



## **Estimation of CH<sub>4</sub> emissions from Livestock manure management in China**

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### **1. Determination of Emission Sources and Key Sources**

CH<sub>4</sub> emission from animal manure management refers to the CH<sub>4</sub> produced during the storage, treatment and land application of animal manure. The term “manure” is the feces (solid part) and urine (liquid part) excreted by livestock. The CH<sub>4</sub> emission factors in the process of animal manure storage, treatment and land application depend on the characteristics of manure, manure management systems, the proportion of different manure management systems, and local climate conditions.

According to the breeding situation and the statistical data availability of livestock and poultry in China, the CH<sub>4</sub> emission sources of animal manure management include 14 kinds of animal manure, including swine, beef cattle, dairy cattle, buffalo, yak, other cattle, goat, sheep, horse, donkey, mule, camel, poultry and rabbit.

Following IPCC guidelines, livestock manure management systems include Pasture/Range/Paddock, daily spread, solid storage, dry lot, liquid storage, lagoon, pit storage under barn, anaerobic digester, burned for fuel, deep bedding, composting, aerobic treatment and others.

At present, livestock manure is mainly used in dry land, fruit trees and vegetable fields after treatment in China, and there is no methane emission caused by anaerobic environment in these ways. The CH<sub>4</sub> emission of livestock manure management in this report is estimated in the process of manure management including storage and treatment.

### **2. CH<sub>4</sub> emission calculation method**

According to the IPCC guidelines and the characteristics of China's animal husbandry farming, this report uses IPCC Tier 2 to estimate CH<sub>4</sub> emission factors for swine, beef cattle, goats, dairy cows, buffalo and sheep. While the manure CH<sub>4</sub> emissions of poultry, yak, other cattle, rabbit, horse, donkey, mule and camel were estimated by IPCC Tier 1 (Table 1).

**Table 1 Methods of CH<sub>4</sub> emission calculation for livestock manure management**

Livestock categories	Method	Emission factor
Swine, dairy cattle, beef, buffalo, sheep, goats	T2	CS
Poultry, yak, other cattle, rabbits, horses, mules/asses, camels	T1	D

### 3. Activity Data and Sources

#### 3.1 Activity level data requirements

According to the method of compiling the CH<sub>4</sub> emission inventory for manure management specified in the IPCC guidelines, for the animals using Tier 1, the activity level data is the average annual in-stock number of various animals in different climate regions. For the animals calculated by Tier 2, in addition to obtaining the total feeding number of various animals in different climate regions, it is also necessary to obtain animal population for different feeding situations and different age stages.

Based on the availability of relevant data, this report selects the year of 2016 to calculate methane emissions from manure management in China's livestock sector.

#### 3.2 Data source and determination method of activity level

Animals that use Tier 1 to estimate CH<sub>4</sub> emissions from animal manure management include poultry, yak, other cattle, rabbits, horses, camels, donkeys, and mules. The activity level data is based on the "2017 China Statistical Yearbook" and "2017 China Animal Husbandry and Veterinary Yearbook". Animals that use Tier 2 to estimate CH<sub>4</sub> emissions from animal manure management include swine, beef, dairy, buffalo, goats and sheep. In addition to the annual in-stock population, it is also necessary to obtain the stock number of different regions, different feeding situations, and different age stages. According to China Relevant statistical data is classified and sorted to obtain detailed activity level data. For the activity level data of different regions, please refer to the attached table 2. The activity data for different feeding situations please refer to the attached table 3. The major regions were East China, South Central and Southwest, the major animal was swine and the major feeding situations were intensive and household.

**Table 2 Populations of various livestock in different regions in China in 2016 (10<sup>4</sup> head)**

Province	Swine	Dairy	Beef	Buffalo	Yak	Other cattle	Sheep	Goats	Poultry	Horses	Assess	Mules	Camels	Rabbits
North China	3369.16	287.6	749.2	0	0.34	72.78	6018.14	2567.85	60398.02	61.73	77.81	18.45	12.73	968.39
Northeast	3480.89	161.82	869.83	0	0	10.8	1386.43	589.81	68398.76	33.47	40.69	7.02	0	175.71
East China	9616.44	130.27	517.21	61.79	0	40.55	890.8	1873.67	184375	1.34	8.17	0.66	0	3648.56
South Central	15830.59	47.39	697.41	519.24	0.01	132.18	97.02	3024.32	207200	22.89	4.25	2.59	0	1799.41
Southwest	9992.51	136.9	1958.33	345.24	359.94	24.74	998.08	3460.99	75619.09	152.9	28.16	32.74	0	6283.75
Northwest	1919.57	273.03	960.25	1.17	433.01	43.44	6848.3	2175.13	21328.96	78.87	100.23	23.06	17.77	349.86
<b>Sum</b>	<b>44209.16</b>	<b>1037.01</b>	<b>5752.23</b>	<b>927.44</b>	<b>793.3</b>	<b>324.49</b>	<b>16238.8</b>	<b>13691.8</b>	<b>617320</b>	<b>351.2</b>	<b>259.31</b>	<b>84.52</b>	<b>30.5</b>	<b>13225.7</b>

**Table 3 The population of intensive feeding livestock by different livestock categories, feeding situations and regions in 2016 (10<sup>4</sup> head)**

Regions	Dairy			Beef			Buffalo		Goats			Sheep			Swine	
	Intensive	Household	Grazing	Intensive	Household	Grazing	Intensive	Household	Intensive	Household	Grazing	Intensive	Household	Grazing	Intensive	Household
North China	144.21	42.33	101.07	130.17	225.85	393.19	0	0	436.59	656.98	1474.28	1261.83	1504.62	3251.68	1488.67	1880.5
Northeast	45.99	67.08	48.76	265.7	387.81	216.33	0	0	272.42	226.04	91.35	289.99	367.58	728.86	1375.64	2105.25
East China	72.97	57.3	0	164.51	352.69	0	12.64	49.16	608.04	1265.63	0	279.68	611.1	0	5805.62	3810.82
South Central	32.99	14.41	0	143.99	553.42	0	103.1	416.14	938.59	2085.74	0	33.94	63.07	0	8216	7614.59
Southwest	61.03	35.62	40.27	136.93	1337.79	483.62	67.06	278.18	428.45	2468.74	563.81	45.85	322.98	629.25	2288.38	7704.12
Northwest	95.66	91.21	86.17	161.79	457.33	341.12	0	1.17	266.03	1318.16	590.94	1683.29	2234.85	2930.17	760.07	1159.49

## 4. Determination of Emission Factors

### 4.1 Emission factors determined by IPCC Tier 1

Climatic conditions and manure management systems are the main factors affecting the CH<sub>4</sub> emissions of livestock manure. Therefore, in calculating CH<sub>4</sub> emission from key emission sources, according to IPCC good practice guidelines, the effects of different climatic regions (warm climate region, cool climate region, temperate climate region) and the proportion of manure management systems on CH<sub>4</sub> emission factors from manure management are considered.

Different climatic regions are defined as: cool climate region with annual average temperature lower than or equal to 15 °C, temperate climate region with annual average temperature higher than 15 °C and lower than 25 °C, warm climate region with annual average temperature higher than 25 °C.

According to the results of key source identification and methodology selection, the emission factors of CH<sub>4</sub> from yak, other cattle, horse, donkey, mule, camel, poultry and rabbit will be determined by IPCC Tier 1.

Tier 1 of the 1996 IPCC Inventory Guidelines provides default CH<sub>4</sub> emission factors for different animal manure management in different climate regions in developing countries.

In this report, the annual average temperature of China's provinces and six regions in 2016 was obtained based on the China Meteorological Data Network, and the CH<sub>4</sub> emission factors of animal manure management (yak, other cattle, rabbit, horse, donkey, mule, camel and domestic poultry) calculated by Tier 1 in different regions were determined (Table 4).

**Table 4 Default CH<sub>4</sub> emission factors for manure management in different climate zones (kg CH<sub>4</sub> head<sup>-1</sup>yr<sup>-1</sup>)**

Climate zone	Yak	Other cattle	Poultry	Horses	mules/asses	Camels	Rabbits
Cool climate regions (North China, northeast and northwest China)	1.0	1.0	0.012	1.1	0.6	1.3	0.08
Warm climate regions (East China, Central South and southwest China)	1.0	2.0	0.018	1.6	0.9	1.9	0.08

### 4.2 Emission factors determined by IPCC Tier 2

The calculation formula for the estimation of the CH<sub>4</sub> emission factor for animal manure management recommended by the Tier 2 of the 1996 IPCC Inventory

Guidelines is as follows:

$$EF_{ik} = VS_i \times 365 \times 0.67 \times B_{oi} \times \sum (MCF_{jk} \times MS_{ijk}) \quad (1)$$

Where:

$EF_{ik}$  : CH<sub>4</sub> emission factor of animal categories i and climate zone k, kg CH<sub>4</sub> head<sup>-1</sup>yr<sup>-1</sup>;

$VS_i$  : Animal categories i daily volatile solid excretion, kg VS day<sup>-1</sup>;

$B_{oi}$  : Manure CH<sub>4</sub> producing capacity of animal categories i, m<sup>3</sup> kg<sup>-1</sup>VS;

$MCF_{jk}$  : CH<sub>4</sub> conversion factors of manure management system j and climate zone k, %;

$MS_{ijk}$  : The proportion of animal category i, climate zone k and manure management system j, %;

0.67: the density of CH<sub>4</sub>, kg/m<sup>3</sup>.

$VS_i$  is calculated by using the data of average daily intake energy and feed digestibility obtained through investigation and using formula 2-2 provided by IPCC;  $B_{oi}$  is the default value recommended by the IPCC;  $MCF_{jk}$  is determined by investigating manure management systems and the annual average temperature of each region;  $MS_{ijk}$  is the proportion of use of various regions, different animals, and different manure management systems obtained through research. The specific methods are as follows:

### (1) Calculation of volatile solid (VS) excretion

The 1996 IPCC Inventory Guidelines provides a calculation method for estimating the excretion of volatile solids (VS), the formula is as follows:

$$VS = GE \times (1/18.45) \times (1 - DE/100) \times (1 - ASH/100) \quad (2)$$

Where:

$VS$  : Volatile solid emissions (dry matter), kg VS day<sup>-1</sup>;

$GE$  : Total energy intake of feed, MJ day<sup>-1</sup>;

$DE$  : Percentage of digestive energy in total energy, %;

$ASH$  : Manure ash content, %.

GE of different animals under different feeding situations is mainly calculated by directly calculating the dry matter intake survey data of the animals and multiplying by 18.45; DE is obtained from the investigation; ASH adopts the default value

recommended by IPCC guidelines, which is 8%; DE and VS of different animals are shown in Table 5.

**Table 5 The investigation of DE and calculation results of VS for different livestock categories and feeding situation**

Livestock	Feed digestibility (DE, %)			Volatile Solid (VS, kg/head/day)		
	Intensive	Household	Grazing	Intensive	Household	Grazing
Dairy cattle	70.0	65.0	70.0	2.60	2.99	2.45
Beef	65.0	65.0	65.0	2.46	2.82	2.96
Buffalo	60.0	60.0		3.16	3.10	
Sheep	65.0	60.0	65.0	0.32	0.41	0.25
Goats	60.0	60.0	60.0	0.40	0.35	0.34
Swine	70.0	70.0		0.28	0.27	

### (2) CH<sub>4</sub> producing capacity (*Bo*)

Manure CH<sub>4</sub> producing capacity (*Bo*) varies with animal species and diets. As there is no research result in China, *Bo* is the default value recommended in the 1996 IPCC inventory guidelines. The recommended values of developed countries are used for intensive breeding, and the recommended values of developing countries are used for household farmers and grazing (Table 6).

**Table 6 The CH<sub>4</sub> producing capacity of manure management for different livestock categories**

Livestock categories	CH <sub>4</sub> producing capacity (m <sup>3</sup> CH <sub>4</sub> kg <sup>-1</sup> VS)		
	Intensive	Household	Grazing
Dairy	0.24	0.13	0.13
Beef	0.19	0.10	0.10
Buffalo	0.10	0.10	
Swine	0.45	0.29	
Sheep	0.18	0.13	0.13
Goats	0.19	0.13	0.13

### (3) Proportion of manure management systems used

13 kinds of animal manure management systems are recommended in the 1996 IPCC inventory guidelines, and the definition of each system is given. According to the definition of manure management systems in "1996 IPCC inventory guidelines", a typical survey was conducted in 69 counties of 6 regions in China. Through the investigation, the proportion of six kinds of animal manure management systems using Tier 2 to calculate the emission factor was obtained, including two kinds of

management systems of scale and farmer raising of dairy cattle, beef cattle, buffalo, goat, sheep and swine in different regions, The investigation result showed that the main manure management system were liquid slurry storage, composting and solid storage, the total percentage range from 65% to 90%, while the major CH<sub>4</sub> emissions may come from liquid or slurry storage.

#### (4) CH<sub>4</sub> conversion factor (MCF)

CH<sub>4</sub> conversion factor is defined as the proportion of actual CH<sub>4</sub> production to CH<sub>4</sub> producing capacity of a certain manure management system. According to the average temperature of each region, select the appropriate IPCC default value. For the CH<sub>4</sub> conversion factor values of different manure management systems in the 6 regions of the country, the related MCF was listed in table 7.

**Table 7 Methane conversion factors of manure management in different regions (MCF, %)**

Regions	Climate zone	Average annual temperature	Pasture/Range/	Daily spread	Burned for fuel	Solid storage	Dry lot	Composting	Deep bedding	Pit storage	Liquid /slurry	Lagoon	Anaerobic digester	Aerobic treatment	Others
North China	cool	12.1C°	1	0.1	10	1	1	0.5	0	0	39	39	10	0.1	1
Northeast	cool	6.8C°	1	0.1	10	1	1	0.5	0	0	39	39	10	0.1	1
East China	cool	9.9C°	1	0.1	10	1	1	0.5	0	0	39	39	10	0.1	1
South Central	warm	17.9C°	1.5	0.5	10	1.5	1.5	1	0	0	45	45	10	0.1	1
Southwest	warm	20.0C°	1.5	0.5	10	1.5	1.5	1	0	0	45	45	10	0.1	1
Northwest	warm	15.4C°	1.5	0.5	10	1.5	1.5	1	0	0	45	45	10	0.1	1

According to Formula 1, the CH<sub>4</sub> emission factors of animal manure management in different regions of 6 main livestock in different feeding situations and different age stages were calculated, the report list the implied emission factor (table 8).

**Table 8 Implied CH<sub>4</sub> emission factors for manure management based on Tier2 (kg CH<sub>4</sub> head<sup>-1</sup>yr<sup>-1</sup>)**

Animal type	Dairy	Beef	Buffalo	sheep	Goat	Swine
<b>Implied EF</b>	14.38	8.58	11.46	1.13	1.61	4.24

### 5. Estimation of CH<sub>4</sub> Emission from Animal Manure Management

CH<sub>4</sub> emissions from animal manure management are equal to the activity level data multiplied by the corresponding emission factors. For the animals using IPCC Tier 1(yak, other cattle, poultry, rabbit, horse, donkey, mule and camel), the CH<sub>4</sub> emission from manure management is equal to the amount on hand in each region in 2016 (Table

2) multiplied by the corresponding default emission factor (Table 5).

For the animals using IPCC Tier 2 (dairy, beef cattle, buffalo, goats, sheep and swine), the CH<sub>4</sub> emissions from animal manure management of different feeding situations and different age groups in different regions were calculated firstly, and then the CH<sub>4</sub> emissions from different animal manure management were summed up. China CH<sub>4</sub> emissions from different animal manure management in 2016 are summarized in Table 9.

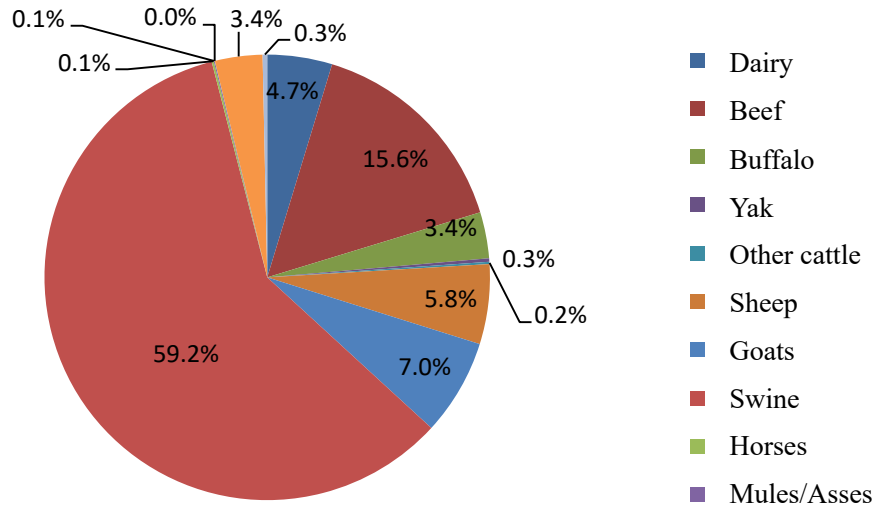
**Table 9 The estimation of CH<sub>4</sub> emission from manure management systems in China in 2016**

Livestock	Emissions (10 <sup>4</sup> tons CH <sub>4</sub> )	Emissions (10 <sup>4</sup> tons CO <sub>2</sub> eq)
Dairy	14.9	313.1
Beef	49.3	1,036.1
Buffalo	10.6	223.2
Yak	0.8	16.7
Other cattle	0.5	11.0
Sheep	18.3	385.3
Goats	22.1	464.1
Swine	187.4	3,936.0
Horses	0.5	9.9
Mules and Asses	0.2	4.8
Camels	0.0	0.8
Poultry	10.9	229.4
Rabbits	1.1	22.2
<b>Sum</b>	<b>316.8</b>	<b>6,652.7</b>

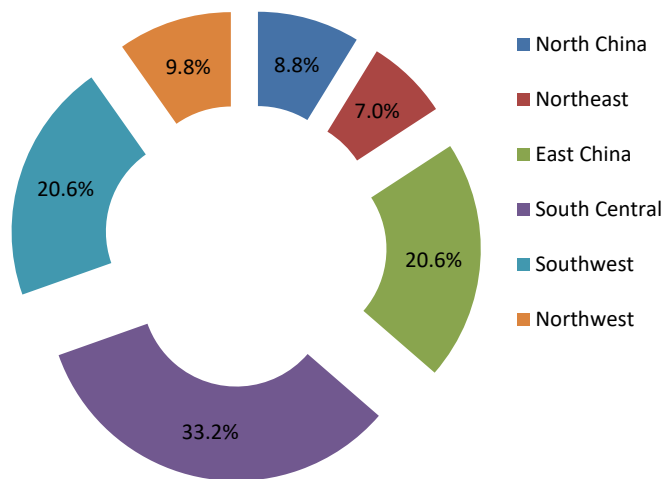
In 2016, the CH<sub>4</sub> emissions from animal manure management were 3.168 million tons, equivalent to 66.527 million tons CO<sub>2</sub>-eq. Swine is the main source of CH<sub>4</sub> emission from animal manure management, accounting for 59.2%. Beef cattle manure CH<sub>4</sub> emissions account for 15.6%. Goats and sheep account for 7.0% and 5.8%, respectively. The proportion of CH<sub>4</sub> emissions from various animal manure management is shown in Figure 1.

Figure 2 shows the manure management CH<sub>4</sub> emissions percentage in different regions, the South Central is the largest contributor region which contribute 33.2 percentage, the following is South West and East China (each region about 20.6%), the rest three region was lower than 10 percentage.





**Fig.1 Proportion of CH<sub>4</sub> emissions from different animal type manure management**



**Fig.2 Proportion of animal manure management CH<sub>4</sub> emissions from different regions**