Assessing Green House Gases (GHGs) Emissions/ Removals in Hanoi, Vietnam

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Abstract

This study tried to integrate GHG inventory methodology, IPCC's emission factors and Vietnam's specific emission factors to assess GHG emissions and removals in various sectors, namely: energy, agriculture & forestry, industrial processes and waste management, for the City of Hanoi.

In the scenario of business as usual (BAU), total GHG emissions in Hanoi have a tendency to increase fast up from 22,881,000 tons CO_2e in 2011 to approximately 43,934,000 tons CO_2e in 2020 and around 90,092,000 tons CO_2e in 2030. Emissions from energy sector contributed the largest share with about 78 to 84 percent.

Hanoi's per capita emission is currently about 21% higher than Vietnam's average and tends to continue to increase in coming years. While this number of emission per capita is currently lower than the global average of 4.35 tons, it is forecasted that from 2021 onward it will rise above the worldwide average.

Hanoi needs to develop appropriate policies, plans and solutions to reduce GHG emissions and contribute to the Viet Nam's commitment with international community to reduce GHG emissions by 8% with domestic resources and 25% with international support by 2030.

Key words: Green House Gas, Emissions, Emissions per capita, Hanoi

1. Introduction

Climate change (CC), a large-scale, long-term shift in the planet's weather patterns or average temperatures, is arguably the most severe challenge facing our planet during the 21st century. The manifestation of CC includes: the warming of the atmosphere and the earth; changing in the composition and quality of atmosphere, hydrosphere, biosphere, geosphere; sea level rise leading to floods in low lands and islands; changing the active intensity of atmospheric circulation, natural water circulation cycle and biochemical cycles; changes in the biological productivity of the ecosystems. The World Meteorological Organization (WMO, 2019) report on The Global Climate in 2015-2019 says that the global average temperature has increased by 1.1°C since the pre-industrial period, and by 0.2°C compared to 2011-2015. The five-year period 2015–2019 is likely to be the warmest of any equivalent period on record globally.

The actors that lead to CC are Green House Gases (GHGs), mainly including CO_2, N_2O, CH_4, HFC, PFC, SF_6, vapors, CFC gases,… which are created due to changes in nature and increasing emissions from human activities. Sources of GHG emissions from human activities (human induced CO_2 emissions) are divided into 4 main groups: energy (energy, manufacturing and construction industries and fugitive emissions); industrial process and product uses (IPPU); agriculture – forestry and land use (AFOLU); and wastes. Emissions of these GHGs are converted into volume of CO_2 equivalent (CO_{2e}) via global warming potential index (GWP) guided by Intergovernmental Panel on Climate Change (IPCC). The period of last 100 years has seen a continued increase in CO_2 emissions and an accelerated increase in the atmospheric concentration of major GHGs. Global emissions of CO_2 increased from 2 billion tons in 1900 to over 36 billion tons in 2015. Between 2010 and 2017, total global CO_2 emissions have increased from 33.1 gigatons to 36.2 gigatons and are projected to increase in the coming years - emission is reported a 2.7 percent increase in 2018 (Hannah Ritchie and Max Roser, 2019).

By country, the top 15 generate 72% of CO_2 emissions. The rest of the world's 180 countries produce nearly 28% of the global total. However, aggregating emissions by country is just one way of assessing the problem. A more useful measurement is carbon emissions per capita. The per capita figures tell a different story (Sean Fleming, 2019). Most of the world's largest economies have high CO_2 emissions per capita – 10 of the top 12 are above the global average of 4.35 tons; the average American is responsible for 19.8 tons per person, Australia is on 20.6 tons per person and the UK is half that at 9.7 tones. Despite having high total emissions, Brazil's and India's CO_2 emissions per capita are comparatively low due to their large populations and relatively low GDP per capita: the average Chinese citizen clocks in at 4.6 tons; India is on a mere 1.2; poorer African nations such as Kenya are on an order magnitude less again – the average Kenyan has a footprint of just 0.3 tons (UCS, 2018), (WB, 2019).

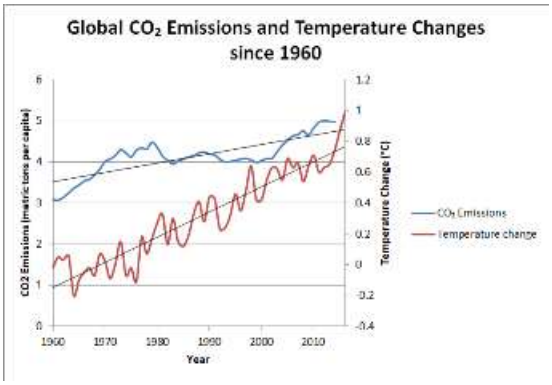

Figure 1: Global CO_2 Emissions and Temperature Changes, 1960 - 2010

Figure 2: Map of CO_2 Emissions per Capita, 2007

Source: Our World in Data

In Vietnam, during the period from 1994 to 2010, the total GHG emission increased rapidly from 103.8 mil tons of CO_{2e} to 246.8 mil tons of CO_{2e}. In 2013, the total emission reached to 259 mil. tons. The two highest emission sources are agriculture and energy, accounted for about 88% of total emissions, where the energy area got the largest growing rate. Vietnam's CO_2 emissions per capita in 2013 was about 2.83 tons, comparatively low to the global average.

Although the CO_2 emissions in total and per capita are comparatively low, Vietnam is one of the countries are most vulnerable to climate change. The Government of Viet Nam has developed and issued a number of policies related to the mitigation of GHG emissions. The Nationally Determined Contribution (NDC) of Viet Nam has defined a roadmap for GHG emissions reduction at national level to 2030, according to which Viet Nam will reduce GHG emissions by 8% compared to the Business As Usual scenario (BAU) by 2030 with domestic resources, and up to 25% by 2030 with international support. Thus, it is necessary for the country and each sector/ locality to do inventory of GHG emissions and removals in order to provide policymakers the information needed for designing GHGs abatement and climate change mitigation plan.

This study aims to assess GHG/ CO_2 emissions and removals of Hanoi – the Capital City of Vietnam, to serve the inventory of GHGs and design City Green Growth Action Plan.

2. Research Methodology

Assessing/ Calculating GHG Emissions and Removals

The sectors related to the City's GHG emissions and removals include: Energy, Agriculture & Forestry, the Industrial Process and Waste management. Transport sector is as an energy consumption sector, thus its emission should be calculated in the energy sector.

Assessment/ calculation of GHG emissions and removals is conducted in compliance with

the Intergovernmental Panel on Climate Change (IPCC) Guidelines, namely: *The Revised 1996 IPCC Guidelines for National GHG Inventories*; *The 2006 IPCC Guidelines for National GHG Inventories* (IPCC 2006 GL) and the *Guide on GHG Inventory for Cities* by Greenhouse Gas Protocol 2015.

GHG emission/ removal volume of an activity is calculated by the formula:

$$\mathbf{Ei = ADi \times EFi \ x \ CO_{2e}}$$

Where:

Ei: GHG emission/ reduction or absorbance volume of activity i (unit in ton of CO_{2e})

ADi: level of activity in sector/ sub-sector i (for example: number of transportation vehicles, rice cultivation areas, the number of husbandries, used fuel volume …)

EFi: GHG emission factor estimated for each unit of activity (for example, kg of carbon emitted on each unit of cultivation area or fuel volume burnt,…).

CO_{2e}: factor for converting emissions in to CO_2 equivalent.

Due to limitations in terms of data, only 3 types of GHG have been assessed, namely CO_2, CH_4, and N_2O, all converted into volume of CO_2 equivalent (CO_{2e}) via global warming potential index (GWP) provided by IPCC in the second report in 1996 (SAR).

Table 1: Weighs for converting GHGs into CO_2 equivalent

Type of gas	Symbolic	Time existing on atmosphere (Years)	Global warming potential index (GWP)
Carbon dioxide	CO_2	100	1
Methane	CH_4	12	21
Nitrous oxide	N_2O	114	310

Sources: IPCC (2006)

GHG Emissions and Removals Projection

The GHG projection towards 2020, 2025 and 2030 are based on socio-economic development targets set by Decision of the Prime Minister on *"Master Plan for Socio-Economic Development of Hanoi City to 2020, Orientations to 2030"* (Decision No. 1081/QĐ-TTg, dated on 06/07/ 2011), and expert consultations on tendency of households' consumption as well as technology trend in some sectors.

Data Sources

Brief on data/ sources used in assessing GHG emissions and removals in Hanoi is presented in Table 2.

Data on economic activity are collected and compiled from City Statistics Office (CSO), city statistics reports and a number of local departments' reports. Some data from relevant studies have also been employed.

Most emission factors (EFs) are default values according to IPCC; only some country-specific emission factors were applied in Energy; Agriculture; Land use, Land use change and Forestry (LULUCF) and Waste sectors.

Table 2: Data Sources for GHG Emission and Removals

Data Source	
Data on Economic Activities	**Emission Factor and other Parameters**
- Annual statistics reports, City Statistics Office - Department of Industry and Trade (DoIT), Electricity Corporate - Department of Planning and Investment (DPI) - Department of Construction (DoC) - Department of Transportation (DoT), Transportation Safety Committee - Cement development reports - National Electricity Master Plan - Local socio-economic development master plans - Land use Matrix 2010- 2014, MONRE - Department of Agriculture and Rural Development (DARD) - Land use and sectoral development plans - Data from scientific researches and projects - Expert consultations	- Emission factors by IPCC 2006 - Electricity transmission emission factor in Vietnam by Ministry of Industry and Trade (MOIT) - Cement Emission Factor in Vietnam - Emission Factors of some fuels in Vietnam - Emission Factors in rice cultivation and husbandry waste management in Vietnam - Reports from Ministry of Natural Resource and Environment (MONRE), Ministry of Agriculture and Rural Development (MARD)…

Source: Author's synthesis and recommendations

3. Research Results and Discussions

3.1. Hanoi's Socio-ecomic Context

Hanoi is the Capital of Vietnam. It covers an area of 3,328.9 square kilometers. With a population of 8.05 million as of 2019, Hanoi is the second largest city in Vietnam and largest city in the North of Vietnam.

Located in the central area of the Red River Delta, Hanoi is the economic, commercial, cultural, and educational center of Northern Vietnam.

Having an nominal GDP of US$32.8 billion in 2018, Hanoi also is the second most productive economic center of Vietnam, following Ho Chi Minh City.

On average, for the three years 2016-2018, the City's Gross Domestic Product (GRDP) increased by 8.41% per year, higher than the 7.3% per year of the period 2011-2015. The economic structure continues to shift in a positive direction: increasing the proportion of industry, service

and construction sectors, as well as a decrease in agriculture. The City's GRDP per capita in 2018 reached US $ 4,080/ person, 1.12 times higher than that of 2015.

In 2016, foreign-invested capital on projects reached US$2.8billion, increasing 2.6 times compared to last year. Total social investment was at VND 277.95 trillion ($12.3million), a rise of 10 per cent over the previous year. The number of foreign visitors to Hanoi in 2018 reached 5.47 million persons, increasing 16% in comparison with that in previous year.

So far, Hanoi possesses nine industrial zones with a total area of 1,310 hectares. The city is also preparing the construction of five other zones with a total area of 817 hectares. Beside, Hanoi has 70 industrial clusters covering an area of 1,337 hectares and containing around 3,100 manufacturing facilities. In 2018, the clusters contributed approximately VND631 billion to the city's budget revenue and attracted around 60,000 workers. To tackle pollution, many industrial production bases has been moved out of the inner city. Investment in high and clean technology and sustainable development is a major trend, therefore, enterprises will increase the density of land use, promote investment in high-tech equipment and synchronous production lines and apply information and technology advances in production management.

As the country's capital and economic locomotive, Hanoi will continue to uphold its central role in cohering and developing production, supply and the distribution of goods with other provinces and cities. Accordingly, value chain linkages will be formed to improve the efficiency and competitiveness in international cooperation and integration, contributing to helping Hanoi to reach and exceed the targets of socio-economic development.

3.2. GHG Emissions from Energy Sector

In energy sector, emissions are inclusive of public heat and electricity production; other energy industries; fugitive emissions from solid fuels, oil and gas, manufacturing industries and construction. Transport sector (domestic aviation, road transportation, rail transportation, domestic navigation, other transportation) is as an energy consumption sector and its emission was calculated in the energy sector.

The total GHG emissions (indirect and direct ones) from Energy sector in CO_2 equivalent quickly increase from 4,047,254 tons in 2010 to 11,341,646 tons in 2015; 18,084,331 tons in 2020; 26,746,642 tons in 2015 and 39,669,519 tons in 2030.

Indirect GHG Emissions from Electricity Consumption

Using data provided by Hanoi Electricity Company (EVN Hanoi), the electricity output fluctuates from 6 million MWh in 2010 to about 45 million MWh in 2030, with average growth rate of about 8 percent per year. The electricity consumption structure is forecast to remain stable from 2010 to 2030, of which: 54% for consumption management, 31% for industry and construction, 8% for commercial, hotels and restaurants, 1% for agriculture and 6% for other activities. In industry, manufacturing is the biggest consumer with particular sub-sectors: food processing, rubber and plastic, metal production, electric and communication equipments production…

Table 3 shows the results of calculating indirect GHG emissions from electricity consumption by activities.

Table 3: Indirect GHG Emissions from Electricity Consumption by Activities

Unit: tons of CO_2 equivalent

Activities	2010	2015	2020	2025	2030
Consumption Management	2,485,727	6,385,831	9,820,995	14,525,206	21,543,188
Residential	*1,943,930*	*5,419,773*	*8,304,336*	*12,282,075*	*18,216,268*
Industry and Construction	1,351,737	3,356,225	5,650,043	8,356,387	12,393,850
Food Processing	*120,745*	*369,017*	*539,245*	*797,541*	*1,182,880*
Rubber and Plastic Products	*62,387*	*200,590*	*375,524*	*555,398*	*823,743*
Metal Products	*135,523*	*318,788*	*603,199*	*892,128*	*1,323,168*
Manufacturing machines and equipment	*66,720*	*159,701*	*296,639*	*438,728*	*650,704*
Manufacturing electric equipment and tools	*54,711*	*136,020*	*562,106*	*831,352*	*1,233,027*
Manufacturing radio and communication equipment	*89,061*	*202,137*	*325,513*	*481,432*	*714,040*
Commercial, Hotels and Restaurants	323,558	835,973	1,370,183	2,026,495	3,005,614
Retails and Whole sales	*166,652*	*493,455*	*853,729*	*1,262,661*	*1,872,726*
Hotels	*76,734*	*168,942*	*267,912*	*396,240*	*587,688*
Restaurants	*19,397*	*87,800*	*112,543*	*166,450*	*246,872*
Agriculture	22,918	71,012	161,036	238,172	353,246
Others	255,897	692,605	1,082,074	1,600,383	2,373,621
Public lighting	*43,538*	*149,499*	*243,831*	*360,625*	*534,864*
Total	**4,439,837**	**11,341,646**	**18,084,331**	**26,746,642**	**39,669,519**

Source: CEGR (2018); Calculated from data provided by DoIT, DARD, DoC etc.

Direct GHG Emissions from Transportation (using Fuel)

In Hanoi, motorcycles play an important role in people's daily transportation. In 2011, the number of motorcycles was 3.9 million. If this type of traffic is maintained, by 2030 the number of vehicles will be doubled to about 7.5 million units. The number of cars will also increase rapidly from 218,507 units in 2011 to 1,532,195 in 2030. The number of vans, buses and trucks will also increase to 1,954,738 units in 2030. The need for fuel in transportation will growth and GHG emissions will increase as a result.

Utilizing the method of calculating GHG emissions for direct emissions activities in the transport sector and the number of vehicles reported/ forecasted, the results of GHG emissions

were calculated as in Table 4. The total emissions from transportation holds increasing trend, from 2,258,840 tons CO_2e in 2011 to 9,618,240 tons CO_2e in 2020 and 20,782,380 tons CO_2e in 2030.

Table 4: Direct GHG Emissions from Transportation

Unit: tons of CO_2 equivalent

	2011	2015	2020	2025	2030
Motorbikes	969,740	1,229,370	1,486,080	1,706,110	1,828,930
Cars	246,110	310,800	702,180	1,229,360	1,725,760
10-16 seat vans	154,030	177,630	*7,429,980*	*12,377,080*	*17,227.680*
2-7 ton buses and trucks	809,230	1,052,610			
> 20 ton trucks	79,740	100,710			
Total	**2,258,840**	**2,871,110**	**9,618,240**	**15,312,540**	**20,782,380**

Source: CEGR, 2018

Direct GHG Emissions from Other Uses of Fuel

Fuel is used in activities such as coal for living, coal for industry, LPG for other activities. The trend of fuel consumption in Hanoi has decreased gradually in the past time and is maintained for the next period.

Table 5 presents the results of total GHG emission calculation from other uses of fuel. Reducing emissions from coal use in industry reflects the trend of shifting to renewable energy consumption (such as LPG…) in Hanoi in particular and Viet Nam in general.

Table 5: Direct GHG Emissions from Other Uses of Fuel

Unit: tons of CO_2 equivalent

	2011	2015	2020	2025	2030
Coal in industry	11,331,000	8,902,000	5,547,000	5,547,000	5,547,000
LPG	56,000	78,000	110,000	110,000	110,000
Coal for people living	206,000	206,000	206,000	206,000	206,000
Total	**11,593,000**	**9,187,000**	**5,864,000**	**5,864,000**	**5,864,000**

Source: CEGR (2018), Calculated from data provided by DoIT

3.3. GHG Emissions from Agriculture Sector

In agriculture, CH_4 and N_2O emissions from enteric fermentation; manure management; rice cultivation; synthetic fertilizers; manure applied to soils; manure left on pasture; crop residues; burning crop residues, savanna and cultivation of organic soils.

The total GHG emissions from Agriculture sector in CO_2 equivalent increase from 3,137,000 tons in 2011 to 3,720,000 tons in 2015 but reduce to 3,525,000 tons since 2020.

Emissions from Cultivation and Aquaculture

The total area of paddy in 2015 was 200,531 ha, a reduction of 4,363 ha compared to that in 2011. From 2020, the area of paddy will reduce to 145,000 ha.

The number of boats for aquaculture also be reduced from 158 units in 2011 to 100 units in 2020. Thus the fuel use in aquaculture is decrease.

The total GHG emission in from Cultivation and Aquaculture is 1,315,190 tons CO_2e in 2011; reduced to 1,292,220 tons CO_2e in 2015 and 944,010 tons CO_2e since 2020 as presented in Table 6.

Table 6: GHG Emissions from Cultivation and Aquaculture

Unit: tons of CO_2 equivalent

	2011	2015	2020	2025	2030
Cultivation	1,309,380	1,287,440	940,330	940,330	940,330
Aquaculture	5,810	4,780	3,680	3,680	3,680
Total	**1,315,190**	**1,292,220**	**944,010**	**944,010**	**944,010**

Source: CEGR (2018), Calculated from data provided by DARD

Emissions from Live Stock/ Husbandry

The livestock sector has the main areas of raising cattles (includes buffalows, dairy cows, sheep, goats, horses and pigs) and raising poultry (chickens and ducks). Cattle raising is one of the major sources of agricultural GHG emissions. Due to the growing demand in consumption, quantity of Hanoi's cattle and poultry have grown strongly year by year. GHG emissions from livestock sector in Hanoi includes CH_4 and N_2O, which are emitted through the digestion of food, feces and storage of animal and poultry wastes.

With data on quantity of cattles and poultry (provided by Hanoi DARD and Statistical Office), employed the formula for calculating GHG emission volume of the activity as in Table 7.

Table 7: GHG Emissions from Live Stock/ Husbandry

Unit: tons of CO_2 equivalent

	2011	2015	2020	2025	2030
Cows	280,104.98	245,098.00	235,988.83	235,988.83	235,988.83
Dairy cows	10,208.29	15,182.00	16,371.29	16,371.29	16,371.29
Buffalows	31,411.45	31,729.22	28,774.23	28,774.23	28,774.23
Sheep	1,244.55	815.96	1,268.40	1,268.40	1,268.40
Horses	236.55	135.57	184.44	184.44	184.44
Pigs	200,800.41	202,789.58	237,063.54	237,063.54	237,063.54
Poultry	1,303,472.46	1,937,259.84	2,064,761.01	2,064,761.01	2,064,761.01
Total	**1,827,478.69**	**2,433,010.16**	**2,584,411.74**	**2,584,411.74**	**2,584,411.74**

Source: CEGR (2018), Calculated from data provided by DARD, CSO

3.4. GHG Emissions and Removals by Forestry Sector

Forests are carbon sinks, which play a particularly important role in the balance of O_2 and CO_2 in the atmosphere. The amount of CO_2 absorbed/ removed depends on the forest type and status. Primary natural forest is 60% more likely to store CO_2 than planted forest.

Beside to the absorption capacity, the forest also emits a large amount of CO_2 due to the biomass growth of the trees, due to other harvesting processes and decay of dead stems.

In Vietnam, to facilitate the forest management and planning, the government has classified forest system and forest land following the functions of special-use forests and protection forests. Each of above forest type is further subdivided into forest types based on human impact, including: natural forests, new-planted forests and re-planted forests.

The total area of forest in 2015 was 29,102 ha (a slightly increase of 454 ha compared to 2011), in 2020 the forest area is 28,681 ha, almost did not change. Of which, in 2015, the area of natural forest was 8,372 ha and the area of planted forest was 20,730 ha.

The total GHG emissions/ removals in Forestry sector is described in Table 8. The sector has changed from an emissions category to a removal since 2011.

Table 8: GHG Emissions/ Removals from Forestry

Unit: tons of CO_2 equivalent

	2011	**2015**	**2020**	**2025**	**2030**
Removals	(267.92)	(282.03)	(279.96)	(279.96)	(279.96)
Emissions	17.79	17.25	33.51	33.51	33.51
Net emissions	**(250.14)**	**(264.77)**	**(246.45)**	**(246.45)**	**(246.45)**

Source: CEGR (2018), Calculated from data provided by DARD

3.5. GHG Emissions by Industrial Process

Main products of the industry in Hanoi include: clean coal, frozen seafood, fish sauce, beer and mineral water, wheat flour, vegetable oil and cement. The cement industry has significant emissions in clinker production, so it is necessary to calculate the emissions in the production process of the cement industry.

There are 4 cement factories in Hanoi with total clinker production capacity was 777,500 tons in 2010; 1,950,000 tons in 2015 and 2,300,000 tons since 2020. GHG emissions from clinker production has significant increased from 394,680 tons in 2011 to 897,000 tons since 2020.

Table 9: GHG Emissions from Industrial Process

Unit: tons of CO_2 equivalent

	2011	**2015**	**2020**	**2025**	**2030**
Cement/ Clinker Production	394,680	760,500	897,000	897,000	897,000

Source: CEGR (2018), Calculated from data provided by DoIT and Cement Corporation

3.6. GHG Emissions by Waste Sector

Emissions by Waste Sector in Hanoi include: CH_4 emission from solid waste disposal sites; CH_4 emission from industrial wastewater; CH_4 emission from domestic wastewater; N_2O emission from human sewage and CO_2 emission from waste incineration.

The total 2015 GHG emission in waste sector is 2,850,000 tons, as presented in Table 10. The biggest share of GHG emissions belongs to solid waste disposal sites with 43.2%, followed by emissions from domestic wastewater with 35.6%. For the other sub-sectors, emissions from human sewage, industrial wastewater and waste incineration are respectively 7.6%, 7.7% and 5.5%.

Table 10: GHG Emissions from Waste

Unit: tons of CO_2 equivalent

	2011	**2015**	**2020**	**2025**	**2030**
CH_4 emission from solid waste disposal sites	575,100	954,000	1,401,000	1,875,500	2,350,000
CH_4 emission from industrial wastewater	156,700	170,000	191,000	207,500	224,000
CH_4 emission from domestic wastewater	752,100	794,000	873,000	924,500	976,000
N_2O emission from human sewage	162,300	168,000	177,000	184,000	191,000
CO_2 emission from waste incineration	80,600	123,000	208,000	260,000	312,000
Total	**1,726,800**	**2,209,000**	**2,850,000**	**3,451,500**	**4,053,000**

Source: MONRE (2017) and CEGR (2018)

3.7. Synthesis on GHG Emission/ Removal Calculation and Projection for Hanoi

Calculation and projection of GHG emissions in Hanoi across several inventory cycles are presented in Table 11 and Figure 3.

Table 11: Total GHG Emissions in Hanoi

Unit: tons of CO_2 equivalent

Source	**2011**	**2015**	**2020**	**2025**	**2030**
Energy	17,873,000	23,440,000	36,908,000	57,718,000	82,804,000
Industrial Process	395,000	761,000	897,000	897,000	897,000
Agriculture & Forestry	2,887,000	3,456,000	3,278,000	2,338,000	2,338,000
Waste	1,727,000	2,209,000	2,850,000	3,452,000	4,053,000
Total	**22,881,000**	**29,865,000**	**43,934,000**	**64,405,000**	**90,092,000**

Source: Synthesized by the authors

The total GHG emissions was 22,881,000 tons CO_2e in 2011; 29,865,000 tons CO_2e in 2015 and 43,934,000 tons CO_2e in 2020.

Emissions from energy sector contributed the largest share with 78.1% in 2011; 78.4% in 2015 and 84% in 2020. The second largest share comes from agriculture & forestry sector with 12.6% in 2011; 11.6% in 2015 and 7.5% in 2020. Followed by waste sector with 7.3% in 2011; 7.4% in 2015 and 6.5% in 2020. And lastly a small amount from industrial process, around 2% (note that emissions from industrial production are accounted for in energy consumption).

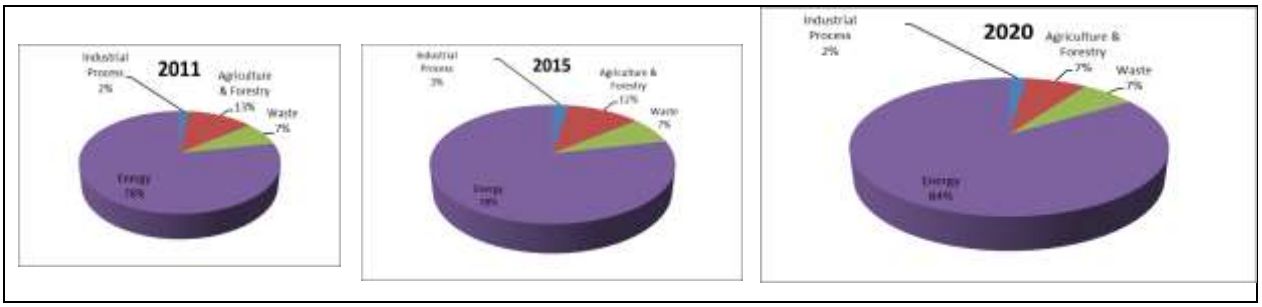

Figure 3. The GHG emission shares of sectors in 2011, 2015 and 2020

Source: Synthesized by the authors

During the period of 2011 - 2020, the total GHG emissions have nearly doubled from 22,881,000 tons CO_2e to 43,934,000 tons CO_2e. By 2030, in the context of Business as Usual (BAU), GHG emissions will continue to increase rapidly, even more than 4 times higher than in 2011 and more than 2 times higher than in 2020.

Emissions in energy sector have gone up the most rapidly, about 4.6 times, from 17,873,000 tons CO_2e in 2011 to 82,804,000 tons CO_2e in 2030, due to the rapid increase of energy demand.

Emissions in waste sector will increase about 2.3 times, from 1,727,000 tons CO_2e in 2011 to 4,053,000 tons CO_2e in 2030.

Emissions in agriculture & forestry sector increase from 2,887,000 tons CO_2e in 2011 to 3,456,000 tons CO_2e in 2015, then begin to decrease - to 3,278,000 tons CO_2e in 2020 and 2,338,000 tons CO_2e in 2025 on ward. This trend in agriculture & forestry sector may be as a result of recent effective reforestation and forest protection activities.

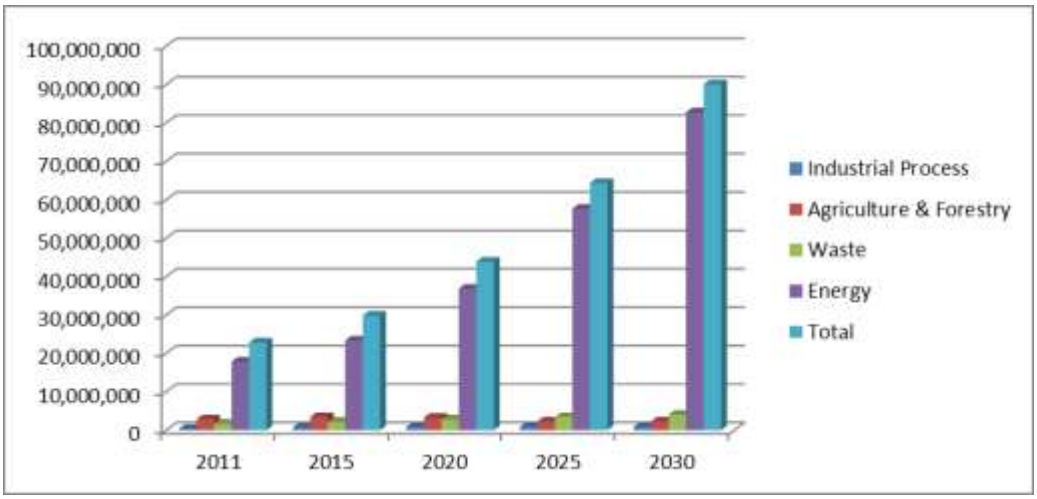

Figure 4: Trends of GHG Emissions in Hanoi

Source: Synthesized by the authors

3.8. GHG Emissions per Capita

During the last years, Hanoi's population is constantly growing (about 3.5% per year) - mostly due to immigration from other provinces - a reflection of the fact that the City is both a major metropolitan area of Northern Vietnam, and also the country's political center. This population growth also puts a lot of pressure on the infrastructure as well as on socio-economic development of the City. In terms of GHG emissions, population growth in accompanying with economic growth is causing increase in production and energy consumption, thus increase in GHG emissions, both in total volume and per capita ones.

Table 12 presents results of projection of GHG Emissions per Capita in Hanoi.

Table 12: GHG Emissions per Capita in Hanoi

Unit: tons of CO_2 equivalent/ person

	Units	**2011**	**2015**	**2020**	**2025**	**2030**
Total GHG Emissions	Tons of CO_2e	22,881,000	29,865,000	43,934,000	64,405,000	90,092,000
Population	Person	6,699,600	7,580,000	10,500,000	12,337,500	14,496,000
GHG Emissions per Capita	**Tons of CO_2e/ person**	**3.42**	**3.94**	**4.18**	**5.22**	**6.21**

Source: Calculated and synthesized by the authors

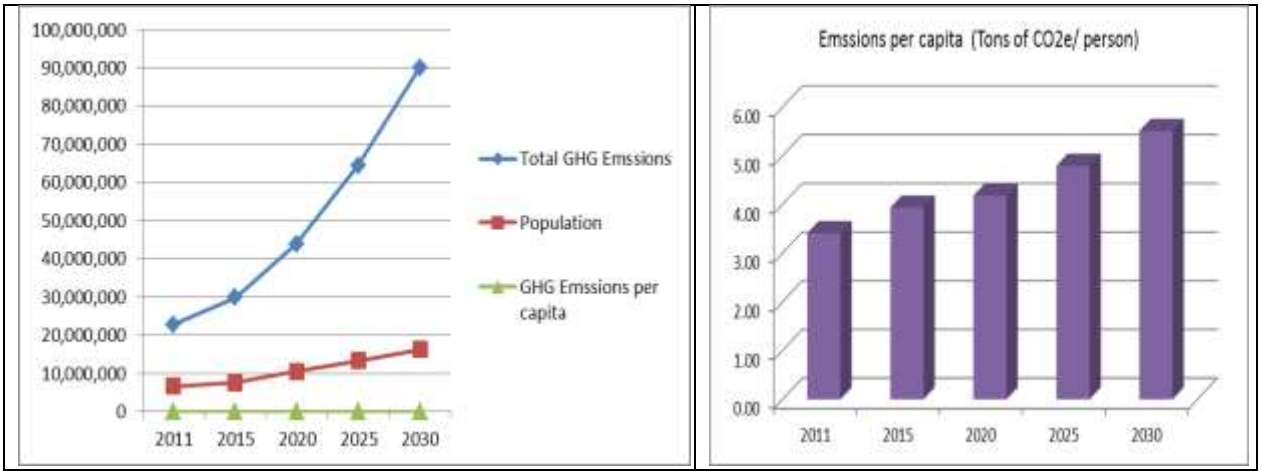

Figure 5: Trends in Total GHG Emissions and Emission per Capita in Hanoi

Source: Synthesized by the authors

In 2011, each people in Hanoi creates an average of 3.42 tons of CO_2e, about 21% higher than the Vietnam's emission per capita. The average Hanoian is responsible for 3.94 tons, 4.18 tons, 5.22 tons and 6.21 tons CO_2e per person in years 2015, 2020, 2025 and 2030, respectively.

4. Conclusion and Recommendations

This study tried to integrate GHG inventory methodology, IPCC's emission factors (Tier 1) and Vietnam's specific emission factors (Tier 2, 3) to assess GHG emissions and removals in various sectors, namely: energy, agriculture, industrial processes and waste management, for the City of Hanoi.

In the scenario of business as usual (BAU), total GHG emissions in Hanoi have a tendency to increase fast up from 22,881,000 tons CO_2e in 2011 to approximately 43,934,000 tons CO_2e in 2020 and around 90,092,000 tons CO_2e in 2030.

Among the sectors, while emissions from sectors like forestry or coal use are reduced, energy sector contributed the largest share in GHG emissions and also have gone up the most rapidly.

Hanoi's GHG emissions account for about 7.8 to 8.8 percent of the whole country's GHG emissions (which was 259 - 293 million tons CO_2e in 2013). Hanoi's per capita emission level is currently about 21% higher than Vietnam's average and tends to continue to increase in coming years. While this number of emission per capita is currently lower than the global average of 4.35 tons, it is forecasted that from 2021 onward it will rise above the worldwide average.

According to Viet Nam's NDC, with domestic resources, by 2030, Viet Nam will reduce GHG emissions by 8% compared to the Business as Usual (BAU) scenario, and this contribution could be increased to 25% if international support is received. Being a "big emitter" in Vietnam, Hanoi needs to develop appropriate policies, plans and solutions to reduce GHG emissions. Orientations for reducing GHG emissions in the city should focus on:

- Restructuring economic structure towards green growth;
- Enhancing the efficiency and effectiveness of energy use;
- Reducing energy consumption; changing the fuel structure in industry and transportation;
- Promoting effective exploitation and increasing the proportion of new and renewable energies in energy production and consumption;
- Practicing sustainable agricultural development, and improving efficiency and competitiveness in agricultural production;
- Managing and developing sustainable forests, enhancing carbon sequestration and environmental services;
- Improving waste management technology;
- Identifying opportunities to reduce GHG emissions in domestic and economic sectors;
- Assessing the costs and benefits of GHG abatement opportunities to select appropriate priorities;
- Calling on domestic and foreign investors to invest in abatement activities.

In the context where Vietnam has been realizing international comitmments on GHG inventory and emission reduction, responding to climate change, it is expected that the initial information/ assessment in Hanoi's GHG emissions/ removals will serve the process of planning and developing a number of policies, plans, programs and projects on GHG mitigation and green growth, and at the same time, will contribute to the City's goals on socio-economic development in the comming years.

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