The Emissions and Measures in Greenhouse Gases Management for Climate Change Mitigation in Developing Countries: A Case of Ho Chi Minh City, Vietnam

Bang Quoc Ho, Khue Vu, Tam Nguyen, Quan Le, Rajnish Rakholia, and Ricardo Simon Carbajo

***Abstract*—Vietnam will achieve net-zero greenhouse gases (GHG) emissions by 2050. Ho Chi Minh City (HCMC) has a considerable amount of GHG emissions (accounted for 20,68% of total GHG in Vietnam). The main GHG sources in HCMC are mainly due to the numerous private vehicles used and the increasing rate of factories. Therefore, to reduce the GHG of the city from these two sources, the bottom-up GHG detailed emission inventory (EI) for major sources must be carried out to determine the potential GHG emission sources. The objectives of this research are 1) to develop detailed GHG EI for HCMC and 2) to develop measures to reduce GHG for HCMC. It is the first bottom-up GHG emission inventory study that applied the EMISENS model to calculate the GHG emission from traffic and industrial sources. The total GHG emission of HCMC in 2019 was 58,272,149 tons CO_2eq/year. The primary emission of GHG in HCMC is from on-road traffic (13,484,958 tons CO_2eq/year) and the industry sector (17,612,942 tons CO_2eq/year). Motorcycles contribute the highest (63%) GHG emission from on-road transportation, whereas the chemical industry contributes the highest (63%) GHG emission from industry sources, followed by the sectors of Paper Production (17.3%), Textile (16.1%), and Metal production (14.7%). The study also developed technical and management solutions to achieve the goal of GHG emission reduction for HCMC and contribute to the National target of net-zero GHG. The main management solutions are based on implementing a Carbon Reporting System for industries and buildings in the city.**

***Index Terms*—Carbon reporting system, greenhouse gas, Ho Chi Minh city, solutions.**

I. Introduction

Climate change is one of the biggest challenges to humanity in the 21st century. Its impact and consequence are no longer a forecast but a phenomenon that has become an urgent and essential issue that needs to be resolved proactively to adapt [1], [2]. The Intergovernmental Panel on Climate Change - Fifth Assessment Report (IPCC-AR5) indicates that coastal countries in Southeast Asia, including Vietnam, are highly vulnerable to climate change and sea-level rises [3]. Therefore, a reliable solution is required to significantly reduce greenhouse gas (GHG) emissions to reduce the impact on climate change.

Ho Chi Minh City (HCMC) is one of the economic-financial centers of the country in Vietnam. It contributed 10% of the population, 22% of the national GDP, and 29% of financial capital in 2018. Along with economic development, this city also faces severe problems due to the fast urbanization process, especially air pollution. Some studies indicated that the industry and transportation emission rate leads to an increase in the amount of carbon dioxide (CO_2), which has been worsening climate change [4]–[6]. Recently, in HCMC, the Government has developed an action plan to implement the Paris Agreement on greenhouse gas reduction in HCM city. The GHG reduction is 2,012,170 tons/year (equivalent to a decrease of 5.2%) compared to the standard scenario without GHG reduction. However, it still needs more effort to reduce GHGs to reach around 9% by 2030, according to Decree No. 4869/BTNMT-BDKH, which was promulgated by the Ministry of Natural Resource and Environment (MONRE) [7], [8]. HCMC must set up the goals and plans to raise awareness and capacity for climate change mitigation in parallel with economic development to enhance the economy's competitiveness.

Although some studies showed the emission inventory from transportation or industrial sectors, it still lacks a comprehensive picture of all main contributions to the total emission in Ho Chi Minh city. Besides, the relevant solutions and plans are still less considering. This study aims to develop a detailed GHG emission inventory (EI) for HCMC from primary emission sources and establish measures to reduce GHG for HCMC. This study applied IPCC's GHG emission inventory method [9]. First, we collected data from traffic sources with motorbikes, cars, buses, and trucks and point sources with industrial sectors in Ho Chi Minh. We then calculated the EI of traffic sources by the EMISEN model [10]. We estimated the EI of point sources (i.e., industrial sectors) based on the EI equations with activity data and emission factors (EF) from plausible values from references. Finally, we suggested solutions and plans to reduce the GHG for the primary emissions contributions. Our study was the first to assess GHG emissions in Ho Chi Minh City comprehensively. Besides, it is the first bottom-up GHG emission inventory study that applied the EMISENS model to calculate the GHG emission from transportation activities and industrial sources. Other cities can use the approach to

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identify the EI and reduce the GHG.

II. Materials and Methods

A. Methods

This study applied the GHG emission inventory method of IPCC [2] , for some specific GHG emission sources, we have used a detailed method for calculating GHG for HCMC. GHG emission from on-road transportation is calculated by applying EMISENS model.

1) For road transportation sources

EMISENS model [3], an emission inventory model for traffic activities (on-road mobile sources), was used in this study. The method is presented in the air emission inventory section.

2) For other sources

GHG emissions are typically calculated using the following basic equation 18.

$E = (AR \times EF) - CCS$

In which:

E: Emission level, (kg/year)

EF: Emission factor, (kg/ton)

AR: The Activity Data (AD) is the number of human activities resulting in GHG emissions, such as gasoline consumption, electricity consumption, waste disposal, refrigerant release, deforestation, etc.

CCS: Carbon capture and storage (ton/year)

Since Vietnam does not have a GHG emission factor for each type of fuel and industry, this study uses guidelines and emission factors from the Intergovernmental Committee on Climate Change (the National GHG Inventory Guidelines [2).

According to IPCC - Intergovernmental Panel on Climate Change, the sources of greenhouse gas emissions are divided into five main areas, including Energy, Industrial Processes and Product Use (IPPU- Industrial Processes and Product Use), agriculture/forest, and other land use (AFOLU - Agriculture, Forestry and Other Land Use), wastes and other sources.

The Emission Factor (EF) is the average rate of GHG emissions per unit of activity data. For example, in HCMC, the EF for electricity consumption is 0.8458 tCO2/MWh (2019). Another EF of the GHG is referred from IPCC [2].

B. Data

1) Traffic sources

In this study, streets were classified into five categories: highways, rural roads, urban streets, suburban streets, and industrial streets (which are located in the industrial zone). Whereas the vehicles were divided into five types, including buses/coaches, heavy-duty vehicles (HDVs) with a total gross weight of over 3.5 tones, light-duty vehicles (LDVs), which weigh less than 3.5 tones, cars (<15 seats), and motorcycles. Motorcycles almost dominated the fleet, accounting for 80% of vehicles and ten times higher than cars. Only 10% of the fleet was contributed by cars, while 10% by the remaining vehicles. The duration of heavy traffic was from 6 am to 6 pm, and only HDV had the peaks at night. A total of 299 roads were counted for traffic flow (Table I).

The survey questionnaire was designed to collect data on on-road traffic emissions of the five primary means of transportation mentioned above. The required information included: vehicle category, vehicle age, fuel type, engine size or loading capacity, mileage of the vehicle, and the number of trips per day.

TABLE I: Traffic Flow for 5 Street Categories in HCMC in 2019 (Number of Vehicle/1 Hour)

Vehicles	Main urban street	Suburban street	Street in the industrial zone	Rural street	Highway
Heavy trucks	58	12	31	7	161
Light trucks	178	71	66	328	428
Buses	39	12	4	43	86
Car	1,314	290	99	427	481
Motorcycles	6,488	2,808	1,845	7,500	4,249

A total of 4,023 interviews (including 2,924 interviews from 'Bang's study [4] and 1099 new interviews) were used for data analysis. The statistical analysis shows that 32% of motorcycles met the EURO III standard, 63% met the EURO II standard, and 10% met the EURO I and previous standard. Concerning the car, 75% met the EURO IV standard, 10% met the EURO III standard, and 10% met the EURO V standard. Half of the buses and trucks (using diesel) met the EURO II standard, and the remaining met the EURO I and III standards. The EF of the GHG used in this study was referred from IPCC [2] and shown in Table II.

TABLE II: GHG Emission Factor for Road Transportation

Vehicle	CO_2 (g/km/veh.)	N_2O(g/km/ veh.)	CH_4(g/km/ veh.)
Bus	1405.2	0.0222	1.280
Car	109.9	0.0039	0.740
Motorcycle	60.1	0.0015	2.302
Heavy truck	1672.4	0.0226	1.024
Light truck	842.1	0.0222	0.365

2) Point sources

This research conducted 753 questionnaires from 753 big factories in all districts representing all industrial sectors in HCMC. The rest of the data used in this study was collected from the Vietnam general statistics office (GSO) published in 2019, which contained the data from 1955 factories.

The survey was based on questionnaires to collect data from factories, such as fuel consumption, fuel type, production output, CCS, etc. The manufacturing facilities in HCMC with the main sectors were textile, metal production, food, and plastic. LPG was the largest amount of fuel using in industry, especially in chemical chemistry. The following was oil types (DO and FO), gasoline, wood and wood products, and coal (Table III).

A total 2708 factories in HCMC that releases air emission and GHG. Emissions were calculated based on related EFs that derived from AP 42 [5], EMEP/EEA air pollutant

emission inventory guidebook [6], CORINAIR [6], and Guidelines for National Greenhouse Gas Inventories [2]. Exhausts from burning fuel and emissions from operation processes were also considered (Table III).

TABLE III: GHG EMISSION FACTOR FOR POINT SOURCES (KG.TON FUEL)

Fuel	CO_2	CH_4	N_2O
Coal	2691.4	0.3642	0.05463
Sawdust	1172	0.3516	0.04688
Rice husk firewood	1172	0.3516	0.04688
Charcoal	2577.3	4.6024	0.092048
LPG	1493.3	0.02662	0.002662
DO	2698.7	0.10926	0.021852
Wood products	1968.9	0.5274	0.07032

3) Other sources

The GHG emissions are calculated based on fuel consumption and collected from other studies [3].

III. RESULTS AND DISCUSSION

A. The GHG Emissions

The EMISENS model was applied to calculate the GHG emissions for on-road transportation. The GHG emission factors for on-road transportation are described in Table [I-II]. Fig. 1 and Table IV show that motorcycles contribute the highest (63%) of GHG emissions of on-road transportation.

TABLE IV: GHG EMISSION FOR ROAD TRANSPORTATION

Vehicle	CO_2 (ton/year)	N_2O (ton/ year)	CH_4 (ton/ year)	CO_2eq (ton/year)
Bus	541,186	9	1	543,751
Car	1,167,388	37	6,267	1,335,229
Motorcycle	7,878,175	20	25,571	8,523,317
Heavy truck	447,202	6	0	449,005
Light truck	2,599,397	54	727	2,633,656
Total	12,633,348	126	32,566	13,484,958

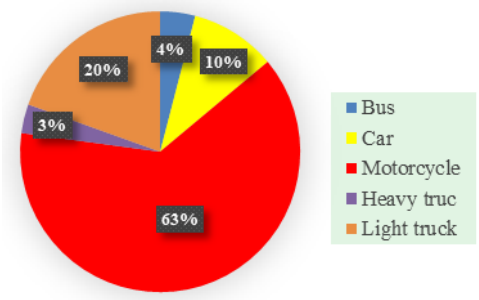


Fig. 1. GHG emission sharing for on-road traffic 2019 in HCMC.

TABLE V: GHG EMISSION FROM FUEL CONSUMPTION FOR THE INDUSTRIAL SECTOR IN HCMC (TON/YEAR)

No.	Industrial sector	CO_2	CH_4	N_2O	CO_{2td}
1	Textile	1,159,591	286.01	35.02018	1,177,177
2	Food	632,314.5	192.1449	19.22918	642,848
3	Paper Production	458,429.7	113.5695	13.73293	465,361
4	Printing	1,955.385	0.20681	0.036742	1,972
5	Chemistry	3,556,804	91.7522	9.340816	3,561,882
6	Construction	5,263.384	0.90192	0.13441	5,326
7	Wood processing	31,904.44	42.72088	5.696215	34,670
8	Beverage	63,759.06	5.380769	0.888944	64,158
9	Metal production	1,505,117	1157.964	154.4547	1,580,094
10	Rubber processing	15,647.52	5.264203	0.709742	15,991
11	Plastic production	98,969.5	15.23085	2.26557	100,025
12	Medicine	16,599.96	23.95346	0.677903	17,401
13	Seafood processing	43,802.38	6.220604	0.941869	44,239
14	Footwear	4,450.388	2.215425	0.303939	4,596
15	Fertilizer	1,739.837	0.274267	0.03994	1,759
16	Fodder	16,151.08	4.058994	0.575191	16,424
17	Coffee roaster	38.70846	0.00069	6.9E-05	39
18	Veterinary medicine, Plant protection product	0	0	0	0
19	Electronic component	931.8844	0.001006	0.000181	932
20	Tobacco	0	0	0	0
21	Thermo-electricity	194,068.8	7.528633	1.505727	194,706
22	Other	1,604.329	0.382556	0.052136	1,629
	Total	**7,809,143**	**1,956**	**246**	**7,931,228**

TABLE VI: GHG EMISSION FROM ELECTRIC CONSUMPTION FOR THE INDUSTRIAL SECTOR IN HCMC (TON/YEAR)

No.	Industrial sector	Electric consumption (1,000 kWh)	CO_{2SD} Electric (ton/year)
1	Textile	1,508,512.8	1,275,900
2	Food	485,240.9	410,416.8
3	Paper Production	2,512,570.3	2,125,132
4	Printing	113,365.73	95,884.73
5	Chemistry	503,969.55	426,257.4
6	Construction	210,632.57	178,153
7	Wood processing	39,767.77	33,635.58
8	Beverage	133,072.9	112,553.1
9	Metal production	749,736.3	634,127
10	Rubber processing	366,048.6	309,603.9
11	Plastic production	732,097.2	619,207.8
12	Medicine	72,469	61,294.28
13	Seafood processing	544.3	460.3689
14	Footwear	502,582.95	425,084.7
15	Fertilizer	0	0
16	Fodder	0	0
17	Coffee roaster	0	0
18	Veterinary medicine, Plant protection product	167.8	141.9252
19	Electronic component	345,156.1	291,933
20	Tobacco	39,500.9	33,409.86
	Total	**8,315,436**	**7,033,195**

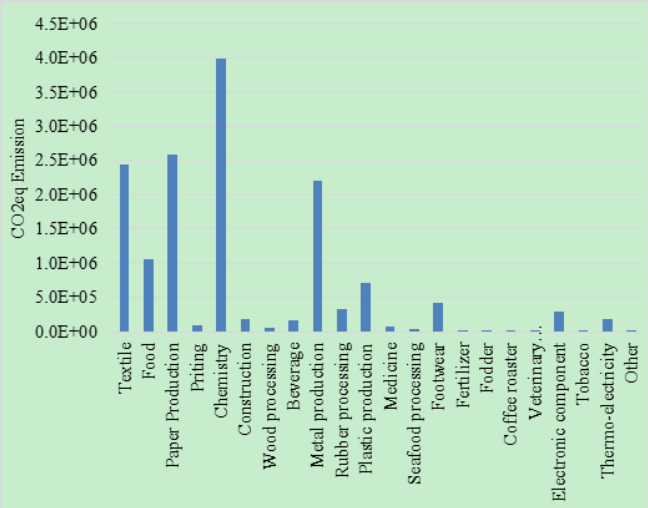


Fig. 2. Sub-sector of industry sharing emission for CO_2eq (ton/year) in HCMC in 2019.

Table [V-VI] and Fig. 2 show that the chemical industries contribute the highest (63%) of GHG emissions from the industrial sector, followed by Paper Production (17.3%), Textile (16.1%), and Metal production (14.7%).

TABLE VII: THE GHG INVENTORY OF HCMC IN 2019 (TON/YEAR)

No.	GHG Emissions and Removals GHG Emissions Sources (By Sector and Sub-sector)	Total GHG (tonCO_2eq/year)
I	**STATIONARY ENERGY**	**37,631,247**
I.1	Residential buildings	11,122,765
I.2	Commercial and institutional building and facilities	7,076,476
I.3	Manufacturing industries and construction	17,612,942
	Fuel consumption*	7,931,228
	Electric consumption and lost electricity due to transmission line	7,033,195
I.4.1/2/3	Energy industries	0
I.4.4	Energy generation supplied to the grid	0
I.5	Agriculture, forestry, and fishing activities	653,640
I.6	Non-specified sources	801,542
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	0
I.8	Fugitive emissions from oil and natural gas systems	363,884
II	**TRANSPORTATION**	**17,258,407**
II.1	On-road transportation*	13,484,958
II.2	Railways	0
II.3	Waterborne navigation	83,624
II.4	Aviation	3,689,825
II.5	Off-road transportation	0
III	**WASTE**	**3,171,469**
III.1.1/2	The solid waste generated in the city	1,959,163
III.2.1/2	Biological waste generated in the city	124,501
III.3.1/2	Incinerated and burned waste generated in the city	30,538
III.4.1/2	Wastewater generated in the city	1,057,269
III.1.3	The solid waste generated outside the city	0
III.2.3	Biological waste generated outside the city	0
III.3.3	Incinerated and burned waste generated outside the city	0
III.4.3	Wastewater generated outside the city	0
IV	**INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)**	**129,601**
IV.1	Emissions from industrial processes occurring within the city boundary	129,353
IV.2	Emissions from product use occurring within the city boundary	248
V	**AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)**	**81,425**
V.1	Emissions from livestock	253,395
V.2	Emissions from land ("-" is removal GHG)	-363,671
V.3	Emissions from aggregate sources and non-CO2 emission sources on land	191,701
	GHG Emissions and Removals	**58,272,149**

Notes: The results are calculated for three scopes: scope 1, scope 2, and scope 3

Reporting is based on Global Protocol for Community-Scale Greenhouse Gas Emission Inventories.

Scope 1 is emissions from sources located within the city boundary; Scope 2 is emissions from the use of grid-supplied electricity, heat, steam, and/or cooling within the city boundary (mainly from electricity consumption); and Scope 3 is all other emissions occurring outside city boundary because

Table VII shows that the total GHG emission of HCMC in 2019 was 58,272,149 tons $CO2_{eq}$/year. The primary emission of GHG in HCMC was reported from on-road traffic (13,484,958 tons $CO2_{eq}$/year) and the industrial sector (17,612,942 tons $CO2_{eq}$/year).

National Context

The GHG emissions of Vietnam and HCMC are 283.9 million tCO_2eq and 58.72 million tCO_2eq, respectively. The emissions of HCMC account for 20,68% of the national GHG emissions, while its population is only around 9% of the national total.

Comparision to other Countries and Cities

Table VII shows the per-capita and GDP GHG emissions of selected C40 Cities. The per capita emissions of HCMC (4.2 tCO_2e) are at the same level as Seoul (4.6 tCO_2e), London (4.7 tCO_2e), and Buenos Aires (4.4 tCO_2e) despite HCMC being much less economically developed than its

counterparts. Emission per GDP in HCMC is the highest among the C40 Cities cited here.

TABLE VIII: SUMMARY GHG EMISSIONS PER CAPITA AND GDP OF SELECTED C40 CITIES

City	Emissions Per Capita (tCO_2e)	Emissions Per GDP	GDP Per Capita (USD)
Seoul	4.638		
London	4.732	82.786	57,157
Los Angeles	7.458	33.422	223,138
Durban	6.588		
Yokohama	5.662	165.596	34,195
Toronto	7.064	123.341	57,273
Buenos Aires	4.395	170.454	25,782
Austin	11.599	121.534	95,437
Madrid	2.869	89.118	32,196
Auckland	5.890	139.831	42,125
Washington DC	12.730	72.891	174,642
Portland	10.064	47.102	213,659
Boston	9.346	54.861	170,355
Salvador de Bahia	1.332	154.384	8,628
Oslo	2.148	24.590	87,361
HCMC	4.157	915.311	4,542

B. GHG Measures

1) Technology solutions and management solutions for industry and buildings in Ho Chi Minh city

The study conducted a detailed survey of the production line and the criteria for energy-saving policy and difficulties in implementation to provide appropriate technology and management solutions for each industry sub-sectors and building sector. The results below represent the survey results and technology and management solutions for the industrial sectors in this study.

2) Survey results on saving and environmental protection activities at businesses

Over 85% of surveyed enterprises said they have specific policies and plans for energy conservation for each year and have staff in charge and responsibility for implementing these activities at their units.

About 15% of surveyed enterprises answered that they do not have a specific policy on energy conservation in their production activities. According to the analysis results, small-scale food production businesses are small-scale enterprises that do not have an energy-saving policy that are not on the critical energy users list.

Among 85% of businesses with this energy-saving policy, asked about which barrier makes it difficult for their energy conservation plans to be implemented, 52% of enterprises answered that it was a financial barrier, and 28% answered it was difficult. Capacity and awareness. 20% of businesses expect the management agency to organize free training courses and classes on energy-saving practices to send staff in charge of learning, exchanging, and updating policies and solutions. About 18% of businesses expect financial support and incentives to install energy-saving equipment. About 18% of companies expect the management agency to organize seminars on energy saving.

3) Detailed technology solutions for the industrial sector in the Ho Chi Minh City

Based on detailed survey results at industrial production plants, the study analyzed the production process of each factory from which to propose practical energy-saving activities. This content will offer potential energy-saving and GHG emission reduction solutions applied from the factory survey status. Some solutions may be similar across industries due to similar equipment. The summary of general energy-saving solutions used by industrial groups is shown in Table IX.

TABLE IX: PRIORITY ORDER OF IMPLEMENTATION OF SOLUTIONS FROM EASY TO DIFFICULT AND INVESTMENT COSTS FROM LOW TO HIGH

No.	Measures
1.	Insulation of boiler system and refrigeration system
2.	Inspect, maintain and enhance boiler and compressed air systems
3.	Installation and replacement of energy-saving lighting equipment
4.	Condensate water recovery
5.	Install the throttle valve at the suction point of the air-conditioning system water pump
6.	Replace the automatic condensate drain valve for equipment in the compressed air system
7.	Heat recovery from air compressors
8.	To use inverter
9.	Solar power

4) Detailed technology solution for the building sector in the Ho Chi Minh city

Based on the survey results, interviews and information gathering, and energy consumption infrastructure in energy-using buildings in Ho Chi Minh City, the results of the analysis in Ho Chi Minh City analysis results show that it is necessary to continue to reduce carbon emissions in the building sector through energy-saving solutions:

- Firstly, the building should use high-efficiency commercial and residential air conditioners.
- Second, high-performance refrigerators should also be put into use. Replace lamps with light-emitting diodes (LEDs) for low-power fluorescent and filament lamps, which have a short lifespan, and consume electrical energy.
- Third, with the advantage of many hours of sunshine in Ho Chi Minh City and taking advantage of the roof area to install a solar energy system used for the building, such as water heaters.

5) Detailed technology solutions for the field of buildings sector in the Ho Chi Minh city

- The action plan was issued by the People's Committee in Ho Chi Minh City for the continued implementation of solutions to manage greenhouse gases.
- Action plan to respond to climate change in the area city. Ho Chi Minh City for 2017 -2020, with a vision to 2030 (Decision No. 1159/QD-UBND dated March 17, 2017, of the People's Committee of Ho Chi Minh City). Plan to

implement the Paris Agreement on climate change in the city. Ho Chi Minh City (Decision No. 3942/QD-UBND dated October 20, 2020).

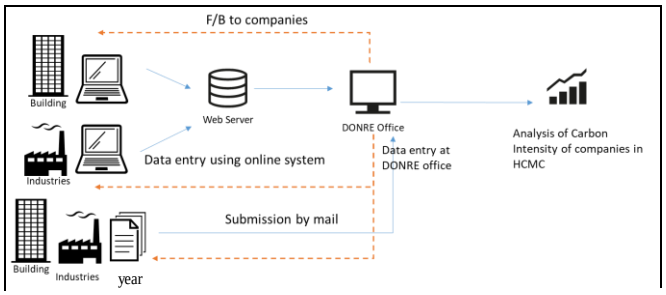
- Proposing the implementation of financial policies for GHG emission reduction activities towards applying carbon pricing tools in Vietnam (carbon tax, carbon market, carbon credit trading system).
- Application of artificial intelligence AI, CN4.0 in GHG management.
- This study proposes a common state management solution to manage GHG activities for the industry and buildings and the natural resources sector, which is the Greenhouse Gas Reporting System. The first reason, currently, the Government and MONRE have requirements related to energy and the environment. For example, Decision 2359/QD-TTg, Decision 1775/QD-TTg [7], Decision 2053/QD-TTg [8], according to 985a/QD-TTg [9] and Directive No. 03/CT-TTg [10]. Therefore, the compilation into a GHG report is necessary. The second reason, the GHG Report is consistent with the roadmap of HCMC in developing the Climate Change Action Plan (CCAP) period (2021-2030) to reduce GHG. Therefore, the preparation of GHG reports is recommended for enterprises to benefit enterprises and help management agencies (e.g., DONRE) grasp GHG information to set GHG reduction targets in line with the current situation's realistic figure.

There are many legal bases for making a GHG Reporting System. The main contents of the GHG Reporting System are presented in Fig. 3 and Fig. 4. The GHG Report includes the following main parts: Summary of the proposed GHG Report for HCMC; sectors of implementation, implementation terms, steps, and responsibilities of state agencies; GHG reduction report form for large energy users in HCMC.

Through this study, the difficulty was found to access the energy consumption data of companies, and it was a fundamental issue for HCMC to encourage energy conservation measures. Although mandatory energy reporting and energy auditing systems for key energy consumers have been implemented, the effect on energy conservation by the implementation of systems could not be evaluated without data. Further actions such as feedback and benchmarking on top of the current energy reporting system are necessary to encourage companies in HCMC to achieve substantial energy efficiency improvement. Especially if HCMC seeks to implement ETS as one of the incentive schemes for mitigation actions in the future, understanding CO2 emissions from companies and engagement of companies as stakeholders through reporting is prerequisite

We suggest introducing a carbon reduction reporting system, including feedback and a benchmark system. Considering that the issues which HCMC's problems are similar to which TMG has experienced and overcome, introducing a carbon reduction reporting system as one of the policy actions drawing on 'TMG's experience are considered beneficial for HCMC.

Considering the existing energy reporting systems and institutional challenges in Viet Nam, the study team brings three options of reporting systems. The scheme and pros/cons of each option are explained in Fig. 3 and Fig. 4.



Carbon Reduction Report

1 General Information

Name of company		
Address of building/factory		
Gross floor area of building/factory		m^2
Type of ownership		☐ Self-owned ☐ Owned by others
Area of Reporting		☐ Whole building ☐ Part of Building(Tenant) ☐ Part of Building (Other)
Main usage of reporting area		☐ Office ☐ Commercial Facility (Sales) ☐ Commercil Facility (Restaulant) ☐ Hotel ☐ Education ☐ Hospital ☐ Factory ☐ Mixed Use ( ) ☐ Others ( )
Responsibe Person of content of report	Name	
	Department/ Role	

2. Information on Production (for Factory)

Name of the Product	Unit	Production Volume of Year 0	Desinged Capacaity

3. Energy Consumption Status and CO2 Emissions Status

Type of Fuel	Annual Consumption Volume	Annual Consumption Unit	Net Calorific Value (TJ/Gg)	Heat Energy (TJ)	Emission Factor (kg CO_2/TJ)		Emission (tCO_2)
Fuel and Heat							
Coal		ton	25.8	0.00000	94600		0.000
Fuel Oil		ton	40.4	0.00000	77400		0.000
Diesel Oil		L	43.0	0.00000	74100		0.000
Gasoline		L	44.3	0.00000	69300		0.000
Natural Gas		Nm^3	48.0	0.00000	56100		0.000
Coking Coal		ton	28.2	0.00000	94600		0.000
Coal Gas		ton	38.7	0.00000	107000		0.000
Purchased Steam		MJ	-	0.00000	60000		0.000
Other ( )							
Other ( )							
Electricity							
Purchased Electricity		kWh			0.795	kgCO2/kWh	0
Captive Electricity (Fuel Type)		kWh					0
Total							**0.000**

Fig. 4. Input and output data of the GHG reporting system.

IV. Conclusions

This study is the first bottom-up GHG emission inventory study that applied the EMISENS model to calculate the GHG emission from transportation activities and industrial sources.

The bottom-up GHG emission inventory showed that The highest GHG emission is related to the on-road transportation and industry sector. These sectors have the potential to reduce GHG emissions by setting–up a new policy. The total GHG emission of HCMC in 2019 is 5,272,149 tons $CO2_{eq}$/year. The primary GHG emissions in HCMC are from on-road traffic (13,484,958 tons CO2eq/year) and the industrial sector (17,612,942 tons CO2eq/year). Motorcycles contribute the highest (63%) GHG emission of on-road transportation. The Chemistry industry contributes the highest (63%) GHG emission of the industry sector, followed by Paper Production (17.3%), Textile (16.1%), and Metal production (14.7%).

Finally, the study proposed technical and management solutions to realize the goal of energy saving and GHG emission reduction for each industry and building, particularly for Ho Chi Minh City. The proposed technical solutions are based on actual survey results. Each technical solution has been analyzed for specific benefits and costs, with potential energy-saving and GHG emission reduction. Regarding management solutions, the study also detailed the implementation of a GHG Reporting System for industries and buildings in the city. Ho Chi Minh City, which mentions the contents that need to implement, is the unit responsible for implementing the annual greenhouse gas report. Department of Natural Resources and Environment is responsible for synthesizing, evaluating data, and proposing solutions, such as specific implementation measures to reduce GHG emissions for each sector in the future. If HCMC applies these measures, the GHG emission reduction for Ho Chi Minh City will be up to about 10% in 2030 (compated with year of 2019) and will contribute to the National target of net-zero greenhouse gas emissions by 2050.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Assoc. Prof. Bang Q. Ho conducted the research and wrote the paper. Vu Hoang Ngoc Khue ran the EMISENS model. Dr. Rajnish Rakholia analyzed the results and prepared this manuscript. Dr. Ricardo Simon Carbajo contributed to developing the method for this manuscript. Dr. Quan Le contributed analysis of the results. MSc. Tam Nguyen contributed to collecting and analyzing data. All authors had approved the final version.

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