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 Dairy

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Content

ABSTRACT

The greenhouse gas (GHG) inventory of dairy industry 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, as well as related uncertainty assessment. 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 2017, the GHG emissions from dairy cattle in Hebei Province were 4085.6 kilotons 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 3035.1 kilotons CO_2e, accounting for 74.3% of total dairy emission; the CH_4 emission from manure management was 576.6 kilotons CO_2e, accounting for 14.1%; and the N_2O emission from manure management was 473.8 kilotons CO_2e, accounting for 11.6%. From the feeding situations, the emission of dairy cattle in intensive feeding was 3740.3 kilotons CO_2e, accounting for 91.5%; the emission of dairy cattle in backyard feeding was 345.3 kilotons CO_2e, accounting for 8.5%. From the type of gases, the main emissions were CH_4, with a total emission of 3611.8 kilotons CO_2e, accounting for 88.4%, and N_2O emissions of 473.8 kilotons CO_2e, and accounting for 11.6%.

The uncertainly of GHG emission was estimated by using error propagation equations provided in IPCC good practice guidance, the uncertainty range of CH_4 emission from enteric fermentation of dairy cattle is ±20.8%, the uncertainty range of CH_4 emission from manure management is ±35.0%, the uncertainty range of N_2O direct emission from manure management is ±61.3%, and the uncertainty range of N_2O indirect emission from manure management is ±52.1%. The overall uncertainty of GHG inventory of dairy cows in Hebei province is ±23.5%.

Based on The Provincial MRV guidance, If all manure treated by the liquid storage both for intensive feeding situation and backyard feeding situation are treated by biogas digesters, change of manure management system from liquid storage to biogas digesters could reduce GHG emissions by 225.5 kt CO_2e, or reduction by 21.5% from manure management, and the total GHG emissions of dairy cattle can be reduced by 5.5% due to the change of manure management system in Hebei province.

In order to ensure the quality of GHG inventory for dairy cattle in 2017, 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. Due to the availability of existing data, it is suggested to further investigate the production characteristics of intensive dairy farms in Hebei Province to reduce the uncertainty.

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 dairy cattle is to test the applicability of "Provincial MRV guidance")and provide examples of GHG inventory MRVs in provinces in China or other countries.

The data source of activity data of dairy cattle is Hebei statistical yearbook 2018. In 2017, the animal population in stock of dairy cattle in Hebei province was 1.246 million heads, the animal population in intensive feeding was 1.126 million heads, and animal population in backyard feeding was 122,400 heads, which accounted for 90.2% and 9.8% of the total dairy stocks, respectively. There was no grazing for dairy cattle in Hebei Province.

In accordance with the requirements of the typical survey of "Provincial MRV guidance" the field survey with sample sizes of 6 intensive dairy farms and 102 backyard dairy farms was conducted in Hebei Province, and the parameters of animal production characteristics, population structure in different growth stage, feeding situation, animal intake, feed quality, feed digestibility and manure management were obtained; Nitrogen excretion from dairy cows came from the second national pollution source survey.

In 2017, the GHG emissions from dairy cattle in Hebei Province were 4085.6 kilotons CO_2e. According to the analysis of emission sources, the CH_4 emission from enteric fermentation was the major emission sources, which contribute to 3035.1 kilotons CO_2e, accounting for 74.3% of total dairy emission; the CH_4 emission from manure management was 576.6 kilotons CO_2e, accounting for 14.1%; and the N_2O emission from manure management was 473.8 kilotons CO_2e, accounting for 11.6%. From the feeding situations, the emission of dairy cattle in intensive feeding was 3740.3 kilotons CO_2e, accounting for 91.5%; the emission of dairy cattle in backyard feeding was 345.3 kilotons CO_2e, accounting for 8.5%. From the type of gases, the main emissions were CH_4, with a total emission of 3611.8 kilotons CO_2e, accounting for 88.4%, and N_2O emissions of 473.8 kilotons CO_2e, and accounting for 11.6%.

The uncertainly of GHG emission was estimated by using error propagation equations provided in IPCC good practice guidance, the uncertainty range of CH_4 emission from enteric fermentation of dairy cattle is ±20.8%, the uncertainty range of CH_4 emission from manure management is ±35.0%, the uncertainty range of N_2O direct emission from manure management is ±61.3%, and the uncertainty range of N_2O indirect emission from manure management is ±52.1%. The overall uncertainty of GHG inventory of dairy cows in Hebei province is ±23.5%.

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, and related calculations for the preparation of GHG inventories for dairy cows in Hebei Province was implemented by the inventory compilation team. The calculation and value of the parameters, the calculation of the emissions of various GHG sources, and the report of GHG inventory were internally audited, and the

problems existing in the data processing and accounting process were corrected. The inventory compilation team also invited the national experts and members of steering committee to conduct external reviews on the rationality of method and relevant parameters choice, emission calculation and GHG inventory report.

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 Provincial Animal Husbandry Station. IEDA-CAAS is responsible for the selection of methods, calculation and acquisition of emission factors, calculation and verification of emissions; Hebei provincial animal husbandry station is responsible for collecting activity level data and assisting in the field survey of parameters required for emission factors. IEDA-CAAS is also responsible for inviting domestic experts to evaluate the reasonableness of the survey results such as dairy production performance parameters, feed characteristics, group structure in different stage, and manure management system to ensure the accuracy and science based of the inventory compilation results.

3. MEASUREMENT OF DAIRY GHG EMISSIONS

According to "Provincial MRV guidance", GHG emissions from dairy cattle include CH_4 emissions from manure management, and N2O emissions from manure management. Based on the availability of data, year 2017 was selected as the case study year to measurement, reporting and verification of GHG emissions from dairy cattle in Hebei Province.

3.1 MEASUREMENT CH_4 EMISSIONS FROM ENTERIC FERMENTATION OF DAIRY CATTLE

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 feeding situation (intensive feeding, backyard feeding, grazing) and in different growth stages (calves, other cattle, mature dairy cow). The activity data of Dairy cattle-the total animal population in stock of dairy cattle in inventory is derived from Hebei Statistical Yearbook 2018. In 2017, the animal population in stock of dairy cattle in Hebei province was 1.246 million heads. the animal population in stock of dairy cattle in different feeding situations are obtained based on statistical data of animal husbandry in Hebei Province; the animal population in stock of dairy cattle in different growth stages is calculated according to the proportional between the three growth stages under the intensive feeding or backyard feeding, which obtained through typical field surveys. Activity data and data sources are detailed in Tables 1 and 2.

Table 1 Activity data for dairy cattle

Feeding situation	Year-end Population in stocks (10^4 heads)	Population in each growth stages (10^4 heads)		
		Calves	Other cattle	Mature dairy cow

Intensive	112.36	11.39	38.89	62.08
Backyard	12.24	1.31	2.42	8.51
Grazing	0.00	0.00	0.00	0.00
Subtotal	124.6	12.70	41.31	70.59

Table 2 Source of activity data for dairy cattle

Source	**Data information provided**
Hebei Statistical Yearbook 2018	● The animal population in stock of dairy cattle at the end of the year in the province and counties
Statistical data of animal industry in Hebei Province in 2017	● The proportion of animal population in stock of dairy cattle in intensive feeding system in the province and counties The proportion of animal population in stock of dairy cattle in grazing system in the province and counties
Typical field survey	● The proportion of animal population in stock of at the end of year in each growth stages in 6 intensive dairy farms ● The proportion of y animal population in stock of at the end of year in each growth stages in 102 backyard farms The key parameters used to calculate emission factors, including body weight, daily weight gain, milk production, milk fat rate, working hours, and pregnancy rate, and lactation rate, etc were invest aged through the typical field survey.

3.1.2 Monitoring and calculation of emission factor and key parameters

The CH_4 emission factors from enteric fermentation from dairy cattle are calculated using Equation 1:

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

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.

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:

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

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 3:

    Table 3. Live-weight of dairy cattle in different feeding situation and growth stage (kg)

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	160.00	475.00	687.50
Backyard	134.62	372.07	546.38

  - 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 of different feeding situation, and calculated the animal population in stocks of dry and lactating cattle (Table 4)

Table 4 Population in stocks of dry and lactating cow with different feeding situation (10,000 heads).

Growth stage / Feeding situation	Lactation rate (%)	Dry dairy cattle	Lactating dairy cattle
Intensive	87.7	7.65	54.43
Backyard	81.2	1.60	6.91

- 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 needed for growth, MJ 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 3.
- *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 688 kg, and the *MW* in backyard farming was 546 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 5.

Table 5 The average daily weight gain of dairy cattle in each feeding situation and growth stage (kg day^{-1}).

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	0.83	0.74	0

Backyard	0.7	0.7	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:

  - $\boldsymbol{M_{milk}}$: 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 6.

Table 6 The daily milk yield, MJ day^{-1}

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	0	0	26.42
Backyard	0	0	16.7

  - $\boldsymbol{F_{fat}}$: 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 7.

Table 7 The fat content of milk (%)

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	0	0	3.84
Backyard	0	0	3.40

- 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 8.

Table 8 percentage of pregnancy for Mature dairy cow (%).

Feeding situation \ Growth stage	Calves	Other cattle	Mature dairy cow
Intensive	0	0	82
Backyard	0	0	84

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

  Calculation formula:

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

  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 9.

Table 9 Feed digestibility (%)

Feeding situation \ Growth stage	Calves	Other cattle	Mature dairy cow
Intensive	70	70	70
Backyard	65	65	65

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

  Calculation formula:

  $$REG = \left\{[1.164 - (5.160 \cdot 10^{-3} \cdot DE) + [1.308 \cdot 10^{-5} \cdot (DE)^2]] - \frac{37.4}{DE}\right\} \quad (2.8)$$

Collection method of parameters:

- *DE*: feed digestibility, %.

  See Table 9 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 10.

Table 10 The total gross energy intake of dairy (MJ head^{-1}day^{-1}).

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	69.8	149.8	336.4
Backyard	68.8	47.5	252.1

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 quality of feed and feed intake. At present, there is no systematic experimental data on Y_m for dairy cattle in China, so the default value (6.5 ±1.0) , given in the 2006 IPCC Guidelines, is adopted in these guidelines. 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 feeding situation and different growth stages are shown in Table 11.

Table 11 Selected CH4 conversion factor for dairy cattle (Y_m, %)

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	6.0	6.5	6.0
Backyard	6.0	7.5	6.5

3.1.2.3 CH_4 emission factor for dairy cattle enteric fermentation

According to Equation 1, calculated the total gross energy intake of feed, CH_4 conversion rate (Y_m) of dairy cattle, CH_4 emission factors for dairy enteric fermentation was calculated (Table 12).

Table 12 CH_4 emission factor from enteric fermentation of dairy cattle (kg CH_4 head^{-1} yr^{-1})

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	27.5	63.9	132.4

Backyard	27.1	72.5	107.5

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 13.

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

Where:

E_{CH4_EN} : CH_4 emissions from dairy cattle enteric fermentation in the province, t CH_4 yr^{-1};

$E_{CH4\_EN(T,\ P)}$: enteric fermentation CH_4 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 13 CH_4 emission from enteric fermentation of dairy cattle in 2017 (kt CH_4 yr^{-1})

Feeding situation \ Growth stage	Calves	Other cattle	Mature dairy cow	Total
Intensive	3.1	24.8	82.2	110.1
Backyard	0.4	1.8	9.1	11.3
Total	3.5	26.6	91.3	121.4

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 feeding situation and 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 system are 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 14.

Table 14 the volatile solids excretion of dairy manure (kg VS day^{-1})

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	1.18	2.54	5.70
Backyard	1.34	2.87	4.90

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 and backyard feeding was taken as 0.24 and 0.13 m^3 CH_4 kg^{-1}VS, respectively.

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 with sample sizes of 6 intensive dairy farms and 102 backyard dairy farms was conducted to determine the usage of different manure management system in Hebei Province. The inventory compilation agencies calculated the average of the ratio of manure handled by the manure management systems, and obtained the amount of manure handled by different manure management systems for intensive feeding and backyard feeding in Hebei province (Table 15).

The parameters of animal production characteristics, population structure in different growth stage, feeding situation, animal intake, feed quality, feed digestibility and manure management were obtained; Nitrogen excretion from dairy cows came from the second national pollution source survey

Table 15 the proportion of dairy manure handled by manure management systems (%)

Feeding situation	Daily spread	Solid storage	Liquid/slurry	Anaerobic digester	Burned for fuel	Deep bedding	Composting	Aerobic treatment	Other
Intensive	0.0	26.2	25.1	12.6	0.3	9.0	5.7	0.5	20.7
Backyard	12.6	33.0	40.4	2.6	0.0	3.3	0.0	0.0	8.1

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 of Hebei Province in 2017 was 13.0 °C. 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 °C are shown in Table 16.

Table 16 CH4 conversion factors of manure management systems for dairy cattle (%)

Feeding situation	Daily spread	Solid storage	Liquid/slurry	Anaerobic digester	Burned for fuel	Deep bedding	Composting	Aerobic treatment	Other
MCF （%）	0.1	2.0	22	10.0	10.0	3.0	0.5	0.1	1.0

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 CH4 emission factors using Equation 4 were shown in Table 17.

Table 17 CH_4 emission factor for manure management (kg CH_4 $head^{-1}yr^{-1}$)

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow
Intensive	5.45	11.69	26.25
Backyard	4.25	9.12	15.59

3.2.3 CH_4 emission from manure management of dairy cattle

Based on activity data of dairy cattle in different feeding situation and different growth stages, and corresponding CH_4 emission factors, equation 6 is used to calculate CH_4 emission from manure management (Table 18).

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

Where:

E_{CH4_MM} : CH_4 emissions from manure management for dairy cattle in the province, 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 18 CH_4 emission from manure management for dairy cattle (kt CH_4 yr^{-1})

Growth stage / Feeding situation	Calves	Other cattle	Mature dairy cow	Total
Intensive	0.62	4.55	16.30	21.46
Backyard	0.06	0.22	1.33	1.60
Total	0.68	4.77	17.62	23.07

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.

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 key parameter for estimating N_2O emissions. The annual nitrogen excretion of dairy cattle in different growth stages in Hebei province was obtained according to the second national pollution source survey data (Table 19). 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 section 3.2.2.3, as shown in Table 20.

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

Feeding situation \ Growth stage	Calves	Other cattle	Mature dairy cow
Intensive	14.42	58.77	96.91
Backyard	14.42	58.77	96.91

Table 20 The nitrogen excretion of dairy cattle managed in different manure management systems, in different feeding situation and growth stages (kg $yr^{-1}head^{-1}$).

Feeding situation		Manure management system								
		Daily spread	Solid storage	Liquid/slurry	Anaerobic digester	Burned for fuel	Deep bedding	Composting	Aerobic treatment	Other
Intensive	calves	0	430244	412180	206911	4926	147794	93603	8211	338284
	Other cattle	0	5987672	5736281	2879567	68561	2056834	1302661	114269	4707864
	Mature dairy cow	0	15761966	15100204	7580182	180481	5414416	3429130	300801	12392996
Backyard	calves	23798	62327	76303	4911	0	6233	0	0	15298
	Other cattle	179186	469297	574534	36975	0	46930	0	0	115191
	Mature dairy cow	1039100	2721453	3331719	214418	0	272145	0	0	667993

3.3.1.2 The choice of direct N_2O emission factor form 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 15).

According to the Table 2-6 in "provincial MRV guidance" and investigation of manure management systems (Table 15), direct N_2O emission factor for different manure management were selected (Table 21).

Table 21 Direct N_2O emission factor for dairy manure management in Hebei Province.

Manure management system	Daily spread	Solid storage	Liquid/slurry	Anaerobic digester	Burned for fuel	Deep bedding	Composting	Aerobic treatment	Other

EF_3 (kg N_2O-N kg^{-1}N)	0	0.005	0	0	0.07	0.01	0.1	0.005	0.001

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 22.

$$E_{N_2O_{D},MM} = \left[\sum_S \left[\sum_{T,P} \left(\left(N_{(T,P)} \bullet Nex_{(T,P)}\right) \bullet \frac{MS_{(T,P,S)}}{100}\right)\right] \bullet EF_{3(S)}\right] / 1000 \bullet \frac{44}{28} \quad (7)$$

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

Feeding situation		Manure management system									Total
		Daily spread	Solid storage	Liquid/slurry	Anaerobic digester	Burned for fuel	Deep bedding	Composting	Aerobic treatment	Other	
Intensi	calves	0.0	3.4	0.0	0.0	0.1	2.3	14.7	0.1	0.5	21.1

ve	Other cattle	0.0	47.0	0.0	0.0	0.8	32.3	204.7	0.9	7.4	293.1
	Mature dairy cow	0.0	123.8	0.0	0.0	2.0	85.1	538.9	2.4	19.5	771.6
	Total	0.0	174.3	0.0	0.0	2.8	119.7	758.3	3.3	27.4	1085.8
Backyard	calves	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.6
	Other cattle	0.0	3.7	0.0	0.0	0.0	0.7	0.0	0.0	0.2	4.6
	Mature dairy cow	0.0	21.4	0.0	0.0	0.0	4.3	0.0	0.0	1.0	26.7
	Total	0.0	25.6	0.0	0.0	0.0	5.1	0.0	0.0	1.3	31.9
Total N_2O emission of dairy cattle		0.0	199.8	0.0	0.0	2.8	124.8	758.3	3.3	28.7	1117.7

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 feeding situation and 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 feeding situation and growth stage are the same as in section 3.1.1, as shown in Table 19.

- **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*, %; 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 23 Percent of nitrogen loss due to volatilization of NO_x and NH_3 from manure management (%).

Animal type	Daily spread	Solid storage	Liquid /slurry	Anaerobic treatment	Burn	Deep bedding	Composting	Aerobic treatment	other	Total
Dairy cattle	7	30	40	40[a]	0	40[b]	20c	20[c]	20[c]	21.1

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] **The proportion of NH_3 and NO_x volatilization from dairy manure managed by deep bedding shall refer to the manure management of deep bedding for swine.**

[c] **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 in different feeding situation and growth stage, was calculated used equation 9 based on "provincial MRV guidance", the results are shown in Table 24.

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

Feeding situation		Manure management								
		Daily spread	Solid storage	Liquid/slurry	Anaerobic treatment	Burn	Deep bedding	Composting	Aerobic treatment	other
Intensive	Calves	0	129073	164872	82765	0	59118	18721	1642	67657
	Other cattle	0	1796301	2294512	1151827	0	822734	260532	22854	941573
	Mature dairy cow	0	4728590	6040082	3032073	0	2165766	685826	60160	2478599
Backyard	Calves	1666	18698	30521	1964	0	2493	0	0	3060
	Other cattle	12543	140789	229813	14790	0	18772	0	0	23038
	Mature dairy cow	72737	816436	1332687	85767	0	108858	0	0	133599

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

As the precipitation is less than the evaporation in Hebei province, 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 country, 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 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.

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

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 intensive feeding and backyard feeding in Hebei Province are shown in Table 25.

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

Feeding situation	Nitrogen deposition	Leach/runoff	Total
Intensive	424.4	0	424.4
Backyard	47.9	0	47.9
Total	472.3	0	472.3

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 from intensive feeding, direct N_2O emissions from backyard feeding, indirect N_2O emissions from intensive feeding and indirect N_2O emissions from backyard feeding. The total N_2O emissions from manure management of dairy cattle in Hebei Province was 1590.0 t N_2O in 2017.

Table 26 Total N_2O emission from dairy manure management (t N_2O yr^{-1})

Feeding situation	Direct emission	Indirect emission	Total
Intensive	1085.8	424.4	1510.2
Backyard	31.9	47.9	79.8
Total	1117.7	472.3	1590.0

3.4 TOTAL GHG EMISSION OF DAIRY CATTLE IN HEBEI PROVINCE

The total GHG emissions from dairy cattle in Hebei province 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 (Table 27).

Table 27 Total GHG emission of dairy cattle in Hebei province

Feeding situation	CH_4 emission from enteric fermentation	CH_4 emission from manure management	N_2O emission from manure management	Total

	(kt CO_2e)	(kt CO_2e)	(kt CO_2e)	(kt CO_2e)
Intensive	2753.7	536.6	450.0	3740.3
Backyard	281.4	40.1	23.8	345.3
Total	3035.1	576.6	473.8	4085.6

In 2017, The GHG emissions from dairy cattle in Hebei Province were 4085.6 kilotons CO_2e. According to the analysis of emission sources, the CH_4 emission from enteric fermentation was the major emission sources, which contribute to 3035.1 kilotons CO_2e, accounting for 74.3% of total dairy emission; the CH_4 emission from manure management was 576.6 kilotons CO_2e, accounting for 14.1%; and the N_2O emission from manure management was 473.8 kilotons CO_2e, accounting for 11.6%. From the feeding situations, the emission of dairy cattle in intensive feeding was 3740.3 kilotons CO_2e, accounting for 91.5%; the emission of dairy cattle in backyard feeding was 345.3 kilotons CO_2e, accounting for 8.5%. From the type of gases, the main emissions were CH_4, with a total emission of 3611.8 kilotons CO_2e, accounting for 88.4%, and N_2O emissions of 473.8 kilotons CO_2e, and accounting for 11.6%.

From the analysis of the enteric fermentation CH_4 emissions of dairy cattle, the main emissions are from mature dairy cow. The total emissions were 2283.3 kilotons CO_2e, accounting for 75.2% of the enteric CH_4 emissions, followed by other cattle, which is 664.8 kilotons CO_2e, accounted for 21.9% of enteric CH_4 emissions, and enteric CH_4 emissions of calves was 87.1 kilotons CO_2e, accounting for 2.9% of enteric CH_4 emissions. In terms of CH_4 emission from manure management, it was the same as CH_4 emission from enteric fermentation. The emission mainly come from mature dairy cattle, the emission was 440.6 kilotons CO_2e, accounting for 76.4% of the emission from manure management. The emission of CH_4 from manure management of other cattle is 119.2 kilotons CO_2e, accounting for 20.7% of the emission from manure management, and the emission of calves only accounts for 2.9% of the emission source. In terms of the emission of N_2O from manure management, it also mainly come from mature dairy cow, with the total emission of 339.7 kilotons CO_2e, accounting for 71.7% of the total emission of N_2O from manure management, followed by other cattle, with the emission of 124.9 kilotons CO_2e, accounting for 26.4% of the total emission of N_2O from manure management, while the total emission of N_2O from manure management of calves in that year was 9.2 kilotons CO_2e, only accounting for 1.9% of the manure management N_2O emission.

3.5 UNCERTAINTY ANALYSIS

In accordance with the requirements of the uncertainty assessment of the "provincial MRV guidance", the propagation equations provided in IPCC good practice guidance was used to calculate the CH_4 emissions from dairy enteric fermentation, CH_4 emissions from manure management, direct N_2O emissions from manure management, indirect N_2O emissions from manure management, and uncertainty of GHG emissions of dairy cattle:

(1) The uncertainty of CH_4 emissions from enteric fermentation of dairy cattle mainly considers the uncertainty of the survey data of animal weight, daily weight gain, and milk production. The

uncertainty is determined by the mean and standard deviation of the survey data. With reference to the IPCC Good Practice Guidance, the uncertainty of the CH_4 conversion factor is ±40%; As the activity data comes from the statistical yearbook, the uncertainty value of activity data is selected as ±5%. The uncertainty range of CH_4 emission from enteric fermentation is ±20.8%.

(2) The uncertainty of CH_4 emissions from dairy manure management mainly considers the uncertainty of the proportion of manure management systems, which is determined by the mean and standard deviation of the survey parameters. The uncertainty of ash in the manure is chosen to be ±20%, the value of the CH_4 conversion coefficient of different manure management systems is the IPCC default value, and the uncertainty value is selected as ±50%; for activity level data, select ±5%. The uncertainty range of CH_4 emissions from manure management is ±35.0%.

(3) The uncertainty of direct N_2O emissions from dairy manure management mainly considers the uncertainty of the proportion of manure management systems, which is determined by the mean and standard deviation of the survey parameters; the uncertainty value of N_2O emission factors for different manure management systems is ±100%; for activity level data, select ±5%. The uncertainty range of the direct emission of N_2O from animal manure management is ±61.3%.

(4) Indirect N_2O emissions from dairy manure management are calculated directly from the default parameters, mainly from the uncertainty of emission factors and the uncertainty of activity levels, of which the uncertainty value of indirect emission factors is ±100%; for activity level data, select ±5%.The uncertainty range of indirect N_2O emissions from animal manure management is ±52.1%.

Based on uncertainty of emissions from above four types of sources, the overall uncertainty of GHG emissions from dairy cattle in Hebei Province was estimated to be ±23.5%.

3.6 SIMULATION OF EVALUATION OF MITIGATION EFFECTS

The Provincial MRV guidance can be used to analyze the effects of different mitigation scenarios. Taking manure management as an example, the Chinese government paid great attention to the utilization of livestock manure; it is proposed that compost and biogas are the main methods for manure management. By 2020, National livestock manure utilization rate will reach 75%. Based on The Provincial MRV guidance, If all manure treated by the liquid storage both for intensive feeding situation and backyard feeding situation are treated by biogas digesters, change of manure management system from liquid storage to biogas digesters could reduce GHG emissions by 225.5 kt CO_2e, or reduction by 21.5% (1050.5 kt CO_2e vs 825.0 kt CO_2e) , and the total GHG emissions of dairy cattle can be reduced by 5.5% due to the change of manure management system in Hebei province (Table 28).

Table 28 Comparison of the effect of change manure management on GHG mitigation

Items		Baseline scenario		Mitigation scenario	
		Intensive	Backyard	Intensive	Backyard
Percentage of manure management（%）	Daily spread	0.0	12.6	0	12.6
	Solid storage	26.2	33	26.2	33
	Liquid storage	**25.1**	**40.4**	**0**	**0**
	Anaerobic digester	**12.6**	**2.6**	**37.7**	**43**
	Burned for fuel	0.3	0	0.3	0
	Deep bedding	9.0	3.3	9	3.3
	Composting	5.7	0	5.7	0
	Aerobic treatment	0.5	0	0.5	0
	Others	20.7	8.1	20.7	8.1
Implied CH_4 emission factor of manure management（kg CO_2e Yr^{-1} $head^{-1}$）		462.8		281.8	
Implied N_2O emission factor of manure management（ kg CO_2e Yr^{-1} $head^{-1}$）		380.3		380.3	
CH_4 emission from manure management（kt CO_2 e)		576.6		351.1	
N_2O emission from manure management（kt CO_2 e)		473.8		473.9	
Total GHG emissions from manure management（kt CO_2 e)		1050.5		825.0	
Percentage of mitigation（%）		21.5			

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 source for dairy cows in Hebei Province. The external review and verification were organized by lead agency of inventory compilation team, the verification group include officials from ministry of agricultural and rural affairs, ministry of ecology and environment, national statistics agency, experts from research institutes, extension experts from station of technology for animal production in county level, city level and provinces. The external review and verification were implemented in according to the verification checklist, and comments are as shown in Table 29.

The results of verification show that the GHG inventory of dairy cattle in Hebei Province is in accordance with the requirements of The Provincial MRV guidance, the adopted method is from Provincial MRV guidance, the activity data was correct. The dairy cattle are further classified into 3 feeding situations and 3 growth stage, the values of parameters for determining the emission factors are come from the field survey which samples from typical farms with different feeding situation, and the emission factors were comparable with that in national inventory.

In the process of verification, the verification experts recommended that change the nitrogen excretion data from fixed values to values in different growth stage. The inventory compilation team corrected nitrogen excretion data, and N_2O emissions was revised accordingly .

Table 29 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 CH4 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 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 : Not applicable to dairy cows. Dairy in stocks data are available in Hebei Statistical Yearbook	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	Yes ☐ No ☒	comments:	Solved ☐

		previous years？ ● Are there detailed explanation in inventory if there is a significant change?	Issues: Because there are no animal stocks in different growth stages in previous years, the data of dairy cows in different growth stages calculated by the research team based on the survey results cannot be compared with previous years		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 ： The comprehensive CH_4 emission factor of dairy enteric fermentation in Hebei Province is 95.79kg CH4 / head / year, which is comparable to Eastern Europe (99kg CH_4 / head / year). At present, the provincial dairy cow emission factors in China directly use the regional GHG emission factors provided in the "Provincial livestock GHG MRV Guidance". The calculation results are comparable to the recommended emission factors	comments：	Solved ☐ Partly ☐ Unsolved ☐

			in North China.		
		● 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: The comprehensive CH_4 emission factor of dairy manure management in Hebei Province is 16.09 kg CH_4 / head / year, which is comparable to Eastern Europe.	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 inventories of other provinces?	Yes ☒ No ☐ Issues: The comprehensive direct N_2O emission factor is 0.79 kg N_2O/head/yr.	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:	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	Yes ☒ No ☐	comments:	Solved ☐

		production and feed are obtained through the survey？ ● Have the representativeness of survey methods and results been demonstrated？	issues：		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 enteric fermentation	● 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 other similar provinces？	Yes ☒ No ☐ issues：	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, 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：	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：	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： Nitrogen excretion is not provided in	comments： Provide nitrogen excretion in	Solved ☒ Partly ☐ Unsolved ☐

			stages	growth stages	
		● 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:	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:	comments:	Solved ☐ Partly ☐ Unsolved ☐

5. APPENDIX

5.1 RELEVANT FORMS FOR GHG EMISSION REPORTS OF DAIRY COWS IN HEBEI PROVINCE

Table 5- 1 Summary of GHG emissions from dairy cows

source categories	CH_4 emissions (ton)	N_2O emissions (ton)	Emissions (ton CO_2e)
CH_4 emissions from enteric fermentation	121405.8		3035144.8
CH_4 emissions from manure management	23065.3		576633.6
N_2O emissions from manure management		1590.0	473818.3
Total	144471.1	1590.0	4085596.7

Table 5-2 Major livestock activity data in feeding situations and in different growth stages

Livestock	**Feed situation**	**Population in stock at the end of the year (10^4 heads)**	**Proportion of different growth stag（%）**		
			Calf/Nursery	other cattle/growing -Finishing	Mature dairy cow /Sow
Dairy cattle	Intensive feeding	112.36	10.1	34.6	55.3
	Backyard feeding	12.24	10.7	19.8	69.5
	Grazing	0	---	----	----
	Total	124.60			

Table 5- 2 Activity data and key parameters for determination of CH_4 emissions from enteric fermentation of dairy cattle

Feeding situation	**Growth stages**	**Population in stock at the end of the year (ten thousand heads)**	**Average gross energy intake（MJ/head/day）**	**Average CH_4 conversion factors（Ym）%**	**CH_4 emission factors (kgCH_4/head/day)**	**CH_4 emissions（ton）**
Intensive	Calf	11.39	69.8	6.0	27.5	3128.7
	Other cattle	38.89	149.8	6.5	63.9	24835.3
	Mature dairy cow	62.08	336.4	6.0	132.4	82185.1
Backyard	Calf	1.31	68.8	6.0	27.1	354.7
	Other cattle	2.42	147.5	7.5	72.5	1755.7
	Mature dairy cow	8.51	11.1	6.5	107.5	9146.3
Grazing	Calf	----	----	----	----	----
	Other cattle	----	----	----	----	----
	Mature dairy cow	----	----	----	----	----

Table 5- 3 Data for determining CH_4 emission factors from enteric fermentation of dairy cattle

Feeding situation	**Growth stages**	Weight （kg）	weight gain (kg/d)	Milk (kg/d)	Fat（%）	Work (hr/d)	pregnant (%)	Feed intake (kg dm/d)	Feed digestibility (%)	Gross Energy intake (MJ/head/year)	CH_4 emission factors (kg CH_4/head/year)
Intensive	Calf	160.0	0.83	0	0	0	0	3.5	70	69.8	27.5
	Other cattle	475.0	0.74	0	0	0	0	7.6	70	149.8	63.9
	Mature dairy cow	687.5	0.0	26.42	3.84	0	82.3	18.2	70	336.4	132.4
Backyard	Calf	134.62	0.70	0	0	0	0	3.2	65	68.8	27.1
	Other cattle	372.07	0.70	0	0	0	0	7.0	65	147.5	72.5
	Mature dairy cow	546.38	0.00	16.7	3.40	0	83.95	13.7	65	11.1	107.5
Grazing	Calf	----	----	----	----	----	----	----	----	----	----
	Other cattle	----	----	----	----	----	----	----	----	----	----
	Mature dairy cow	----	----	----	----	----	----	----	----	----	----

Table 5- 4 Activity data and key parameters for determining CH_4 emission from manure management

Livestock	Feeding situation	Growth stages	population at the end of the year (ten thousand heads)	Ratio of climaticzones(%)			Average annual temperature(℃)	Average animal weight (kg)	Average VS excretion (kg DM/ head/day)	Average maximum CH_4 producing capacity (B_0)(m^3CH_4/kg VS)	CH_4 emission factors ($kgCH_4$/head/day)	CH_4 emissions (ton)
				Cool	Temperate	Warm						
Dairy cattle	Intensive	Calf	11.39	100	0	0	13	160.0	1.18	0.24	5.45	620.4
		Other cattle	38.89	100	0	0	13	475.0	2.54	0.24	11.69	4545.7
		Mature dairy cow	62.08	100	0	0	13	687.5	5.70	0.24	26.25	16296.3
	Backyard	Calf	1.31	100	0	0	13	134.62	1.34	0.13	4.25	55.7
		Other cattle	2.42	100	0	0	13	372.07	2.87	0.13	9.12	220.7
		Mature dairy cow	8.51	100	0	1.18	13	546.38	4.90	0.13	15.59	1326.5
	Grazing	Calf	----	----	----	----	----	----	----	----	----	----
		Other cattle	----	----	----	----	----	----	----	----	----	----
		Mature dairy cow	----	----	----	----	----	----	----	----	----	----

Table 5- 5 Manure management systems and corresponding CH_4 conversion facto (%)

Animal category	Feeding situation	Psature /Range /Paddock	Daily spread	Burned for fuel	Solid storage	Dry lot	Composting	Deep bedding	Pit storage	Liquid storage	Lagoon	biogas digester	Aerobic treatment	Other
Dairy cattle	Intensive	0.0	0.0	26.2	0.0	25.1	0.0	0.0	12.6	0.3	9.0	5.7	0.5	20.7
	Backyard	0.0	12.6	33.0	0.0	40.4	0.0	0.0	2.6	0.0	3.3	0.0	0.0	8.1
	Grazing	----	----	----	----	----	----	----	----	----	----	----	----	----
	MCF（%）	1.0	0.1	2.0	1.0	22	71	3.0	10.0	10.0	3.0	0.5	0.1	1.0

Table 5- 6 Parameters related to dairy cattle manure management and N_2O emissions

Animal category	Feeding situation	Growth stages	Stocks (ten thousand heads)	Typical animal weight（kg）	N excretion rate (kg/head/year）	Nitrogen content in different manure management systems（kg N/year）													Total N（kg N/year）	Total amount of volatilized ammonia（kg N/year）	Total amount of leached and runoff nitrogen	Emission factors			Emissions (t N_2O)		
						Pasture/Range/Paddock	Daily spread	Burned for fuel	Solid storage	Dry lot	Composting	Deep bedding	Pit storage	Liquid storage	Lagoon	Biogas digester	Aerobic treatment	Other				Direct emissions (kg N_2O/head/year）	N deposition (kg N_2O-N/kg N)	Runoff and leakage (kg N_2O-N/kg N)	Direct emissions	N deposition	Runoff and leaching
airy cows	Intensive	Calves	11.39	160.0	14.42	0	0	4926	430244	0	93603	147794	0	412180	0	206911	8211	338284	1642153			0.185			21.1		
		other cattle	38.89	475.0	58.77	0	0	68561	5987672	0	1302661	2056834	0	5736281	0	2879567	114269	4707864	22853709			0.754			293.1		
		Mature dairy cow	62.08	687.5	96.91	0	0	180481	15761966	0	3429130	5414416	0	15100204	0	7580182	300801	12392996	60160176			1.243			771.6		
	Backyard	Calves	1.31	134.62	14.42	0	23798	0	62327	0	0	6233	0	76303	0	4911	0	15298	188869			0.047			0.6		
		other cattle	2.42	372.07	58.77	0	179186	0	469297	0	0	46930	0	574534	0	36975	0	115191	1422113			0.190			4.6		
		Mature dairy cow	8.51	546.38	96.91	0	1039100	0	2721453	0	0	272145	0	3331719	0	214418	0	667993	8246828			0314			26.7		
	Grazing	Calves	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			--			--		
		other cattle	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			--			--		
		Mature dairy cow	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			--			--		
Total nitrogen in manure management systems (kg N/year）						0	1242084	253968	25432959	0	4825394	7944352	0	25231221	0	10922964	423281	18237626	94513848								
Direct emission factors EF_3(kg N_2O-N/kg N)						0.02	0	0.007	0.005	0.02	0.1	0.01	0.002	0	0.0	0	0.005	0.001									
EF_4（%）						20	7	0	30	20	20	40	20	40	35	40	20	20		30053509			0.01			472.3	
EF_5（%）						0	0	0	0	0	0	0	0	0	0	0	0	0			0			0.0075			0
The amount of direct emissions（kgN_2O）						0	0	2794	199830	0	758276	124840	0	0	0	0	3326	28659							1117.73		
The amount of indirect emissions（kg N_2O）						0	1366	0	119898	0	15166	49936	0	158596	0	68659	1330	57318									
Total emissions（kg N_2O）						0	1366	2794	319729	0	773442	174776	0	158596	0	68659	4656	85977							1117.73	472.3	0

5.2 TYPICAL QUESTIONNAIRE OF LIVESTOCK GHG EMISSION INVENTORY DATA IN HEBEI PROVINCE

Table A1- 1 Investigation on the Population Structure of Dairy Cows

Province：

Hebei Province

County：

All districts and counties

Year of Investigation：

2017

Data source:

Typical survey

Investigator：

Zhu Zhiping

Survey Date：

Dec. 2019

Livestock	Feeding situation	Total amount of livestock population in the province (10^4 heads)	Total amount of livestock population in sample county* (10^4 heads)	Proportion of growth stages (%)		
				Calf/ Nursery	Other cattle/ Growing-finishing	Mature dairy cow/ sows
Dairy cattle	Intensive	112.36	80.0	10.1	34.6	55.3
	Backyard	12.24	11.54	10.7	19.8	69.5
	Grazing	112.36	80.0	10.1	34.6	55.3

Intensive feeding: refers to individual farms (zones) where the stock of dairy cattle ≥ 100 heads, or the annual output of swine ≥ 500 heads.

Grazing: refers to dairy cattle raised in 266 pastoral and semi-pastoral districts and counties in 13 provinces (autonomous regions) designated by the administrative divisions of China.

Backyard feeding: refers to livestock raised by a single family. In this guideline, farm feeding, which is smaller than the standard for intensive feeding, is included in backyard feeding.

Note: * The counties of the sample sites in this table are summarized and obtained from the overall data of the pollution source survey in Hebei

Table A1- 2 Production characteristic parameters—Dairy cattle

Province：Hebei Province   County: Typical Survey Means of Hebei Province   Investigator：Wei Sha, Zhu Zhiping   Survey Date：October-December 2019

Feeding Situation			Intensive				Backyard			
Subject			Births	Calves	Other cattle	Mature dairy cow	Births	Calves	Other cattle	Mature dairy cow
Age（day）			—	NA	NA	NA	—	185	365	365
Average weight（kg）			NA	160	475	687.5	NA	134.6	372.1	546.4
Daily weight gain（kg/day）			—	0.83	0.74	0	—	0.7	0.7	0
Lactation milk production（kg/day/head）			—	—	—	26.4	—	—	—	16.7
Lactation days（day/year）			—	—	—	321.8	—	—	—	NA
Milk fat content（%）			—	—	—	3.8	—	—	—	NA
Lactation rate of brood cows（%）			—	—	—	88	—	—	—	81
Pregnancy rate of brood cows（%）			—	—	—	82	—	—	—	84
Calving number（heads）			—	—	—	1	—	—	—	1
Feed composition	TMR feed（kg/day）		—	3.5	7.6	18.2	—	3.2	7.0	12.9
	concentrates（kg/day）		NA	NA	NA	NA	NA	NA	NA	NA
	Roughage（kg/day）		—	NA	NA	NA	—	NA	NA	NA
	Roughage（kg/day）	Silage	—	NA	NA	NA	—	NA	NA	NA
		Hay, Alfalfa hay	—	NA	NA	NA	—	NA	NA	NA
		Ammoniated straw	—	NA	NA	NA	—	NA	NA	NA
		Dried Stover	—	NA	NA	NA	—	NA	NA	NA
		Juicy feedstuff for root tubers, Green forage	—	NA	NA	NA	—	NA	NA	NA
	Distiller's grains, wheat bran		—	NA	NA	NA	—	NA	NA	NA
Gross energy intake（MJ/day）			—	NA	NA	NA	—	NA	NA	NA
Feed digestibility（%）			—	NA	NA	NA	—	NA	NA	NA

Note: NA indicates that survey data cannot obtain detailed data in stages

Table A1-3 Questionnaire on manure management methods of dairy cows

Province：Hebei Province County: Typical Survey Means of Hebei Province Investigator： Zhu Zhiping Survey Date： December 2019

Livestock	Feeding situation	Ratio of manure treatment（%）													
		Grazing /Range /Paddock	Daily spread	Burned for fuel	Solid storage	Dry lot	Composting	Deep bedding	Pit storage	Liquid storage	Lagoon	Biogas digester	Aerobic treatment	Other	poultry manure with litter
Dairy cow	Intensive feeding	0.0	0.0	0.3	26.2	0.0	5.7	9.0	0.0	25.1	0.0	12.6	0.5	20.7	0
	Backyard feeding	0.0	12.6	0.0	33.0	0.0	0.0	3.3	0.0	40.4	0.0	2.6	0.0	8.1	0

Grazing------ The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.

Daily spread------ Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.

Burned for fuel------ The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel.

Solid storage------ The storage of manure, typically for a period of several months, in unconfined piles or stacks.

Dry lot------ A paved or unpaved open confinement area without any significant vegetative cover. Dry lots do not require the addition of bedding to control moisture. Manure may be removed periodically and spread on fields.

Composting------Aerobic fermentation of livestock solid manure by silo, batch, tank agitation or static ventilation after collection.

Deep bedding------As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months.

Pit storage------Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.

Liquid storage------Manure is stored as excreted or with some minimal addition of water or bedding material in tanks or ponds outside the animal housing, and removed periodically.

Lagoon-----A type of liquid storage system designed and operated to combine waste stabilization and storage. The supernatant water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.

Anaerobic digester------ Animal manure with and without straw are collected and anaerobically digested in a containment vessel or in covered lagoon. CH_4 and CO_2 are produced during the anaerobic fermentation process, Biogas is captured and used as a fuel.

Aerobic treatment------The biological oxidation of manure collected as a liquid with either forced or natural aeration (e.g. wetland).

Poultry manure with litter------Using the bedding material for poultry, and the manure and litter cleaning out together.