GREENHOUSE GAS EMISSIONS IN AGRICULTURE, BUILDINGS AND WASTER SECTORS IN HO CHI MINH CITY

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Abstract: *Climate change (CC) is a common problem for all people with a strong influence on the world. One of the main causes of climate change is greenhouse gases (GHG). Viet Nam has implemented the National greenhouse gas inventories for five sectors: agriculture, energy, industrial processes, waste, land use change and forestry. Being the biggest economic development centre in Viet Nam, Ho Chi Minh City has emitted numerous amounts of greenhouse gases every year. This paper presents results of GHG calculations in agriculture, waste and buildings in Ho Chi Minh City applying the 2006 IPCC guideline. It is found that greenhouse gases in Ho Chi Minh were about 1.1 million, 3 million and 0.4 million tons of CO_2 equivalent in agriculture, waste and buildings, respectively.*

Keywords: *IPCC Guideline 2006, greenhouse gas inventory for agriculture, waste, buildings.*

1. Overview of agriculture, waste and buildings sectors in Ho Chi Minh City

1.1 Agriculture

Crop Cultivation: Crop structure continues to reduce rice area while increases area of flower, safe vegetables, fodder grass and other annual industrial crops. By 2013, the total area of rice cultivation in the city was about 29,293 hectares. According to the master plan to 2020, rice area will reduce to 3,200 ha.

Livestock: By 2020, the number of dairy cows and pigs are expected at 75,000 heads, 25,600 heads, 800 heads and 275,000 heads, respectively.

Aquaculture: Area of saltwater aquaculture was about 8,460 ha, concentrating mainly in Can Gio and 1,640 ha of freshwater fisheries, mainly in Binh Chanh and Cu Chi Districts. The farming area by 2020 according to the planning has not changed. [2]

1.2 Waste

Thee volume of domestic solid waste was brought to landfills and solid waste treatment plants in the city estimate about 8,300 tons/day.

However, domestic solid waste has not been classified at source, causing great pressure on treatment facilities. Solid waste treatment technology is mainly landfill method (about 75% of the total volume), the rate of solid waste treated by compost processing method was about 15%, the rate of solid waste is treated by burning technology was about 5-10%.

The wastewater sector includes domestic wastewater, medical waste water and industrial wastewater. Regarding domestic wastewater, the amount of urban wastewater was about 2.75 million tons/day, of which 13% was treated. Wastewater from health facilities was around 17,750m^3/day, industrial wastewater from 13 industrial parks, 3 export processing zones and 33 production facilities is about 278,191m^3/day.

In the situation of increasing waste and impacts of climate change, Ho Chi Minh City needs a master plan to deal with substances of which clearly defining the scale and location of waste treatment facilities. The buildings investment roadmap and technology

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in each stage must be specifically set up to keep up with the city's development speed.

1.3. Buildings

Total of high-rise buildings in 2013 in Ho Chi Minh City is 452 piles including 126 projects in district 1, 107 projects in district 7, 66 projects in district 3, 24 projects in district 2. The total electricity consumption for these buildings was 725 million KWH, in which district 1 consumed about 385 million KWH, accounting for 52%. The total electricity consumption for the facilities accounted for 4% of the city's total electricity consumption.

2. Data and research methods

2.1 Database

2.1.1. Agriculture

Data in the agriculture sector was collected from the Department of Agriculture and Rural Development of Ho Chi Minh City.

2.1.2. Domestic solid waste

Nowadays, Ho Chi Minh City Urban Environment Company is mainly responsible for collecting the solid waste amount. All domestic solid waste is treated by two main methods, namely burial and compost production, where concentrated in Da Phuoc and Tay Bac Cu Chi treatment areas (Landfill No. 2, Vietstar Company). Of which, burial method accounts for about 85%, whereas compost is about 15%.

Table 1. Composition of Domestic solid waste in Ho Chi Minh City

Composition	%
Paper	2.8
Garbage	0
Food	67.9
Wood/ Straw	0.06
Textile	6.4
Skin	2.24
Others	20.6
Total	100

(Source: Department of Solid Waste Management, Department of Natural Resources and Environment of Ho Chi Minh City)

Table 2. Volume of treated domestic solid waste

Types	Volume (tons/year)	Volume (tons/day)	Rate %
Landfill	2,007,135	5,499	80
Burning	146	400	6
Compose	327,040	896	13
Recycle	19,710	54	1
Total	2,499,885	6,849	100

2.1.3. Wastewater

According to survey information of Saigon University, processing technology of EPZs / IPs in Ho Chi Minh City was all Aerotank and SBR forms. These technologies treat wastewater by biological methods under aerobic conditions. Although the centralized wastewater treatment systems of EPZs/IPs are managed and operated relatively methodically, the treatment efficiency has not been as expected, so the group chose MCF = 0.2 to calculate emissions.

Table 3. Wastewater composition of industrial zones and export processing zones in Ho Chi Minh City

No.	KCN-KCX	Actual capacity (m^3/day)	BOD5	COD	N-Total	TSS	Coliforms
1	An Ha	1,100	51	70	12.6	236	12,000
2	Binh Chieu	350	354	632	114	196	4.6x106
3	Cat Lai II	2,400	185	330	18.2	105	9x105
4	Vinh Loc	4,600	200	600	60	300	5,000-8,000
5	Hiep Phuoc	3,500	100	400	60	200	-
6	Cu Chi	3,100	60	109	26.8	82	2x104
7	Le Minh Xuan	9,800	150	600	60	200	-
8	Linh Trung	2,000	500	800	30	300	104
9	Linh Trung II	1,700	-	225	73.50	122	-
10	Tan Binh	4,200	55-135	105-280	16.27	59	1,500-3,000
11	Tan Phu Trung	2,300	198	325	39.6	215	104
12	Tan Tao	1,500	220	500	40	220	105-106
13	Tan Thoi Hiep	5,000	576	1,384	39.7	300	-
14	Tan Thuan	400	88	135	32.8	92	4.6x104
15	Dong Nam	30	Trial operation				
16	Hoa Phu	80	Under buildings				

2.1.3. Buildings

Data for buildings was collected from Department of Construction.

2.2. Methods

2006 IPCC Guidelines for Greenhouse Gas Inventories were applied to calculate GHG for the three sectors in Hochiminh City, as follows:

2.2.1. Agriculture

The method identifies emission of GHG mainly CO_2, CH_4, N_2O through emission factors in each field and industry. These emission factors are included in the IPCC emission calculation formulas for each category of greenhouse gases.

- Rice Cultivation: Annual CH_4 emission from rice

$$CH_{4Rice} = A * t * EF_i * 10^{-6} \quad (1)$$

Where: CH_{4Rice}= Annual CH_4 emission from Rice Cultivation (Gg CH_4 yr-1), EF_i: Adjusted daily emission factor for a particular harvested area (kg CH_4 ha-1 day-1), t = Cultivation period of rice (day), A = Annual harvested area (ha yr-1).

- Livestock:

In this article, greenhouse gases in livestock generated from the intestinal fermentation of livestock and manure management process were calculated.

Methane Emissions from Enteric Fermentation

$$CH_4\ Enteric = N(T) * EF(T) * 10^{-6} \quad (2)$$

Where: CH_4 Enteric= Emission factor for Enteric Fermentation (Gg CH_4 yr-1), N (T)= Number of animals (head), EF(T)= Emission factor for Enteric Fermentation (kg head-1 yr-1).

Table 4. Emission factor for Enteric Fermentation

Category of animal	EF(T) (kg head-1 yr-1)
Dairy Cattle	61
Other Cattle	47
Buffalo	55
Swine	1

Methane Emissions from Manure Management

$$CH_4\ Manure = N(T) * EF(T) * 10^{-6} \quad (3)$$

Where: CH_4 Manure= CH_4 emissions from Manure Management (Gg CH_4 yr-1), EF(T)=Emission factor for Manure Management (kg head-1 yr-1), N (T)= Number of animals (head).

Table 5. The coefficient of methane emission from faeces of some livestock [4]

Category of animal	26°C	27°C	>28°C
Dairy Cattle	28	31	31
Other Cattle	1	1	1
Buffalo	2	2	2
Swine	6	7	7

Direct N_2O Emissions from Manure Management Systems

$$N_2O\ (mm) = NEMMS * EF3(S) * 44/2 \quad (4)$$

Where: N_2O (mm)= Annual direct N_2O emissions from Manure Management (kg N_2O yr-1), NE_{MMS}=Total nitrogen excretion for the MMS (kg N yr-1), EF3(S)=Emission factor for direct N_2O-N emissions from MMS [kg N_2O-N (kg N in MMS)-1], 44/28 =conversion of (N_2O-N) (mm) emissions to N_2O(mm) emissions

Table 6. Default values for nitrogen excretion rate in Asia (kg n (1000 kg animal mass) -1 day-1)

Category of animal	Nrate (kgN/ton/day)	TAM (kg/head)
Dairy Cattle	0.47	350
Other Cattle	0.34	200-275
Swine	0.42	60
Buffalo	0.32	350-550

$$Nex_{(T)} = Nrate(T) * TAM * 10\text{-}3 * 365 \quad (5)$$

Where: $Nex_{(T)}$=Annual N excretion per head of species/livestock category (kg N animal-1 year-1), Nrate(T)= Default N excretion rate [kg N (1000 kg animal)-1 day-1], TAM= Typical animal mass for livestock category (kg)

Amount of manure nitrogen that is loss due to volatilisation of NH_3 and NO_x

$$V_{olatilization\text{-}MMS} = NE_{MMS} * Frac_{(GasMS)} \quad (6)$$

Where: NE_{MMS}=Total nitrogen excretion for the MMS, $Frac_{GasMS}$=Fraction of managed livestock manure nitrogen that volatilises (Dairy Cattle =40%, Other Cattle =45%, Buffalo =25%, Swine =45%.)

- Aquaculture:

$$CH_4\ EmissionWWflood = P * E(CH_4)diff * Aflood\_total\ surface * 10\text{-}6 \quad (7)$$

Where: $CH_{4\ EmissionsWWflood}$=Total emission CH_4 from flood surface (GgCH_4 yr-1); P: time, day yr-1; $Af_{lood\_\ total\ surface}$=Annual flood total surface area (ha).

2.2.2. Domestic solid waste

Formula to calculate greenhouse gas emissions from landfills:

$$Lo = Wx\ MCF \times DOC \times DOCF \times (16/12)\ xF \quad (8)$$

Where: Lo = CH_4 generation potential, Gg; W = mass of waste deposited, Gg; DOC = degradable organic carbon in the year of deposition, fraction, Gg C/Gg waste; DOCf = fraction of DOC that can decompose (fraction); MCF = CH_4 correction factor for aerobic decomposition in the year of deposition (fraction); DOC, Gg F = fraction of CH_4 in generated landfill gas (volume fraction) 16/12 = molecular weight ratio CH4/C (ratio).

Formula to calculate greenhouse gas emissions from biological waste treatment by biological method

*CH_4 emissions from biological treatment

$$CH_4\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3} - R \quad (9)$$

Where: CH_4 Emissions=total CH_4 emissions in inventory year, Gg; CH_4 Mi=mass of organic waste treated by biological treatment type i, Gg; EF=emission factor for treatment i, g CH_4/

kg waste treated; i=composting or anaerobic digestion; R=total amount of CH_4 recovered in inventory year, Gg CH_4.

*N_2O emissions from biological treatment

$$N_2O\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3} \quad (10)$$

Where: N_2O Emissions=total N_2O emissions in inventory year, Gg N_2O; Mi=mass of organic waste treated by biological treatment type i, Gg; EF=emission factor for treatment i, g N_2O/kg waste treated; i=composting or anaerobic digestion;

Formula to calculate greenhouse gas emissions from burning solid waste by burning method

$$E_{j,f} = M_f * EF_{j,f} \quad (11)$$

Where: $E_{j,f}$=Gas discharge load j of the type of fuel f used during combustion, (ton); M_f=Fuel consumption type f, (TJ); $EF_{j,f}$=Gas emission factor default j of f fuel type (ton/TJ); J:Type of exhaust gas; F: The type of fuel used during combustion/firing.

2.2.3. Wastewater

Greenhouse gases in the field of wastewater management in Ho Chi Minh City include emissions from wastewater treatment activities. Formula to calculate greenhouse gas emissions in the field of wastewater management:

$$CO_2 = Q \times BOD_5 \times B_0 \times MCF \times GWP\_CH_4 \quad (12)$$

Where: Q: wastewater flow (m3/day);

BOD_5: country-specific per capita BOD in inventory year, g/person/day;

B_0 = maximum CH_4 producing capacity, kg CH_4/kg BOD (0,6kgCH_4/kg BOD);

MCF = methane correction factor (fraction)

2.2.4. Buildings

Method of calculating greenhouse gas emissions for energy consumption

$$E_{CO2} = M * EF_e \quad (13)$$

Where: M: Total of Electric energy consumption (MWH); EF_e: Emission factor of electricity (EF_e= 0.56 TCO_2/MWH from the Department of Meteorology, Hydrology and Climate Change)

3. Results and Discussions

3.1. GHG emissions in Agriculture

According to the calculation results, CO_2 emissions in the agricultural sector in 2013 was about 1.16 million tons of CO_2eq, of which emissions from livestock accounted for the majority. The forecast according to the plan until 2020 emissions will be reduced to about 800 thousand tons of CO_2 equivalent.

Table 7. Total CO_2 emissions in the agricultural sector

Field	2013	2020
Cultivation	243,273	73,125
Livestock	830,662	652,452
Aquaculture	85,274	77,785
Agriculture	1,159,209	803,362

3.2. Greenhouse gas emissions in the waste sector

Solid waste sector

Total emissions in the solid waste sector in Ho Chi Minh City was 2,764,212.52 tons of CO_2, of which emissions mainly from landfills, followed by emissions from biological methods.

Waste water

Total GHG emissions from the wastewater treatment sector in Ho Chi Minh City 143,347.9 tons of CO_2 equivalent, emissions mainly from industrial wastewater emit 81,973 tons of CO_2 (accounting for 57.2%), emissions from untreated domestic wastewater are about 58,945.2 tons of CO_2 (41.1%).

3.3. Greenhouse gas emissions in the buildings sector

Total GHG emissions in 2013 in high-rise buildings in Ho Chi Minh City was 406,294 tons of CO_2, corresponding to electricity consumption of over 700 million KWH. District 1 was the largest emission (53.2%), where most of the office buildings and large commercial centres are located. The second and the third were District 7 and District 3, accounting for 15.8% and 9.1%, respectively.

Table 8. Total CO_2 emissions (tons of CO_2) in the solid waste sector

Treatment	Landfill	Compost	Burning	Total
CO_2 eq. yr -1	2,750,275	110,610	2,876.52	2,764,212.52

Table 9. Total volume of wastewater in 2016 in Ho Chi Minh City

Type of treatment	CO2 eq. yr -1	Rate (%)
Domestic wastewater	58,945.2	41.1
Aerobic treatment	0	0
Untreated	58,945.2	41.1
Medical waste water	2,429.5	1.7
Industrial Wastewater	81,973.2	57.2
Total	**143,347.9**	**100**

4. Conclusion

In the context of the developing economy, the calculation of GHG emissions contributes to develop Ho Chi Minh's economy while reducing the risk of climate change in agriculture, waste and buildings sectors based on 2006 IPCC guidelines for GHG Inventory and data from relevant authorities.

In agricultural sector, there was about 1.1 million tons of CO_2 in 2013, in which, the largest emission was from livestock (71.7%), followed by cultivation (21%) and the least emission was from aquaculture (7.4%). Main proposed technical measures to decrease GHG in livestock includes reducing CH_4 emissions from the intestinal tract, add starch to plant fibre in diets, providing MUB nutrition cake (Molasses Urea Block) for dairy cows.

Total emissions in the waste industry in Ho Chi Minh City were about 3 million tons of CO_2 equivalent, of which 2,863,761 CO_2eq (95,2%) in the solid waste sector and 143,348 CO_2 eq (4,8%) in wastewater treatment. Major actions have been implemented in Ho Chi Minh City for decreasing GHG in solid waste such as encouraging CH_4 fermentation technology with combined with electricity generation, developing policies to support recycling actions or reducing solid waste amount treated by disposal sites or burning.

In the buildings sector, the amount of greenhouse gas emissions was 406,294 tons of CO_2 equivalent from the consumption of more than 700 million KWH for buildings. Some solutions to decrease emissions consist of applying Building Energy Management System in buildings to increase energy savings, using air conditioners and refrigerators with high energy efficiency in households, implementing energy-saving solutions in lighting systems.

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