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Greenhouse gas emission inventory of Can Tho City using Bilan Carbone method

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Abstract. Greenhouse gas (GHG) emission inventory has always been considered a crucial first step towards any development of climate change mitigation plans and measures. In this paper, the Bilan Carbone (Carbon Balance) version 6, an easy-to-use Excel-based GHG inventory tool developed by the French Environment and Energy Management Agency, is used to make an inventory of GHG emissions generated within Can Tho City's territory. The data used for the direct and indirect GHG emissions were collected from Can Tho City's 2020 Statistical Yearbook, relevant businesses, and administrative units. Ten sectors, namely *Energy Industry*, *Industrial Processes*, *Tertiary Sector*, *Residential Sector*, *Agriculture and Fishing*, *Transporting Goods*, *Travel by People*, *Construction and Highways*, *End-of-life Waste*, and *Food*, were taken into account for the related analysis. Considering all GHGs cited in the Kyoto Protocol coupled with emission factors updated for Vietnam and the magnitude of emission sources, we found out that the total GHG emission of Can Tho City in 2020 is 4,311,952 tons of CO_2 equivalent (CO_2e) with an average of approximately 3.5 tons of CO_2e per capita. *Residential Sector*, *Industrial Processes*, and *Travel by People* contribute the most to the total GHG footprint of the city, in which *Residential Sector* accounts for the largest share (743,346 tons of CO_2e, making up 17.2% of the total GHG emission). *Industrial Processes* ranks second with 727,504 tons of CO_2e (representing 16.9%), and *Travel by People* is third with 619,823 tons of CO_2e, accounting for 14.4%. Some scientific and realistic interpretations of such sectorial findings are also provided to facilitate the next step of initiating and carrying out associated GHG mitigation measures for the city.

Keywords: Bilan Carbone, Can Tho City, GHG emission inventory, CO_2e

1 Introduction

At present, climate change is apparently the greatest challenge putting our globe and our future generations at stake. A lot of research on climate change conducted by some well-known international organizations shows that Vietnam is one of the five countries worldwide to be severely hit by climate change [1]. This is why the Deputy Prime Minister of Vietnam ratified the National Strategy in response to Climate Change until 2050, dated July 26th, 2022, to cope with the biggest threat in the 21st century.

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With a total area of 1,439 km^2, Can Tho – the fourth largest city in Vietnam and the largest city of the Mekong Delta – is situated in the most vulnerable area affected by climate change in the country. Can Tho is also one of six key cities carrying out the project on developing Vietnamese cities to respond to climate change. The city has recently been transforming itself to become Vietnam's first smart city in the southwestern region by 2025. It has the potential to become a centre of hi-tech industry, trading, service and tourism, science and technology, healthcare, and education and training, as well as a communication centre for the whole Mekong Delta [2]. Can Tho, as such, hopes to further encourage its public engagement, increase its competitiveness, and improve its socio-economic development in a sustainable approach.

According to the Government of Vietnam, all centrally-run ministries, industries, provinces, and cities are legally obliged to develop and implement their own climate change action plans. As a city directly under the Central Government, Can Tho is no exception. In addition, the city has proactively taken part in the *Global Covenant Of Mayors For Climate & Energy* (GCoM) and *One Planet City Challenge* (OPCC) programs launched respectively by the European Commission (EC) and the World Wide Fund for Nature (WWF) to improve its capacity on climate change adaptation and mitigation and promote its environmentally friendly image. One of the very first steps of this activity is to quantify the greenhouse gas (GHG) emissions in the city's territory.

Based on the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) developed by the World Resources Institute (WRI), C40 Cities Climate Leadership Group (C40), and Local Governments for Sustainability (ICLEI), many Excel-based tools supporting the GHG inventory have been in place, namely the City Inventory Reporting and Information System (CIRIS), the Bilan Carbone (BC), and the Community Protocol (CP) developed by C40, French Environment, Energy Management Agency, and ICLEI-USA, respectively. Among them, the Bilan Carbone has been widely used because it is regularly updated according to GPC guidelines. At the end of 2019, the number of Bilan Carbone inventories carried out worldwide was estimated at over 9,000 [3].

There have been some studies on the use of the Bilan Carbone for GHG inventories in Viet Nam. The analysis results on GHG emissions of Thu Dau Mot University using the Bilan Carbone method conducted in 2019 by Hanh et al. shows that the three largest GHG emission activities are *Electricity Consumption* (383,358 kg of CO_2e), followed by *Diesel Oil Consumption* (4,268.25 kg of CO_2e) and *Printing Paper Consumption* (2,944.72 kg of CO_2e) [4]. At the city level, the study on GHG emissions of Hue City using the Bilan Carbone tool conducted by Tuan in 2013 shows that the three sectors releasing the largest GHG emissions are *Transport* (66,655 tons of CO_2e), *Residential Sector* (62,480 tons of CO_2e), and *Tertiary Sector* (40,371 tons of CO_2e) [5].

The main objective of this paper is to provide a summary of Can Tho City's GHG inventory results. While compiling GHG emissions from various sectors of the city, we also attempt to provide some scientific and realistic evidence on the GHG emission analysis, which is expected to pave the path for the next step of initiating some associated GHG mitigation options for Can Tho City.

2 Materials and methods

2.1 Bilan Carbone method

Taking into account all six greenhouse gases noted in the Kyoto Protocol (CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs), the Bilan Carbone tool serves as an accounting method for estimating direct and indirect GHG emissions in tons of CO_2e. Regarding the inventory scope, the GHG emission sources are grouped into three categories based on where they occur: Scope 1, Scope 2, and Scope 3 (Table 1).

Table 1. Definitions of scopes for city inventories [6]

Scope	Definition
Scope 1	GHG emissions from sources located within the city boundary
Scope 2	GHG emissions that occur as a consequence of the use of grid-supplied electricity within the city boundary
Scope 3	All other GHG emissions occurring outside the city boundary as a result of activities taking place within the city boundary

The basic method for quantifying GHG emissions is to multiply the activity level or rate (A) by its corresponding emissions factor (EF):

$$\text{GHG Emissions} = \text{Activity data (A)} \times \text{Emissions Factor (EF)}$$

Activity data is the level or rate of a specific action that produces emissions. More specifically, activity data refers to the amount of energy consumed or waste generated, while the emissions factor represents the rate or quantity of GHG emissions generated because of a specific activity [6]. In other words, the Bilan Carbone calculation method is similar to the *Rapid Assessment of Sources of Air, Water, and Land Pollution* techniques since it is based on the scale of emission source scale (X, Y, and Z) and emission factors (F1, F2, and F3) (Fig. 1). Workbooks and spreadsheets in MS Excel with ready-made computing and converting formulas form the foundation of the Bilan Carbone tool.

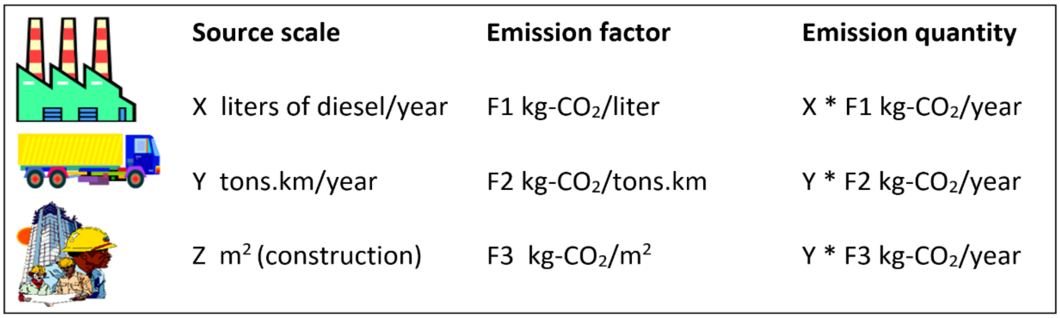

Fig. 1. Estimation of GHG emissions based on magnitude of various sources and corresponding emission factors

The Bilan Carbone-based analysis results are presented in Excel spreadsheets in conformity with the GHG Protocol and ISO 14069 standards [2]. The Bilan Carbone method makes the following assumptions in order to simplify the inventory of GHG emissions:

- The Global Warming Potential (GWP) has a time horizon of 100 years (see GWP value of some GHGs in Table 2).
- Ozone is not considered because of the following factors: its short lifetime in the atmosphere, the scarcity of emission sources, and the difficulty in calculating it in indirect emission sources.
- Water vapour is also not taken into account due to its short lifetime in the atmosphere.

Table 2. GWP value of some GHGs in a time horizon of 100 years [7]

GHGs	Time horizon of 100 years
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbon (HFCs)	1,240–14,800
Perfluorocarbon (PFCs)	7,390–12,200
Chlorofluorocarbon (CFCs)	4,750–14,400

All emission factors are organized in their own spreadsheet and linked to their corresponding cells in other spreadsheets. Therefore, when users add or change emission factors, the results in associated cells and spreadsheets are updated accordingly [3]. Users are advised to replace these emission factors with local, regional or national ones (if any). In previous studies on GHG inventory using the Bilan Carbone tool in Vietnam, the emission factor of the national grid in 2020 developed by the Department of Climate Change is often used. In particular, we also used the national emission factors specified in the *List of emission* *factor catered for greenhouse gas inventory*, which was legally issued on Oct. 10, 2022, by the Ministry of Natural Resources and Environment.

Compared with previous Bilan Carbone versions, Version 6 is more comprehensive and informative because it provides a higher level of modularity with a site/multi-site that enables it to be adapted to a maximum of cases to use the Bilan Carbone, either for businesses or local governments. Furthermore, it provides a new architecture that allows users to carry out the Bilan Carbone more easily and introduces a new territory module for expanding its application to various territories [7].

2.2 Data collection

The secondary data used for the GHG emission analysis were mainly collected from the Statistical Yearbook 2020 of Can Tho City, while the primary data were gathered from relevant companies and provincial departments, such as the Department of Industry and Trade, Department of Agriculture and Rural Development, Can Tho Water Supply and Sewerage Joint Stock Company.

The data collection covered ten activity categories of the city, including *Energy Industry*, *Industrial Processes*, *Tertiary Sector*, *Residential Sector*, *Agriculture and Fishing*, *Transporting Goods*, *Travel By People*, *Construction and Highways*, *End-Of-Life Waste*, and *Food.* The whole data collection process and GHG emission analysis are shown in Fig. 2.

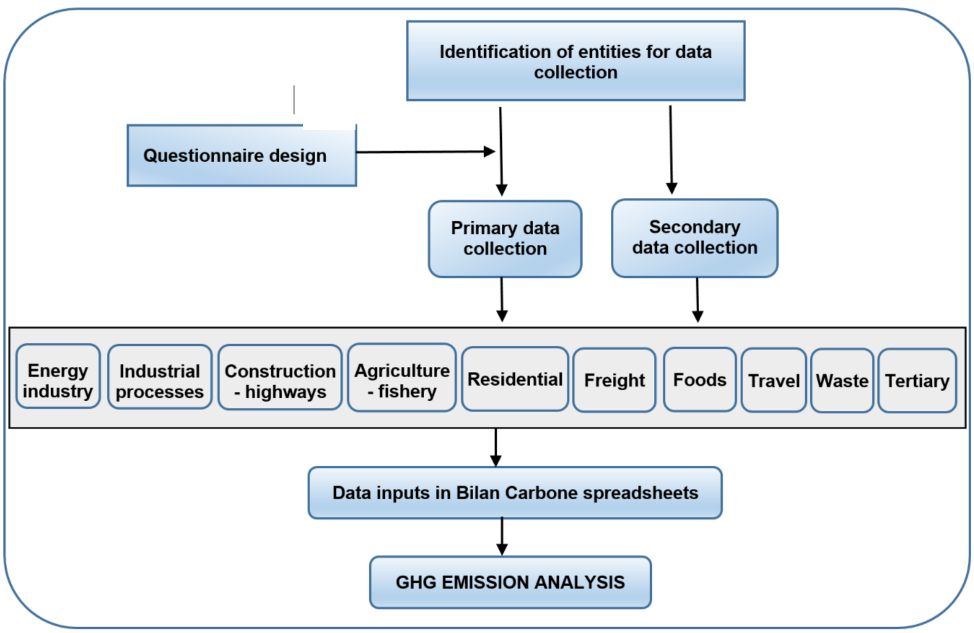

Fig. 2. GHG emission analysis process for Can Tho City

3 Results and discussion

3.1 Greenhouse gas emission analysis

The GHG inventory of Can Tho covers five GPC's activity sectors (Stationary Energy; Transport; Industrial Processes and Product Use (IPPU); Agriculture, Forestry, and Other Land Use (AFOLU), and Waste) because these five sectors are broken down by the Bilan Carbone into ten activity categories: Energy Industry, Industrial Processes, Tertiary Sector, Residential Sector, Agriculture and Fishing, Transporting Goods, Travel by People, Construction and Highways, End-of-life Waste, and Food. Table 3 provides a summary of GHG emissions released within Can Tho City's boundary. Three domains identified as the largest GHG emission sources were Residential Sector, Industrial Sector, and Travel by People. The data shown in Table 3 also reveal that Transporting Goods, Construction and Highways, and End-of-life Waste in the city didn't emit a lot of GHGs.

Table 3. Summary of GHG emissions produced by Can Tho City

No	Sectors	Emissions in tons of CO_2e	Share, %	Share ranking
1	Energy industry	332,387	7.7	6
2	Industrial processes	727,504	16.9	2
3	Tertiary sector	559,956	13.0	4
4	Residential sector	743,346	17.2	1
5	Agriculture and fishing	517,711	12.0	5
6	Transporting goods	105,790	2.5	10
7	Travel by people	619,823	14.4	3
8	Construction and highways	110,991	2.6	9
9	End-of-life waste	276,771	6.4	8
10	Food	317,673	7.4	7
	TOTAL	**4,311,952**	100	

Among the three highest GHG emission shares, *Residential Sector* contributes most to the total GHG emission of Can Tho with 791,276 tons of CO_2e, representing 17.3% of the total. In this domain, *Residential Electricity* releases 418,680 tons of CO_2e, making up approximately 56% of the total sectorial emission. This emission share can be explained by the fact that Can Tho City is one of the largest cities in Vietnam and home to a population of more than 1,24 million people in 2020. In addition, Can Tho's population density is 886 people/km^2, three times the national population density and ranks 12th out of 63 provinces and cities nationwide [2]. Therefore, the local residents of Can Tho make up a considerable share of GHG emissions in their daily activities, such as households' electricity use. The other GHG emission shares of *Residential Sector* are presented in Table 4.

Table 4. Detailed GHG emissions produced by the *Residential Sector* of Can Tho City

No	Residential sector	Emissions in tons of CO_2e	Share, %	Share ranking
1	Direct accounting of fuels	101,541	13.7	3
2	Residential electricity	418,680	56.3	1
3	Electricity line losses	32,428	4.4	5
4	Kyoto halocarbons	88,520	11.9	4
5	Halocarbons excluding Kyoto	102,177	13.7	2
	SUBTOTAL	**743,346**	100	

The second highest share is *Industrial Processes*, which releases 727,504 tons of CO_2e, accounting for 16.9% of the total GHG emission [Table 3]. Like *Residential Sector*, the highest GHG emission share in this domain also comes from electricity use. Accordingly, the electricity produced outside the region is the largest source of GHG emission, generating 578,754 tons of CO_2e, which represents more than 79% of the total sectorial GHG emission. According to Ohara et al., this is explicable and reasonable in that electricity use is always the largest contributor to the GHG emission in most of the surveyed cities and countries in Asia [8]. Table 5 shows the other shares of GHG emissions in Can Tho City's *Industrial Processes.*

Over the past ten years, Can Tho has transformed its economic structure from traditional agriculture to industry, commerce, services, and tourism, and has been boosting its socioeconomic development in a rapid and sustainable manner in line with speeding up the economic structure transformation into the paradigm of *Industry – Service – Agriculture*. The city recorded an 8.04% growth in *Gross Regional Domestic Product* in the first six months of 2022, the highest for the past three years. In which, industry and construction contribute the most (11.8%) to the overall growth rate, and the *Industrial Production Index* has recently made up 12.9% year-on-year [2].

With respect to *Travel by People*, the Bilan Carbone-based analysis reveals that the GHG emission contribution of this sector is 619,823 tons of CO_2e, representing 14.4% of the total (Table 3). As noted above, Can Tho has a large population with a high population density. Moreover, public transport in the city is currently in poor condition. Thus, the residents of Can Tho make up a considerable share of GHG emissions in their daily travel with their private cars and motorcycles. Other GHG emission shares in *Travel by People* are presented in Table 6.

Table 5. Detailed GHG emissions produced by the *Industrial Processes* of Can Tho City

No	Industrial processes	Emissions in tons of CO_2e	Share, %	Share ranking
1	Direct accounting of fuels	129,436	17.8	2
2	Electricity produced outside the region	578,754	79.6	1
3	Kyoto gases excluding energy	15,316	2.1	3
4	Gases excluding Kyoto	3,998	0.5	4
	TOTAL	**727,504**	100.0	

Table 6. Detailed GHG emissions produced by the *Travel by People*

No	Travel by people	Emissions in tons of CO_2e	Share, %	Share ranking
1	Direct accounting of fuels	300,025	48.4	1
2	Road transit of people	50,741	8.2	3
3	Residents' travel by car	44,607	7.2	6
4	Residents' travel by bus and coach	14,659	2.4	8
5	Residents' travel by plane	49,943	8.1	4
6	Residents' travel by rail	14,943	2.4	10
7	Visitors' car traffic	21,657	3.5	9
8	Visitors by coach and bus	37,714	6.1	5
9	Visitors' air traffic	55,568	9.0	2
10	Visitors' rail traffic	29,966	4.8	7
	TOTAL	**619,823**	100	

When converting Bilan Carbone's ten activity categories to five activity sectors of GPC, *Stationary Energy*, *IPPU*, and *Transport* contribute most to the total GHG footprint of the city (Fig. 3). For the electricity consumption alone, its GHG emission is 1,563,246 tons of CO_2e, representing 36.3% of the city's total GHG emission. In this domain, *Residential Sector* releases the most, followed by *Industrial Sector* and *Tertiary Sector* (Fig. 4).

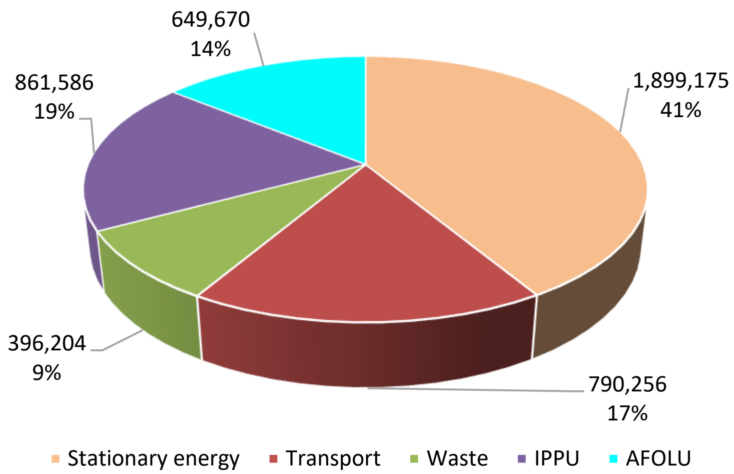

Fig. 3. Can Tho City's GHG emissions broken down into GPC's five sectors

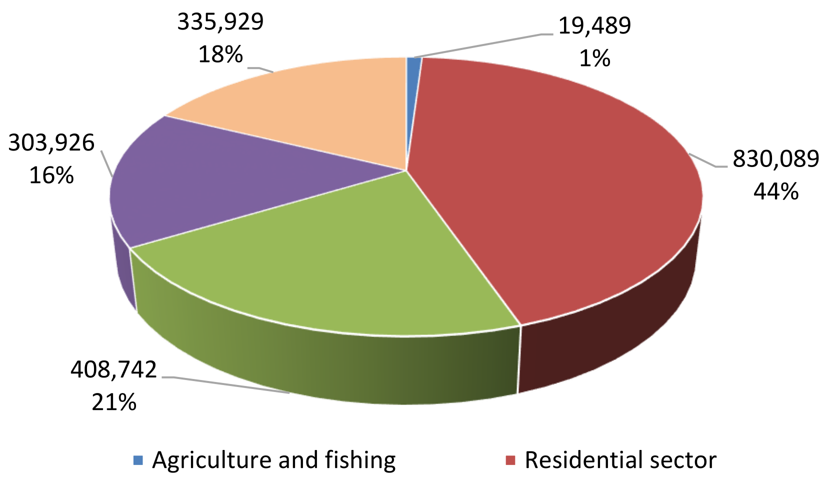

Fig. 4. Can Tho City's GHG emissions generated by electricity consumption

With a population of 1,240,731 in 2020, Can Tho City experiences an average GHG emission per capita of approximately 3.5 tons of CO_2e. This level is higher than that of Tam Ky, Hue, Vinh, Dong Hoi, Hoi An, and Dong Ha, which are smaller and less developed cities than Can Tho. Can Tho's GHG emission per capita is also a bit higher than that of centrally-run Da Nang City (3.4 tons of CO_2e in 2016). However, since the GHG inventories of the compared cities were carried out in previous years, such comparison is somewhat relative.

From the above analysis results, it can be seen that energy use, including direct use of fuels for *Travel by People* and electricity use in *Residential Sector* and in *Industrial Processes*, is the most important target for initiating potential GHG mitigation measures in the city. These findings would definitely assist the city in paving the path for considering priority areas and then carrying out necessary follow-up activities for GHG emission mitigation at the city level. The analysis results are also expected to provide a deeper understanding and help the city come up with its appropriate action plans in response to climate change.

4 Conclusion

The Bilan Carbone method provides an overview of the various greenhouse gas emission sources of Can Tho City and their contribution to climate change. The Bilan Carbone-based analysis shows that among ten activity categories of the City, *Residential Sector*, *Industry Processes*, and *Travel by People* account for the largest contribution to the city's total greenhouse gas footprint, which represented 17.2, 16.9, and 14.4% of the city's total greenhouse gas emission, respectively. Thus, it is highly recommended that Can Tho should set priority for energy, particularly electricity use when undertaking potential greenhouse gases emission mitigation measures for the city.

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