Analysis of CO₂ Emissions from Industrial Parks: A Case Study in Ho Chi Minh City, Vietnam

T LVan\(^*\), V T T Ho\(^2\), H D T Thanh\(^1\), N T Thong\(^1\), Q Huynh\(^1\) and Q L B Nguyen\(^3\)

\(^1\)NTT-Hi Tech, Institute, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam
\(^2\)Hochiminh City University of Natural Resources and Environment (HCMUMRE), Vietnam
\(^3\)VNU-HCM High School for the Gifted

\(^*\)Corresponding author’s e-mail: lvtn@ntt.edu.vn

Abstract. Every day industrial production emissions accounts for a significant share of overall greenhouse gas emissions, in particular carbon dioxide (CO₂). The issue of CO₂ emissions management has always been of particular interest in the context of the industrialization process and urbanization taking place more and more complex. Ho Chi Minh is a large city in Vietnam, where many industrial parks (IPs) and export processing zones (EPZs) are located. In Vietnam, there are not many assessments of CO₂ emissions from industrial processes with unrealistically and seriously surveyed data. This paper aims to evaluate and estimate CO₂ emissions of the industrial and export processing zones based on the fuel consumption and power consumption surveyed in industrial / processing zones in order that proposing the long-term solutions for low-carbon metropolis. The results show that the CO₂ emissions of 13 HCMC IPs/ EPZs in the atmosphere is 227214.1869 tons CO₂/year. This is the annual CO₂ emissions calculated from the emissions of facilities in Ho Chi Minh industrial/ export processing zones. Tan Phu Trung industrial park had the highest emissions (133010.7499 tons CO₂/year) and Linh Tru 2 export processing zones is the lowest with 1745.817984 tons CO₂/year. Evaluating and calculating the CO₂ emissions of individual sources makes it possible for experts to adopt appropriate and effective policies to reduce national emissions and easily reach the goal of building a low carbon city.

1. Introduction
Climate change has been attracting attention due to its serious consequences, threatening to development and health of humankind. A great deal of efforts has been devoted to mitigating the effects of climate change, including cutting greenhouse gas emissions. Among the gas emissions, the carbon dioxide (CO₂) was emitted from human activities such as burning fossil fuels, industrial production, agriculture, transport which was known as a primary gas causing the climate change. According to the Asian Development Bank (ADP, 1994), Vietnam, particularly the Mekong River Delta, is one of the countries, which is seriously affected by climate change. Furthermore, the Ministry of Natural Resources and Environment estimated that the sea level will increase up to be 33 centimeters in the 2050 and continuous increase of 1 meter in 2100. With these impacts, Vietnam will suffer losses of about $ 17 billion annually.
According to HEPZA (Ho Chi Minh City Export Processing and Industrial Zones Authority), Ho Chi Minh City is a vibrant, dynamic city offering a stable manufacturing base and an increasingly affluent population as a potential market. Up to now, Ho Chi Minh City has contributed to the nation 20% of GDP, 30% of industrial output, 40% of export revenues and the national budget collection of HCMC have been 91305 billion VND. At this juncture, Ho Chi Minh City has 17 operated industrial parks/export processing zones. Up to 30/9/2015, the 3 export processing zones and 10 industrial parks in Ho Chi Minh City have attracted 1387 investment projects with the total registered capital of 9043 billion USD. Besides that, there are 559 foreign investment projects with the investment capital of 5.4 billion USD and 828 domestic investment projects with the investment capital of 54641 billion VND (equivalent to 3.65 billion USD). The exports have been valued 46 billion USD with the big major markets are Japan, Europe, the USA, Taiwan and with their products were exported to more than 50 countries and territories. The negative effect of climate change such as sea level 40% - 45% of land cover on Ho Chi Minh City is 0 – 1m in elevation, 15% - 20% is 1 – 2m and very land sit above 4m. Furthermore, Ho Chi Minh City more and more suffers the storms, storm surges, and tidal flooding appear with intensity, resulting from directing of climate change [1].

Le Thanh Hai and Le Thi Thanh Dung [2] 2012 have carried out the project "Research, assess the current situation and forecast greenhouse gas emissions in Ho Chi Minh City and propose mitigation measures". The study has used the method of greenhouse gas inventory according to the Intergovernmental Panel on Climate Change (IPCC) to conduct inventory for four areas of greenhouse gas emissions in HCMC. The inventory results show that the energy sector emits 9,280,463 tons CO₂ billion / year, accounts for 79.17%, the industry and using products emit 161,842 tons CO₂ billion / year, accounting for 1.38%, The agricultural sector emits 951,912 tons CO₂ billion/year, accounting for 8.12% and the waste storage area, releases 1,328,415 tons CO₂ billion/year, accounting for 11.33%. Thus, between different industries, the greenhouse gas emission factors are also different. The inventory result is that the sectoral statistics based on statistics do not show the spatial relationship between the sources of CO₂ emissions and absorption and the status of emissions. Therefore, the proposed solutions of the topic are of macro or local management nature in some sectors but have not yet addressed the current state of greenhouse gas emissions for each specific spatial area.

Pham Khac Lieu and co-workers [3] (2010) have studied "Calculation of greenhouse gas emissions of Hue city government with Bilan Carbone". The work has used the Carbon Balance tool to calculate the greenhouse gas emissions of Hue city, Vietnam based on relevant data collected from 81 units under the city government. The results of statistical analysis using the Carbon Balance tool show that other areas causing high emissions of the city government are travel (1,824 tons of CO₂ equivalent), input materials (1,813 tons of CO₂), energy use (equivalent), transportation (1,462 tons CO₂ equivalent) and energy used (540 tons CO₂ equivalent).

However, there is still a little number of studies on evaluating and calculating the amount of CO₂ emission in the production process at industrials/exports zones of Ho Chi Minh City. [4-6] Herein, we have studied to analyses the CO₂ emissions of the industrial and export processing zones based on the fuel consumption and power consumption surveyed in industrial/processing zones in order that proposing the long-term solutions for low-carbon metropolis. The results of work are a good measurement to manage and mitigate the city policies for environmental planning.

2. Data and methods

2.1. Data

By using HCMC Export Processing & Industrial Zones Authority (HEPZA) information, factories and enterprise of Ho Chi Minh industrial/ export processing zones were surveyed in 2016. Even the industrial parks/export processing zones are located in 9 districts: Thu Duc, Nha Be, Tan Phu, Binh Tan, Cu Chi, Binh Chanh, District 2, District 7 and District 12, only 7 districts have surveyed results. The results from 205 enterprises, factories from 13 industrial/ export processing zones with data on the amount of fuel used and the amount of electricity consumption were sent back.
2.2. Methods

2.2.1 Methods of calculating GHG emissions: Calculating GHG emissions based on GHG emission factors of IPCC 2006 and IEA (2011b) and other relevant local and regional studies were used. (Figure 1).

\[
\text{Emissions}_{\text{GHG, fuel}} = \text{Fuel Consumption}_{\text{fuel}} \times \text{Emission Factor}_{\text{GHG, fuel}}
\]  

(1)

Where \( \text{Emissions}_{\text{GHG, fuel}} \) is emissions of a given GHG by type of fuel (kg GHG), \( \text{Fuel Consumption}_{\text{fuel}} \) is the amount of fuel combusted (TJ), and \( \text{Emission Factor}_{\text{GHG, fuel}} \) is default emission factor of a given GHG by type of fuel (kg gas/TJ). [2]

The formula of \( \text{CO}_2 \) emissions from power consumption is [3]:

\[
\text{Total CO}_2 \text{ from Electricity Use (tCO}_2\text{)} = \text{Basic units (kWh)} \times \text{CO}_2 \text{ EF (tCO}_2\text{/kWh)} \]  

(2)

Where Basic units are the amount of electricity used (in kWh), \( \text{CO}_2 \) EF is \( \text{CO}_2 \) Emission factor for each Country which is 0.4130283 by IEA [7] as \( \text{CO}_2 \) Emissions Factor of Viet Nam was not available in UNEP 2009 Greenhouse Gas calculator manual.

2.2.2 GIS mapping \( \text{CO}_2 \) emission

A geographic information system (GIS) is a conceptualized framework that provides the ability to capture and analyze spatial and geographic data. GIS applications are computer-based tools that allow the user to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyze spatial information output, and visually share the results of these operations by presenting them as maps. By GIS software, the \( \text{CO}_2 \) emission of the districts of Ho Chi Minh City was distributed in the administrative map of Ho Chi Minh City in this work by (i) Create assessment map of \( \text{CO}_2 \) emission by administrative unit of ward/commune/town; (ii) used spatial and non-spatial data for the process of mapping \( \text{CO}_2 \) assessment and used coefficients \( \text{CO}_2 \) calculation method for the calculation process; (iii) Non-spatial data by Data on names of districts and wards / communes / towns of HCMC; (iv) Data collected amount of fuel used and electricity consumption of factories and enterprises in the IZ / EPZ.
and (v) The coordinates of the location of the enterprise factories by ward / commune / town on Google Earth and Spatial data was administrative boundaries of HCMC. [7-9]

3. Results and discussion

Ho Chi Minh City places the junction between the Southeastern and South West, includes 19 urban districts and 5 suburban districts, which was illustrated in Figure 2. The size of the area is 2095.06 km².

![Administrative map of Ho Chi Minh City](image)

**Figure 2.** Administrative map of Ho Chi Minh City

The amount of fuel in the production process of 121 factories, which was operating in 13 industrials/exports zones in Ho Chi Minh City was surveyed and employed to estimate the CO₂ emission of Ho Chi Minh City industrial parks in this work. As can see in Table 1, the primary fuel was utilized to be the electricity (~295164489 kWh/year) and the oil fuel (~39032167.88 liters/year), meanwhile, the natural gas and coal were almost used in the surveyed manufactories.

| No. | Fuel type  | Unit       | Fuel consumption (*) |
|-----|------------|------------|----------------------|
| 1   | Oil Fuel   | Liter/year | 39032167.88          |
| 2   | Natural gas| Kg/year    | -                    |
| 3   | Diesel Oil | Liter/year | 1595188.00           |
| 4   | Coal       | Kg/year    | -                    |
| 5   | Firewood   | Kg/year    | 6438546.00           |
| 6   | Electricity| Kwh/year   | 295164489.00         |

(*The data collected from surveyed result/reports)
By using the Equation (1) and (2), the CO\textsubscript{2} emission of 121 manufactories in studied 13 industrials/exports zones in Ho Chi Minh City was estimated based on the amount of surveyed fuel (Table 1). The calculated results indicated that the industrials/exports zones with the high occupancy rates of over 80\% exhibited a large amount of CO\textsubscript{2} emission. (Table 2).

**Table 2.** The amount of CO\textsubscript{2} emission of industrials/exports in Ho Chi Minh City

| No. | Industrial/exports zones       | Total CO\textsubscript{2} emissions (tons CO\textsubscript{2} / year) |
|-----|--------------------------------|---------------------------------------------------------------------|
| 1   | Tan Thuan EPZ                 | 94587.51                                                            |
| 2   | Tan Binh IP                   | 63209.63                                                            |
| 3   | Tan Thoi Hiep IP              | 30405.32                                                            |
| 4   | Tay Bac Cu Chi IP             | 16277.63                                                            |
| 5   | Le Minh Xuan IP               | 15644.14                                                            |
| 6   | Linh Trung 1 EPZ              | 11761.34                                                            |
| 7   | Vinh Loc IP                   | 11584.74                                                            |
| 8   | Hiep Phuoc IP                 | 8911.14                                                             |
| 9   | Tan Tao IP                    | 7793.57                                                             |
| 10  | Binh Chieu IP                 | 5583.8                                                              |
| 11  | Cat Lai IP                    | 4515.39                                                             |
| 12  | Linh Trung 2 EPZ              | 2476.88                                                             |
| 12  | Tan Phu Trung IP              | 378.29                                                              |
|     | Total                         | 273129.38                                                          |

As results in Table 2, the CO\textsubscript{2} emission of the industrial/exports park of Ho Chi Minh City was estimated to be \(\sim 273129.38\) tons CO\textsubscript{2}/year. In the 13 industrials/exports zones was surveyed, the highest CO\textsubscript{2} emission was attributed to the Tan Thuan export park of 7 District and Tan Binh zone of Tan Phu District with \(\sim 94587.51\) tons/year and \(\sim 63209.63\) tons CO\textsubscript{2}/year, corresponding to \(\sim 34.63\%\) and \(\sim 23.14\%\) of the CO\textsubscript{2} emission total. In contrast, the Tan Phu Trung industrials of Cu Chi District and Linh Trung exports of Thu Duc District exhibited the lowest CO\textsubscript{2} emission to be around \(378.29\) tons CO\textsubscript{2}/year and \(2476.88\) tons CO\textsubscript{2}/year, corresponding to about \(0.14\%\) and \(0.90\%\) of the CO\textsubscript{2} emission total (Figure 3). This different amount of CO\textsubscript{2} emission was attributable to the difference in factory numbers and the scale production as well as the different fuel in producing a process of the surveyed manufactories in this work. For instance, according HCMC Export Processing & Industrial Zones Authority indicated the Tan Phu Trung of Cu Chi District and Cat Lai industrials of 2 District have very few businesses and factories meanwhile, the Tan Binh industrials of Tan Phu District have the amount of the manufactories to be \(\sim 4\)-folds higher than that of the Cat Lai industrials, albeit it’s lower area. The concentration of a large number of businesses and factories in a district was showed the result in the high CO\textsubscript{2} emission versus that of another district, which the lower amount of businesses and factories.
Figure 3. The amount of CO$_2$ emission of industrials/exports in Ho Chi Minh City

The industrials/exports zones were concentrated in District Thu Duc, District Cu Chi, District Binh Tan, and District Binh Chanh, which had two to three industrials/exports in each district. Among District 2 have only a Cat Lai industrial with the low area. The amount of CO$_2$ emission of districts in Ho Chi Minh City was estimated and showed in Table 3.

Table 3. The amount of CO$_2$ emission of districts in Ho Chi Minh City

| No. | District | Industrials/exports | Total CO$_2$ emissions (tons CO$_2$/year) |
|-----|----------|---------------------|------------------------------------------|
| 1   | Thu Duc  | Binh Chieu IP       | 19821.22                                 |
|     |          | Linh Trung 1 EPZ    |                                          |
|     |          | Linh Trung 2 EPZ    |                                          |
| 2   | District 2| Cat Lai IP          | 4515.39                                  |
| 3   | Nha Be   | Hiep Phuoc IP       | 8911.14                                  |
| 4   | Binh Chanh| Le Minh Xuan IP     | 22053.81                                 |
|     |          | Vinh Loc IP         |                                          |
| 5   | Tan Binh | Tan Tao IP          | 1508.06                                  |
| 6   | Binh Tan | Tan Tao IP          | 12968.63                                 |
|     |          | Vinh Loc IP         |                                          |
| 7   | Tan Phu  | Tan Binh IP         | 63209.63                                 |
| 8   | Cu Chi   | Tan Phu Trung IP    | 16655.92                                 |
|     |          | Tay Bac Cu Chi IP   |                                           |
| 9   | 12       | Tan Thoi Hiep IP    | 30405.32                                 |
| 10  | 7        | Tan Thuan EPZ       | 94587.51                                 |
|     |          |                     | **Total** 273129.38                      |
As an estimated result, the District 7, District Tan Phu and District 12 exhibited the largest CO₂ emission, corresponding to about ~94587.51 tons CO₂/year; 63209.63 tons CO₂/year and 30405.32 tons/year. The amount of CO₂ emission of three districts was estimated to be ~68.91% of CO₂ emission total, practically, the District 7 and District Tan Phu and District 12 were about ~34.63%; 23.14%; and 11.13%, respectively. Meanwhile, District Tan Binh and District 2, which had the amount of CO₂ emission to be around 1508.06 tons CO₂/year and 4515.39 tons CO₂/year, have the lowest CO₂ emission. (Figure 4). The dominant industrial/processing zones productions are mechanics, apparel and chemicals productions. Binh Tan and Cu Chi which gather 7 HCMC industrial parks have 5 industrial parks in the study. District 2 has only one industrial park named Cat Lai whose land is small size. Although it was not the least polluting industrial park, Cat Lai was the only industrial park in District 2. That makes the overall emissions of District 2 compared to other districts be the lowest. In addition, Cat Lai had a very low density of enterprises and factories. Unlike Cat Lai, Tan Binh Industrial Park which is in Binh Tan district is a small land size industrial park. But the number of factories and enterprises in Tan Binh is more than four times that in Cat Lai. A number of factories in an industrial park and a number of industrial parks in a district caused a large concentration of emissions.

![Figure 4. The amount of CO₂ emission of districts in Ho Chi Minh City](image)

By GIS software, the CO₂ emission of the districts of Ho Chi Minh City was distributed in the administrative map of Ho Chi Minh City (Figure 5). As a result, the District 7 and District Tan Phu exhibited the highest CO₂ emission 35000 tons CO₂/year, which were ascribable to the concentration of a lot of factories, meanwhile, the District Cu Chi and District Binh Chanh exhibited few CO₂ emission versus that District 7 and District Tan Phu, albeit it was larger area. This can propose due to some reasons such as: (i) the relocation of factories from District 7 and District Tan Phu to District Cu Chi and District Binh Chanh to decrease CO₂ emission of the center District in Ho Chi Minh City; (ii) plant a lot of green trees at industrials/exports zones at District 7 and District Tan Phu for them absorb CO₂ resulting in the significant decrease CO₂ emission of these districts.
4. Conclusions
This study gives real reviews of CO\textsubscript{2} emissions from industrial parks/export processing zones by calculating fuel and power consumption surveyed data, it will be better if surveyed data is accurate and detailing. The results show that the CO\textsubscript{2} emissions of 13 HCMC IPs/EPZs in the atmosphere is 227214.1869 tons CO\textsubscript{2}/year. This is the annual CO\textsubscript{2} emissions calculated from the emissions of facilities in Ho Chi Minh industrial/export processing zones. Tan Phu Trung industrial park had the highest emissions (133010.7499 tons CO\textsubscript{2}/year) and Linh Trung 2 export processing zones is the lowest with 1745.817984 tons CO\textsubscript{2}/year. Evaluating and calculating the CO\textsubscript{2} emissions of individual sources makes it possible for experts to adopt appropriate and effective policies to reduce national emissions and easily reach the goal of building a low carbon city.
5. References
[1] Kuo–YingW, Jia–LinW and Wen–Tzu L 2014 Atmospheric Pollution Research 5 179-188
[2] Hai L T and Dung L T T 2012 project “Research, assess the current situation and forecast greenhouse gas emissions in Ho Chi Minh City and propose mitigation measures”
[3] Lieu P K, Tuan T A 2015 Conference: National Science Conference “Wetlands and Climate Change” Volume: Science and Technology Publishing House, Hanoi
[4] Wygonik E and Goodchild A 2011 IATSS Research 35 7-15
[5] Kim T, Lee S, Chae C U, Jang H and Lee K 2016 Sustainability 8(7) 663
[6] Bryant R, Bundy M and Zong R 2015 J Air Waste Manag Assoc 65(7) 863-70
[7] IPCC 2006 Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, V2
[8] UNEP 2009 Greenhouse Gas calculator manual p 30
[9] IEA (2011b) 2008 Statistics by country/region for electricity/heat

Acknowledgments
This work is supported by the Ministry of Natural Resources and Environment project, number TNMT.2016.05.25. Thanks to Dr. Nguyen Xuan Truong, Dr. Tran Thong Nhat, Mr. Huynh Minh Thien for their supports for this work.