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Analysis of Greenhouse Gas Source and Sink Balance in Bogor Municipality

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Abstract

The research about analysis of greenhouse gas (GHG) source and sink balance in Bogor Municipality as an effort to implement GHG emission reduction policies mandated by the Kyoto Protocol and Republic of Indonesia Law Number 17 of 2004 concerning Ratification of the Upper Kyoto Protocol United Nations Framework Convention on Climate Change. The study of GHG was guided by the results of the countries agreements through the Intergovernmental Panel on Climate Change (IPCC) forum in 2006. This study aims 1) to identify sources of emissions and reduction of GHG emissions in the Bogor Municipality; 2) to analyse of GHG source and sink balance in Bogor Municipality through calculation of GHG emission quantities and available absorption/sinking capabilities, and 3) to formulate strategic plan as an effort to reduce GHG emissions in the Bogor Municipality. The research was carried out through four main step activities, namely 1) identification of GHG sources and sinks; 2) quantification of the value of GHG sources and sinks; 3) calculation of GHG emissions and sinks, and 4) study of GHG emission mitigation strategies and adaptation. The results of this study showed that GHG sources and sinks in Bogor Municipality are caused by 3 main sectors, namely the sector of energy, the sector of agriculture forestry and other land use, and the waste sector with the total GHG emission is 1.82 Mt (2014), 1.81 Mt (2015) and 1.39 Mt (2016) while the total GHG sink are 0.15 Mt (2014), 0.14 Mt (2015) and 0.14 Mt (2016). From the results of the analysis of GHG source and sink balance in Bogor Municipality in 2014–2016 it was obtained at 1.66 Mt (2014), 1.67 Mt (2015) and 1.25 Mt (2016) GHG emissions that can't be absorbed by sinks. Based on the results of the analysis of GHG source and sink balance, are formulated strategies for mitigating GHG emissions and adaptation of GHG impacts in Bogor Municipality.

Keywords: adaptation, emission, greenhouse gas, mitigation, source and sink

INTRODUCTION

Global warming whose impact has been felt in various regions in Indonesia has become an important issue nowadays. This phenomenon is caused by the increasing concentration of GHG in the atmosphere [1, 2] especially CO_2, NH_4 and N_2O gas [3] with the potential to cause various adverse effects on humans. Advanced industrial countries and developing countries including Indonesia have given special attention to this global warming. The State of Indonesia has ratified the Kyoto to the United Nations Protocol Framework Convention on Climate Change (UNFCC) through the establishment of the Republic of Indonesia Law Number 17 of 2004 concerning Ratification of the Kyoto Protocol on the United Nations Framework Convention on Climate Change. The Kyoto Protocol contains obligations for advanced industrial countries to reduce GHG emissions. The response to GHG reduction efforts resulted in the agreement of countries to conduct GHG inventories. Through the Intergovernmental Panel on Climate Change (IPCC) in 2006, the GHG inventory covers 4 categories, namely 1) energy; 2) industrial processes and product use; 3) agriculture, forestry, and other uses; and 4) waste.

Along with the development of science and technology, efforts to diversify GHGs are also present through various studies. Research related to GHG inventories has been carried out in several other countries such as the GHG inventory in the UK [4, 5], GHG inventory in China [6, 7, 8], GHG inventory in Taiwan [9], GHG inventory in South Africa [10] and GHG inventory in several African countries, Asia, Latin American and Caribbean countries [11]. GHG inventory is also carried out specifically according to the type of activity [12, 13, 14, 15, 16]. The GHG inventory also uses a spatial model to predict seasonal CO_2 gas

emissions in the East Asia region [17]. Some developed and developing countries have calculated the quantity of GHG emissions produced. Developed country categories, such as the United States (USA) in 2007 contributed emissions of 7,107.2 Mt, Japan in 2007 accounted for 1,374.3 Mt of emissions and China in 2007 contributed 4,057.6 Mt of emissions [18] while the category of developing countries such as Indonesia in 2016 contributed 1.515 million tons of emissions [19].

The realization of Indonesia's commitment to GHG policies was carried out through the implementation of the National GHG inventory based on the Presidential Regulation of the Republic of Indonesia Number 71 of 2011 concerning the Implementation of National Greenhouse Gas Inventories. The policy mandates that each Regional Government (Province and Regency/ Municipality) implements a GHG inventory. This is by the mandate of the GHG inventory guidelines (IPCC 2006) that GHG inventories are carried out from the bottom level. Several cities in several countries have carried out GHG emission inventories, such as the Madrid City GHG inventory in Spain and Salvador City in Brazil [20], GHG inventories of several cities in India, namely Delhi, Mumbai, Chennai and Bangalore [21], GHGs inventory in Beijing urban areas [22], and GHG inventories of several cities in European countries [23].

The challenge in GHG inventories in urban areas is primarily the availability of data to estimate GHG emissions [24]. Urban areas are GHG producers, so they are often regarded as the main cause of climate change [25]. When compared to urban and rural areas in producing carbon, urban areas will produce higher emissions [26]. Therefore, urban areas are the main GHG contributors [27], especially from the energy sector [28]. For developing countries (including Indonesia) the availability of data to estimate GHG emissions is a major obstacle, so that capacity building is needed for developing countries to be able to implement it [29].

In line with the GHG inventory policy carried out starting at the district/city level (bottom up), the Bogor Municipality Government has an obligation to inventory GHGs. Bogor Municipality is one of the urban areas that has become the centre of settlements and non-agricultural activities of the community. The condition of population density and the growth in the number of vehicles increasing daily plus other activities such as industry, agriculture and livestock and others which are not followed by the expansion of green open space (GOS) can potentially increase GHG emissions in the Bogor Municipality area. The condition of Bogor Municipality GHG emissions in 2012 reached 2,536,851 tons, and in the same year, CO_2 absorption was only 113,893 tons [30]. This result showed that CO_2 absorption rates are only around 4.5%. The CO_2 produced can be absorbed by nature through the vegetation found in green open space, but over the past 5 years, the green open space of the Bogor Municipality has decreased as a result of the development of residential areas [31]. The Bogor Municipality Environment Agency reported that GHG emissions in Bogor Municipality in 2014 reached 1,961,262 tons, in 2015 it reached 1,976,871 tons and in 2016 reached 1,583,032 tons [32].

Referring to the policy of the Government of the Republic of Indonesia towards the GHG policy, the Bogor Municipality Government is required to provide GHG baseline data. China as a developing country produces quite a lot of GHGs, preparing the GHG baseline data starting from the local level to the national level [33]. Thus, it is very important for the Bogor City Government to assess how much natural capacity and various development activities in the city of Bogor are in emissions contributing or as a sink from the GHG emissions. Therefore, the purpose of this research is 1) to identify sources of emissions and reduction of GHG emissions in the Bogor Municipality; 2) to analyse of GHG source and sinks balance in Bogor Municipality through calculation of GHG emission quantities and available absorption/sinking capabilities, and 3) to formulate strategic plan as an effort to reduce GHG emissions in the Bogor Municipality.

MATERIALS AND METHODS

Data Analysis Procedure

This research was conducted in the administrative area of Bogor Municipality (West Java - Indonesia) from July to May 2019. This study required materials, namely secondary data in the form of Bogor Municipality Greenhouse Gas Inventory Report in the last 3 years. It included report on the 2015 Bogor Municipality GHG inventory (containing 2014 data), Bogor Municipality 2016 GHG inventory report (containing 2015 data), and the Bogor Municipality GHG Inventory Report 2017 (containing data for 2016). The research material was obtained from the Environmental Agency of Bogor Municipality. The tools used were in the form of laptops and software such as Microsoft Excel and Microsoft Word.

The activity of inventorying sources of data and sinks GHG emissions in Bogor Municipality as well as procedures for data analysis was carried out through a series of activities as presented in **Figure 1**.

The data analysis process carried out includes the process of identifying of GHG sources and sinks; Quantification of the value of GHG sources and sinks; relevant emission factor collections from literature studies, calculation of total GHG emissions and absorption to obtain value balance of sources and sinks of GHG and then formulate emission mitigation strategies and GHG impact adaptation strategies as seen in **Figure 2**.

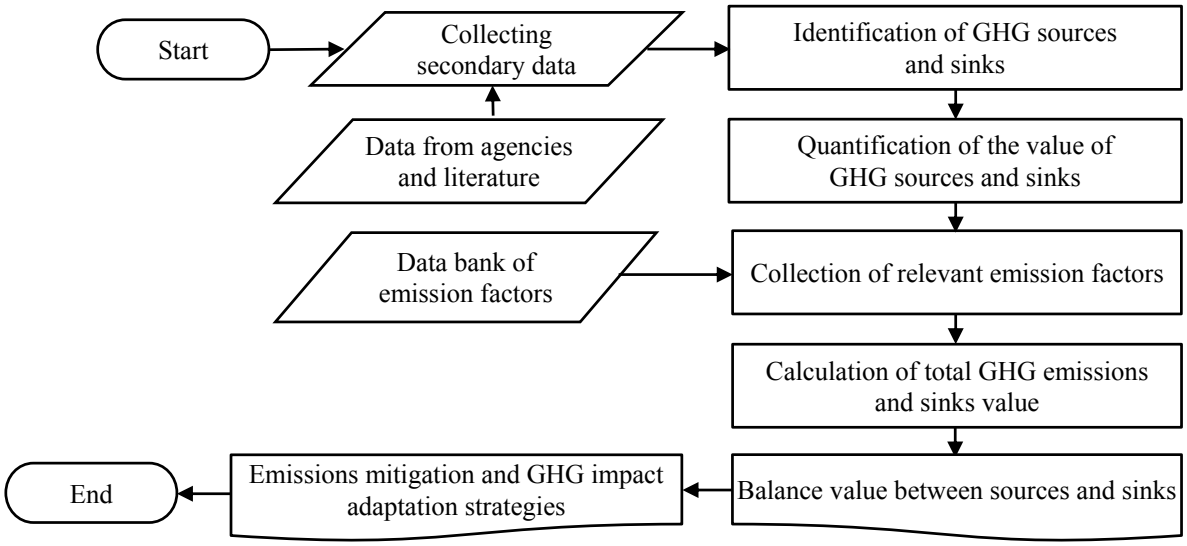

Figure 1. Flowchart of the research procedure

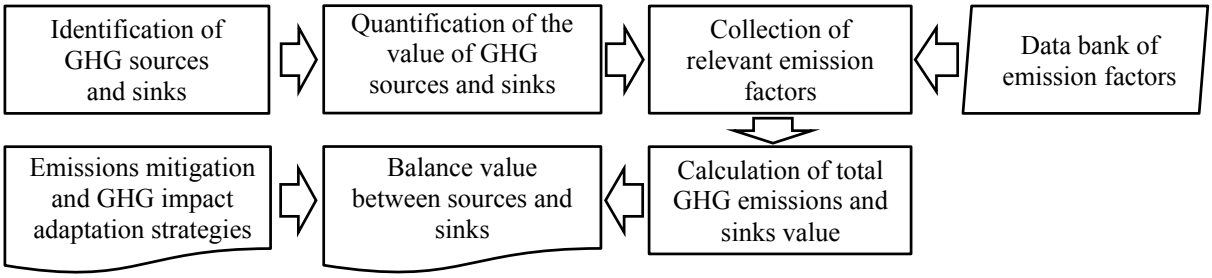

Figure 2. Calculation procedure of the quantity of GHG emissions and absorption (modifications of [34])

Collecting Secondary Data

The research was first carried out by collecting secondary data in the form of the Bogor City GHG Inventory Report for 2015-2017 (containing 2014-2016 data) obtained from the Environmental Agency of Bogor Municipality.

Calculation Quantity of GHG Emissions and Sinks

After the data is collected, identification of sources of GHG emissions and sinks is then carried out in the Bogor Municipality. The emissions sources and sinks of GHG are grouped according to the division of the GHG sector from IPCC 2006, namely the energy sector, the forestry agricultural sector and other land uses, and the waste sector. The corresponding emission factors are collected from various sources to calculate the amount of GHG emissions. GHG sinks are calculated based on the area of land cover in the form of vegetation or trees. The ability to sinks in absorbing GHG back into the earth or as a GHG belay is a product of the extent of vegetation cover and its emission factor. Quantification calculation of the sources value and sinks of GHG emissions refers to the IPCC 2006 formulation. In general, the equation for estimating the quantity of sources and sink of GHG emissions is as follows:

Emission/sink GHG = AD x EF

where:

AD = Activity data EF = Emission factors

The calculation of the quantity of GHG emission and sinks in the Bogor Municipality for each GHG sources and sinks category of produced refers to the default emission factor (Tier 1) according to IPCC 2006, which includes:

1. Calculation of GHG emission quantity:
   a. Energy sector:

      The category of fuel combustion, includes calculation of 1) emissions (CO_2) of electricity consumption; 2) emissions (CO_2, CH_4, N_2O) consumption of fuel oil in vehicle; 3) emissions (CO_2, CH_4, N_2O) consumption of lubricants in vehicle; 4) emissions (CO_2, CH_4, N_2O) consumption of natural gas in industrial/ commercial; 5) emissions (CO_2, CH_4, N_2O) consumption of charcoal in industrial/ commercial; 6) emissions (CO_2, CH_4, N_2O) consumption of paraffin wax in industrial/ commercial; 7) emissions (CO_2, CH_4, N_2O) consumption of lubricants in industrial/ commercial; 8) emissions (CO_2, CH_4, N_2O) consumption of natural gas in residential and 9) emissions (CO_2, CH_4, N_2O) consumption of Liquefied Petroleum Gas in residential.

   b. Agriculture, forestry and other land use sector:

      The category of livestock, includes calculation of 1) emission (CH_4) of enteric fermentation activities; 2) emissions (CH_4) of manure management activities; 3) emissions (N_2O) of direct from manure management

system and 4) emissions (N_2O) of indirect from manure management system. Category of aggregate sources and non-CO_2 emissions sources on land, including calculation of: 1) emissions (CH_4, N_2O) of biomass burning activities in croplands; 2) emissions (CO_2) of urea application activities and 3) emissions (CH_4) of rice cultivations activities.

c. Waste sector:

The category of solid waste disposal, includes the calculation of emissions (CH_4) in sites the unmanaged waste disposal (open dumping) activity. Category biological treatment of solid waste, including the calculation of emissions (CH_4 and N_2O) in biological treatment activities of solid waste. The category incineration burning and open burning of waste, includes the calculation of 1) emissions (CO_2, CH_4, N_2O) of waste burning activities through incineration and 2) emissions (CO_2, CH_4, N_2O) of waste open burning activities. Category waste water treatment and discharge, including the calculation of emissions (CH_4, N_2O) in domestic waste water treatment and discharge activities.

2. Calculation of GHG sinks quantity:

Agriculture, forestry and other land use sector:

Other land use categories, include calculation of GHG sinks from changes in carbon deposits to estimate CO_2 absorption in forest land, cropland, grasslands and settlements.

The formulation of effective and efficient GHG emission and adaptation impacts mitigation strategies is developed to determine alternative choices from various proposed strategies to reduce emissions and adjust to the GHG impacts in Bogor Municipality. The formulation of alternative GHG emission mitigation and adaptation strategies in the Bogor Municipality was reviewed based on the results analysis of greenhouse gas source and sink balance in Bogor Municipality.

RESULTS AND DISCUSSIONS

Source and Quantification of the GHG emission in Bogor Municipality

From the results of the data compilation, it was identified the sources of GHG emissions in Bogor Municipality from 2014–2016 were from 3 main sectors, namely:

Energy Sector

The sources of GHG emission in Bogor Municipality originating from the energy sector during the 2014-2016 sourced from the category of fuel combustion activities covering 3 sub-categories namely:

1. The sub-category of energy industries activities. This sub-category is the main activity electricity and heat production in the form of electricity generation.
2. The sub-category of transportation activities. This sub-category is road transportation activity.
3. Sub-categories of the activities of the other sectors. This sub-category is related to commercial/industrial and residential activities.

The results of calculating the quantity of Bogor Municipality GHG emissions in the energy sector in 2014-2016 can be seen in the following **Table 1**.

Table 1 Bogor Municipality GHG emissions in the energy sector in 2014-2016

Emission	Unit	2014	2015	2016
CO_2	kg	1,577,034,431.84	1,553,359,906.64	1,135,095,851.53
CH_4	kg	437,681.52	465,280.28	282,885.43
N_2O	kg	34,874.07	38,038.18	20,721.86
Total	kg	1,577,506,987.43	1,553,863,225.10	1,135,399,458.82
CO_2-e	kg	1,597,036,704.27	1,574,922,628.84	1,147,460,223.65
CO_2-e	ton	1,597,036.70	1,574,922.63	1,147,460.22
CO_2-e	Mt	1.60	1.57	1.15

Agriculture, Forestry and Other Land Use Sectors

The sources of GHG emission in Bogor Municipality from the agriculture, forestry and other land use sectors during the 2014-2016 is derived from 2 categories of activities, namely:

1. Categories of livestock activities. The livestock activity consists of 2 sub-categories of activities, namely sub-categories of enteric fermentation activities and sub-categories of manure management activities.
2. Category of aggregate sources and non-CO_2 emissions sources on land. The category of aggregate sources and non-CO_2 emissions sources on land consists of 3 sub-categories of activities, including sub-categories of biomass burning activities (specifically biomass burning activities on croplands), sub-categories of urea application activities, and sub-categories of rice cultivations activities.

The results of calculating the quantity of Bogor Municipality GHG emissions in the agriculture, forestry and other land use sectors in 2014-2016 can be seen in the following **Table 2**.

Table 2: Bogor Municipality GHG emissions in the agriculture, forestry and other land use sectors in 2014-2016

Emission	Unit	2014	2015	2016
CO_2	kg	43,800.00	91,600.00	107,600.00
CH_4	kg	457,260.53	256,583.09	261,831.44
N_2O	kg	2,305.62	582.12	598.64
Total	kg	503,366.15	348,765.21	370,030.08
CO_2-e	kg	10,361,014.67	5,660,301.57	5,791,638.96
CO_2-e	ton	10,361.01	5,660.30	5,791.64
CO_2-e	Mt	0.01	0.01	0.01

Waste Sector

The sources of GHG emission in Bogor Municipality from the waste sector during the 2014-2016 is derived from 4 categories of activities, namely:

1. Categories of solid waste disposal activities. This category is activities of unmanaged waste disposal sites or open dumping in the Galuga Solid Waste Site Disposal.
2. Categories of biological solid waste treatment activities. This category is activities of biological solid waste treatment through composting.
3. Category of garbage burning activities with incinerators and open waste burning. This category of activities consists of sub-categories of waste burning activities through incinerators and sub-categories of open waste burning activities.
4. Category of wastewater treatment and discharge activities. This category is activities of domestic wastewater treatment and discharge.

The results of calculating the quantity of Bogor Municipality GHG emissions in the waste sector in 2014-2016 can be seen in the following **Table 3**.

Table 3 Bogor Municipality GHG emissions in the waste sector in 2014-2016

Emission	Unit	2014	2015	2016
CO_2	kg	23,809,753.60	33,388,435.89	34,235,508.38
CH_4	kg	7,858,357.88	8,365,030.53	8,542,581.81
N_2O	kg	57,541.71	65,276.57	66,591.61
Total	kg	31,725,653.19	41,818,742.99	42,844,681.78
CO_2-e	kg	206,673,196.90	229,289,814.06	234,273,122.29
CO_2-e	ton	206,673.20	229,289.81	234,273.12
CO_2-e	Mt	0.21	0.23	0.23

From the quantity calculation of Bogor Municipality GHG emissions, it appears that Bogor Municipality GHG emissions are reviewed based on the main gas component in GHG during the 2014-2016 period, dominated by CO_2 gas followed by CH_4 gas and N_2O gas as shown **in Figure 3** while being reviewed by sector in GHG during the 2014-2016 period was dominated by the energy sector followed by the waste sector and the agriculture, forestry and other land use sectors as presented in **Figure 4**.

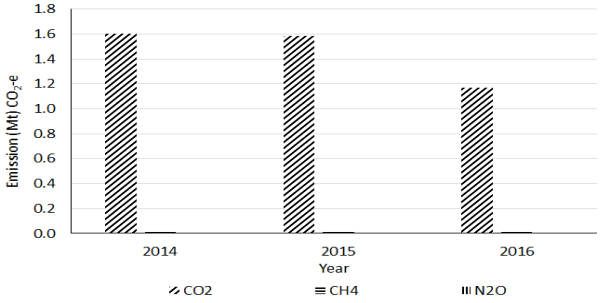

Figure 3 Bogor Municipality GHG Emissions according to the 2014-2016 GHG main gas component

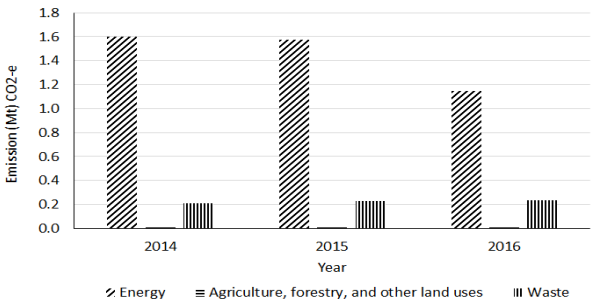

Figure 4 Bogor Municipality GHG Emissions according to the 2014-2016 GRK sector division

Sink and Quantification of the GHG sink in Bogor Municipality

GHG sink is influenced by the type of land use [35]. Land use categories that have the potential for absorption of CO_2 gas include forest land, croplands, grasslands and residential land [36, 37]. The absorptive potential of high CO_2 gas is found in croplands and forest land [30]. Sinks of GHG in the Bogor Municipality during the period 2014-2016, came from the agriculture, forestry and other land use sectors.

Agriculture, Forestry and Other Land Use Sectors

The sink GHG of Bogor Municipality originating from the agriculture, forestry and other land use sectors during the period 2014-2016 comes from other land use categories can be seen in **Table 4**.

Table 4 Sinks GHG of Bogor Municipality from other land use categories in 2014-2016

Sub-categories	Unit	2014	2015	2016
Forest land	kg	13,299,407.10	13,299,407.10	13,299,407.10
Croplands	kg	98,603,288.30	11,290,236.15	11,290,236.15
Grasslands	kg	8,749,224.10	81,407,841.90	81,407,841.90
Residential land	kg	31,525,410.00	34,328,970.50	34,328,970.50
Total	kg	152,177,329.50	140,326,455.65	140,326,455.65
	ton	152,177.33	140,326.46	140,326.46

GHG Source and Sink Balance in Bogor Municipality

The balance of GHG sources and sinks is a condition in which GHG emissions production are equal to the amount of GHG emissions that can be tethered. The balance of GHG sources and sinks in Bogor Municipality in 2014-2016 can be seen **Table 5** and **Figure 5**.

Table 5 The balance of GHG sources and sinks in Bogor Municipality in 2014-2016

Sector	Unit	2014	2015	2016
Energy	Mt	1.60	1.57	1.15
Agriculture, forestry and other land use	Mt	0.01	0.01	0.01
Waste	Mt	0.21	0.23	0.23
Emission total	Mt	1.82	1.81	1.39
CO_2 tethering from other land use	Mt	-0.15	-0.14	-0.14
Net emission CO_2-e	Mt	1.67	1.67	1.25

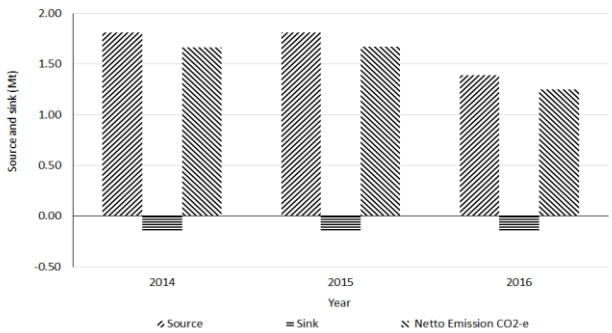

Figure 5 The balance of GHG sources and sinks in Bogor Municipality in 2014-2016

The results of the analysis of GHG sources and sinks balance in Bogor Municipality in 2014-2016 above were obtained 1.66 Mt (2014), 1.67 Mt (2015) and 1.25 Mt (2016) GHG emissions that can't be absorbed by sinks.

Emission Mitigation Strategy and Adaptation of GHG Impacts in Bogor Municipality

The implementation of GHG emission mitigation and adaptation to the impact of GHGs is guided by the Republic of Indonesia Presidential Regulation Number 61 of 2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions, wherein each regional government is obliged to carry out activities in the Greenhouse Gas Regional Action Plan (GHG-RAP).

Referring to the presidential regulation, mitigation is a strategy to reduce emissions and increase GHG losses while adaptation is a strategy to adjust to conditions resulting from the effects of GHG emissions.

Therefore, mitigation and adaptation are responses or actions that can be taken to reduce emissions and increase GHG removals and adjust to conditions resulting from GHG emissions impacts, can be seen in **Figure 6**. Emission mitigation strategies and adaptations GHG impacts in Bogor Municipality can be seen in **Table 6**.

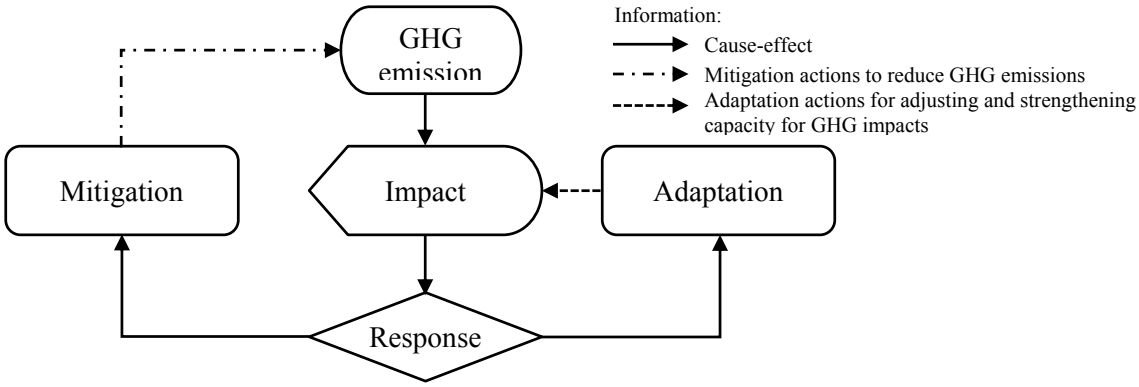

Figure 6 Emissions mitigation and GHG impact adaptation schemes

Table 6 Emission mitigation strategies and adaptations GHG impacts in Bogor Municipality 2014-2016

Sector	Strategies	
	Mitigation	Adaptation
Energy	Efficiency movement and limitation of energy use (fuel oil and other fuels)	The use of energy is environmentally friendly and according to needs
	Movement of walking and cycling to the office	The use of community-based and environmentally friendly transportation tools
	Savings movement using electricity	The use of buildings with natural lighting systems
Waste	Movement to increase coverage of waste water sanitation system services	The use of communal-based liquid waste sanitation services
	Review the implementation of the 3R (Reduction-Reuse-Recycle) system in handling urban waste in Bogor Municipality and making regulations on waste through regional regulations	Recycling solid waste
		Minimize paper consumption and paper recycling
		Save on the use of plastic bags
Agriculture, forestry and other land use	Increased area of forest land in green open space (GOS)/city parks	Protection of forest land and maintenance of trees (CIFOR forest, Bogor botanical gardens and GOS/city parks)
	Making rules about sustainable croplands protection through regional regulations	Protection of croplands (rice fields)

To reduce Bogor Municipality GHG emissions, the Municipality must follow a GHG emission reduction policy. The mitigation of GHG emissions is not only seen in the general context and not just to meet targets at the national or regency/municipality level, but it needs to be controlled by the driving factors or sources causing GHG emissions [38]. The policy for reducing GHG emissions is made in stages, starting from the short-term, medium-term and long-term stages [39]. The implementation of this GHG emission reduction policy in Malaysia is committed to reducing GHG emissions by up to 40% [40]. To reduce GHG emissions, the role of the government is critical especially in making innovation and policy formulation [41]. Therefore, the Government of Bogor Municipality is obliged to commit to reducing GHG emissions expressly.

CONCLUSIONS

The conclusions that can be drawn from the research are as follows:

1. Sources of GHG emissions in Bogor Municipality are generated by 3 main sectors, namely the energy sector, the agriculture, forestry and other land use sectors and the waste sector with total emissions generated at 1.82 Mt (2014), 1.81 Mt (2015) and 1.39 Mt (2016). The GHG sinks in Bogor Municipality which tethering CO2 came from agriculture, forestry and other land uses, namely from other land use categories with a total loss of 0.15 Mt (2014), 0.14 Mt (2015) and 0.14 Mt (2016).
2. From the results of the analysis of GHG sources and sinks balance in Bogor Municipality in 2014-2016 were obtained 1.66 Mt (2014), 1.67 Mt (2015) and 1.25 Mt (2016) GHG emissions that can't be absorbed by sinks.
3. Emission mitigation strategies and adaptations GHG impacts in Bogor Municipality, consists of:
   1) Strategies in the energy sector, namely:
      a) Mitigation through efficiency movement and limitation of energy use (fuel oil and other fuels), with adaptation through the use of energy is environmentally friendly and according to needs.
      b) Mitigation through movement of walking and cycling to the office, with adaptation through the use of community-based and environmentally friendly transportation tools.
      c) Mitigation through savings movement using electricity, with adaptation through the use of buildings with natural lighting systems.
   2) Strategies in the waste sector, namely:
      a) Mitigation through movement to increase coverage of waste water sanitation system services, with adaptation through the use of communal-based liquid waste sanitation services.
      b) Mitigation through review the implementation of the 3R (Reduction-Reuse-Recycle) system in handling urban waste in Bogor Municipality and making regulations on waste through regional regulations, with adaptation through recycling solid waste, minimize paper consumption and paper recycling and save on the use of plastic bags.
   3) Strategies in the agriculture, forestry and other land use sector, namely:
      a) Mitigation through increased area of forest land in green open space (GOS)/city parks, with adaptation through protection of forest land and maintenance of trees in the CIFOR forest area, Bogor botanical gardens and GOS/city parks area.
      b) Mitigation through making rules about sustainable croplands protection through regional regulations, with adaptation through protection of croplands (rice fields).

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