emission factor for manure management (kg CH_4 $head^{-1}yr^{-1}$)

Growth stage	Calves	Other cattle	Mature dairy cow
CH_4 emission factor	3.25	5.37	14.47

3.2.3 CH_4 emission from manure management of dairy cattle

Based on activity data of dairy cattle under different growth stages, and corresponding CH_4 emission factors, equation 6 is used to calculate CH_4 emission from manure management (Table 17).

$$E_{CH_4\_MM} = \sum_{T,P} \frac{\left(EF_{CH4\_MM,\ (T,P)} \cdot N_{(T,P)}\right)}{10^3} \qquad (6)$$

Where:

E_{CH4_MM} CH_4 emissions from manure management for dairy cattle in the intensive dairy 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 17 CH_4 emission from manure management for dairy cattle (t CH_4 yr^{-1})

Growth stage	Calves	Other cattle	Mature dairy cow	Sum
CH_4 emission	0.56	1.98	8.91	11.46

3.3 N_2O EMISSION FROM MANURE MANAGEMENT OF DAIRY CATTLE

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

3.3.1 Direct N_2O emission from manure management of dairy cattle

3.3.1.1 Activity data

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

Annual average N excretion rates is another key parameter for estimating N_2O emissions, there is no measured data for the case dairy farm. The annual nitrogen excretion of dairy cattle in different growth stages in the case intensive farm was obtained according to the second national pollution source survey data (Table 18). The annual nitrogen excretion of dairy cattle in different feeding situation, growth stages and manure management was calculated based on the fraction of manure managed in different manure management in Table 14 in section 3.2.2.3, as shown in Table 19.

Table 18 The nitrogen excretion of dairy cattle in different growth stages (kg $yr^{-1}head^{-1}$).

Growth stage	Calves	Other cattle	Mature dairy cow
Nex	14.42	58.77	96.91

Table 19 The nitrogen excretion of dairy cattle managed in different manure management systems and growth stages (kg $yr^{-1}head^{-1}$).

Manure management system		Daily spread	Pit storage (< 1 month)	Anaerobic fermentation	composting
Growth stage	Calves	249	624	624	998
	Other cattle	2168	5421	5421	8674
	Mature dairy cows	5970	14924	14924	23878

3.3.1.2 The choice of direct N_2O emission factor from manure management of dairy cattle

The manure management systems and fraction of usage of different manure management used to calculate N_2O emission are the same as in section 3.2.2.3 (Table 14).

According to the Table 2-6 in “Provincial MRV Guidance” and investigation of manure management systems (Table 14), direct N_2O emission factor for different manure management were selected (Table 20).

Table 20 Direct N_2O emission factor for dairy cattle manure management systems

Manure management system	Daily spread	Pit storage (< 1 month)	Anaerobic fermentation	composting
EF_3 (kg N_2O-N kg^{-1}N)	0	0.002	0	0.1

3.3.1.3 Direct N_2O emission from manure management of dairy cattle

Direct N_2O emission was calculated used equation 7 based on “Provincial MRV Guidance”, the results are shown in Table 21.

$$E_{N_2O_D,MM} = \left[\sum_S \left[\sum_{T,P} \left(\left(N_{(T,P)} \bullet Nex_{(T,P)}\right) \bullet \frac{MS_{(T,P,S)}}{100}\right)\right] \bullet EF_{3(S)}\right] / 1000 \bullet \frac{44}{28} \qquad (7)$$

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 21 The direct N_2O emission from manure of dairy cattle in different manure management systems and growth stages (t N_2O yr^{-1}).

Manure management system		Daily spread	Pit storage (< 1 month)	Anaerobic fermentation	composting	Total
Intensive	Calves	0	0.002	0.000	0.157	0.16

feeding	Other cattle	0	0.017	0.000	1.363	1.38
	Mature dairy cows	0	0.047	0.000	3.752	3.80
	Total	0.00	0.066	0.000	5.272	5.34

3.3.2 Indirect N_2O emission from manure management of dairy cattle

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 dairy cattle 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 dairy cattle:**

Activity data of dairy cattle in different growth stage are the same as in section 3.1.1, as shown in Table 1.

- **Nitrogen excretion rate:**

Nitrogen excretion rate of dairy cattle in different growth stage are the same as in section 3.1.1, as shown in Table 18.

- **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 9:

$$N_{volatilization,MM} = \sum_S \left[\sum_{T,P}\left[\left(\left(\left(N_{(T,P)} \cdot Nex_{(T,P)}\right) \cdot \frac{MS_{(T,P,S)}}{100}\right) \cdot \left(\frac{Frac_{GasMS(T,S)}}{100}\right)\right)\right]\right] \quad (9)$$

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*, %; The parameter values of the percentage loss of N due to volatilization of ammonia and NOx are derived from Table 10.22 of the 2006 IPCC Inventory Guidelines. The results are shown in Table 22.

Table 22 Percent of nitrogen loss due to NH_3 volatilization and NO_x emissions from manure management (%).

Manure management system	Daily spread	Pit storage (< 1 month)	Anaerobic fermentation	composting
Ammonia and NOx loss ratio	7	28	40[a]	20[b]

Note:[a] The proportion of NH_3 volatilization and NO_x emissions 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 dairy cattle managed in different manure management systems and growth stage, was calculated used equation 9 based on "Provincial MRV Guidance", the results are shown in Table 23.

Table 23 Nitrogen loss due to NH_3 volatilization and NO_x emissions from manure management in different growth stage (kg N yr^{-1}).

Manure management system		Daily spread	Pit storage (< 1 month)	Anaerobic fermentation	composting
Intensive feeding	Calves	17	175	249	200
	Other cattle	152	1518	2168	1735
	Mature dairy cows	418	4179	5970	4776

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

As the precipitation is less than the evaporation in the area of case study 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 dairy 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.

3.3.2.2 Indirect N_2O emission factor from nitrogen deposition form manure management of dairy cattle

According to "Provincial MRV Guidance", Indirect N_2O emission factor from nitrogen deposition in manure management of dairy cattle 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 $kg^{-1}N$.

3.3.2.3 Indirect N_2O emission from manure management of dairy cattle

According to “Provincial MRV Guidance”, equation 11 and 12 were used to calculated indirect N_2O emission due to N deposition and leaching/runoff from manure management, respectively.

$$N_2O_{volatilization,MM} = \left(N_{volatilization,MM} \cdot EF_4\right) \cdot \frac{44}{28}/1000 \quad (11)$$

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 23.
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.

$$N_2O_{Leach,MM} = \left(N_{Leach,MM} \cdot EF_5\right) \cdot \frac{44}{28}/1000 \quad (12)$$

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 8 and the relevant parameters determined, indirect N_2O emission emissions from manure management in this case are shown in Table 24.

Table 24 Indirect N_2O emission from manure management of dairy cattle (t N_2O yr^{-1})

Emission source	Nitrogen deposition	Leaching/runoff	Total
Indirect N_2O emission	0.34	0	0.34

3.3.3 Total N_2O emission from manure management of dairy cattle

The total N_2O emissions from manure management of dairy cattle is equal to the sum of direct N_2O emissions and indirect N_2O emissions. The total N_2O emissions from manure management of dairy cattle in the intensive dairy farm was 5.68 t N_2O in 2018.

Table 25 Total N_2O emission from dairy manure management (t N_2O yr^{-1})

Emission source	Direct emission	Indirect emission	Total
N_2O emissions	5.34	0.34	5.68

3.4 TOTAL GHGS EMISSION OF CASE DAIRY CATTLE IN THE INTENSIVE DAIRY FARM

The total GHG emissions from the dairy farm is equal to the sum of CH_4 emissions from enteric fermentation, 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, See Table 26.

Table 26 Total GHG emission of dairy cattle

Emission source	CH_4 emission from enteric fermentation (t CO_2e)	CH_4 emission from manure management (t CO_2e)	N_2O emission from manure management (t CO_2e)	Total （t CO_2e）
Emission	3321.0	286.4	1691.7	5299.1

In 2018, the GHG emissions from case dairy farm were 5299.1 tons CO_2e. According to the analysis of emission sources, the CH_4 emission from enteric fermentation was the major emission sources, which contribute to 3321.0 tons CO_2e, accounting for 62.7% of total dairy emission; the CH_4 emission from manure management was 286.4 tons CO_2e, accounting for 5.4%; and the N_2O emission from manure management was 1691.7 tons CO_2e, accounting for 31.9%. From the growth stages, the

emission of mature females was the major sources, which contribute to 3974.1 tons CO_2e, accounting for 75.0%; the emission of other cattle was 1099.9 tons CO_2e, accounting for 20.8%, the emission of calves was 225.1 tons CO_2e, accounting for 4.2%. From the type of gases, the main emissions were CH_4, with a total emission of 3607.4 tons CO_2e, accounting for 68.1%, and N_2O emissions of 1691.7 tons CO_2e, and accounting for 31.9%.

3.5 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.

3.6 SIMULATION OF EVALUATION OF MITIGATION EFFECTS

In this case study, the GHG mainly comes from enteric fermentation CH_4 emission, so the priority mitigation technology should be given to reducing enteric fermentation CH_4 emission technology. Based on the production performance of the dairy farm in this case, it is recommended to promote the use of mineral licking bricks for lactating cows. Related studies have shown that adding mineral licking bricks can improve feed conversion efficiency and reduce enteric CH_4 emissions. If this technology is used in this case, the CH_4 conversion rate (Ym) of mature dairy cows can be reduced from 6% to 5.5%. According to the method of the "Provincial MRV Guidance ", the total CH4 emission from enteric fermentation can be reduced by 6.4%, the total GHG emissions of the case farm can be reduced by 4.0%.

4. VERIFICATION OF GHG INVENTORY

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 GHG source for dairy cows. The verification was implemented in according to the verification checklist, and comments are as shown in Table 27.

The results of verification show that the GHG inventory of case intensive dairy farm is in accordance with the requirements of the “Provincial MRV Guidance”, the adopted method are from Provincial MRV Guidance, the activity data was correct. Relevant data is obtained according to the actual situation on the farm site, and the emission factors are comparable to the national inventory-related cow GHG emission factors.

Table 27 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 level of the methodology applied for CH_4 emissions from enteric fermentation appropriate?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the level of the methodology applied for CH_4 from manure management CH_4 appropriate?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the level 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 a 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 classification correct?	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
2.3	Calculation of animal population in stock based on	If the stocks is calculated based on the output， ● Are the calculation methods of	Yes ☐ No ☒ issues ： Stocks data for direct	comments：	Solved ☐ Partly ☐

	numbers of animal produced	animal population in stock clearly described？ ● Are numbers of animal produced correct？ ● Are the hypothesis of alive of animals days appropriate？	surveys		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:	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 ： Not applicable, obtained directly from the farm	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 ： Higher than the implied factor of dairy cows in Hebei Province, mainly due to the weight and production performance of dairy cows are higher than the average level in Hebei	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 dairy cows and swine manure management comparable with the default values of IPCC, the values of the national inventory and	Yes ☒ No ☐ Issues:	comments：	Solved ☐ Partly ☐ Unsolved ☐

		inventories of other provinces？			
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:	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:	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 dairy cows weight, mature dairy weight, weight gain per day, feed intake, feed digestibility, milk production etc?	Yes ☒ No ☐ Issues:	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：	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：	comments：	Solved ☒ Partly ☐ Unsolved ☐
3.4	The comparability of key parameters to determine CH_4 emission factors for	● Are the parameters such as dairy cattle weight, mature dairy 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	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐

	enteric fermentation	other similar provinces？			
		● 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, 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？	Yes ☒ No ☐ issues：	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● Are the milk yield per lactating dairy cows comparable with that of FAO, national statistical yearbook and other data？	Yes ☒ No ☐ issues：	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 dairy cows used in calculation of CH_4 emission factors from enteric fermentation and manure management consistent?	Yes ☒ No ☐ issues：	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, farm-specific 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 emission factor of manure management	● Are the values of volatile solid content comparable to IPCC defaults, applied values in national inventory and other province?	Yes ☒ No ☐ issues : Not applicable, farm-specific data	comments：	Solved ☐ Partly ☐ Unsolved ☐
		● 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, single farm data, uncertainty cannot be calculated	comments:	Solved ☐ Partly ☐ Unsolved ☐
		● Have the data source and evidence to determine the parameters for the calculation of uncertainty been clearly described?	Yes ☐No☒ issues : Not applicable, single farm data, uncertainty cannot be calculated		
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, single farm data	comments:	Solved ☐ Partly ☐ Unsolved ☐

5. ANNEX

Annex Table 1：Basic performance parameters of cattle at different feeding stages of the studied farm

Item	Calves	Other cattle	Mature dairy cattle
Average in stock (heads)	173	369	616
Feeding period (days)	180	365	365
Average body weight (kg)	230	550	750
Daily gain (kg/day)	0.94	0.67	0
Daily milk yield (kg/day)	—	—	34.7
Milk fat content (%)	—	—	4.01
Work time (hr/day)	—	0	0
Feed intake (kg DM/d)	NA	NA	NA
Pregnancy ration (%)	—	—	90
Feed digestibility (%)	70	70	70
Gross energy (MJ/d/head)	94.4	155.9	420.3
CH_4 conversion factor (%)	6.0	6.5	6.0